Master Thesis

Socio-technical challenges in applying the Nature-based solution of Wetland Restoration for Climate Action in the Netherlands

Source: https://flumewater.com/wp-content/uploads/2023/02/Marsh-at-sunrise.jpeg

By

Dani Benjamin

Student No: 3236293

1st Supervisor: Dr. Laura Franco Garcia

2nd Supervisor: Dr. Steven McGreevy

As part of

Master of Environmental and Energy Management Program (2023-24)

University of Twente, The Netherlands

Table of Contents

Table of Figures

Table of Tables

List of Abbreviations

CBD	:	Convention on Biological Diversity
CO2	:	Carbon Dioxide
EPA	:	Environmental Protection Agency of United States
EU	:	European Union
GHG	:	Greenhouse Gases
IUCN	:	International Union for Conservation of Nature
KW	:	Kilo watt
MEEM	:	Master of Environment and Energy Management
Mg C ha	:	Mega grams of Carbon per Hectare
MRV	:	Measurement, Report and Verification
NbS	:	Nature-based Solutions
NGO	:	Non-government Organization
NDC	:	National Determined Contribution
NRDC	:	Natural Resource Defense Council
PES	:	Payment for Ecosystem Services
STS	:	Socio-Technical System
SDG	:	Sustainable Development Goals
UN	:	United Nations
UNEP	:	United Nations Environment Programme
UNESCO	:	The United Nations Educational, Scientific and Cultural Organization
US	:	United States
REDD+	:	Reducing Emission from Deforestation and Forest Degradation (Conservation, sustainable management and enhancing carbon stock)

Acknowledgement

Environmental topics has always been my passion right from my childhood days and I always dreamed of pursuing a career in the field of environment and nature. It is the key reason and motivational factor for joining the MEEM (Master of Environmental and Energy Management) program at the University of Twente. And the journey of MEEM has been a spectacular experience which I was literally living my dream of becoming an Environmental professional.

In this journey, I would like to extend my heartfelt appreciation to the whole MEEM Program including the highly talented lecturers whom by sharing their immense knowledge and expertise, program coordinators who were impeccable in organizing the course conduct, study advisors who provided excellent guidance and value-added support throughout, and my fantastic MEEM classmates who were the best batch and friends forever with cherished memories. You all have been fundamental in transforming me to the professional who I am now.

Coming to the realization of my master thesis. an earnest thanks to all the participants who contributed significantly to my study. Your invaluable inputs have greatly enhanced the consolidation of my thesis.

And I would like to express my sincere gratitude to my both supervisors for providing exceptional guidance and support who both were instrumental in successfully completing my thesis journey. My first supervisor is Dr. Laura Franco Garcia, whom I consider as my mentor for lifetime. Her unwavering supports, advises and motivations have enabled me to refine my thoughts into meaningful ideas, and to overcome the challenges I encountered during the thesis process. And my second supervisor Dr. Steven Mcgreevy. Meeting him was the crucial turning point in my thesis journey, who guided me to the right focus and direction to my research which was a broader concept until then. It is exactly from that point my thesis has took off its flight to the destination.

And ultimately, I am deeply grateful to the god almighty, my family and friends who gave unconditional support, both morally and physically, and enhancing my self-belief and confidence for completing this wonderful journey and realizing my dream.

Taking a leaf out of from a recent song, to conclude my acknowledgement.

“Look who we are, we are the dreamers……. We make it happen, 'cause we believe it. Look who we are, we are the dreamers……. We make it happen 'cause we can see it.”

Abstract

Climate change has been the root cause for the major threats to humanity's well-being and survival on Earth and the core reason for natural calamities such as floods, droughts and global warming through carbon emissions. Despite the proven potential of Nature-based solutions as a remarkably sustainable method of mitigating these disasters, globally, their widespread application is still limited. Particularly, wetlands restoration is an initiative that has all the potential to counter the aforementioned disasters. However, various socio-technical factors have identified worldwide as the major barriers in widespread adoption of the Nature-based solution of wetlands restoration. Therefore, this study aims to explore about the socio-technical challenges occurred in the wetland restoration programs in the Netherlands, where it is successfully applied, and understand how these challenges were addressed and overcome during the implementation & management stages of wetland restorations.

The study utilized the Socio-technical Systems framework and investigate based on the 9 socio-technical factors outlined in the STS framework. The study adopted mixed method approach by collecting both qualitative and quantitative data through interviews with key personnel involved in the wetland restoration programs in the Netherlands. A meticulous content analysis, regression analysis and relational network data matrix analysis has been applied to assess the influence of these challenges on wetland restorations and successful strategies employed to address them. The derived results revealed that challenges related to "Land use", "Governance policies and regulations" and "Process Management" are the key socio-technical challenges that can influence the effective application of wetland restoration in the Netherlands. The study underscores that these socio-technical challenges impact the effective application of the wetland restorations due to their identified strength of influence on the process, which is shaped by the dynamic interrelations and interdependence among them. And "Communication of Knowledge", "Participatory approach", "Process Optimization", "Flexibility in compensation & Regulations" and "Integrated & Balanced Distribution" are identified as the key strategies applied to overcome these challenges, and further corroborates its combined application.

The study further recommends similar research at different context (Global South) which will provide a different perspective and multiple variants of the same challenges, and to investigate about the nuanced differences in challenges between large-scale and small-medium scale wetland restoration projects which will provide valuable insights into developing exclusive strategies for different scale projects. Overall, these studies will contribute to develop effective strategic framework for resolving socio-technical challenges in wetland restorations, and its universal application, globally.

Keywords: Nature-based solutions, Wetland restoration, Socio-technical challenges, Decarbonization, Climate change and adaptation.

1. Introduction

This study is conducted based on the background of climate change, and the Netherlands initiatives for climate resilience and decarbonization by applying the Nature-based solution (NbS) of Wetland restorations. The present global temperature is already 1.1 degree Celsius higher than the pre-industrial levels and projected to increase between 2 to 3 degrees by 2100, if current policies and regulations remains unchanged (McKay et al., 2021). Despite numerous voices and campaigns for enhancing green growth and green innovations, the institutions globally, have not given paramount importance to nature-based solutions as similar to grey solutions (Sowińska-Świerkosz and García, 2022). This hesitancy triggered my curiosity and served as an impetus to investigate about the hesitancy or lack of interest in adopting green solutions.

This chapter details about the background aspect of the study, i.e., the climate change, the importance of Wetlands in climate actions, and the Netherlands efforts towards climate actions and wetland restorations. It further describes about the problem that triggered the research i.e., the socio-technical factors that leads to the hesitancy towards applying NbS that further contributes to the depletion of wetlands. Then it defines the targeted objective of this research and the research question which is answered with the completion of this study, and finally, the research outline that indicates the structure of this report.

1.1. Background

1.1.1. Climate Change

Globally, climate change is one of the widely discussed topic since the turn of millennium, as it represents significant challenge and threat to not only human race, but all living beings. It questions the survival of planet Earth itself. As per Rockstrom et al. (2009), since the beginning of Anthropocene epoch, with the outset of industrial revolution, the human actions is one of the main drivers which triggers environmental variations. According to the planetary boundary analysis, 6 out of 9 essential Earth system processes, are in the zone of either uncertainty or beyond uncertainty level (Richardson et al., 2023). A depiction of planetary boundary status is shown in (Figure 1). Hence it is imperative to tackle the climate change deterioration and to contain it in safe limits (Globaia, 2009). Owing to the importance of this, the United Nations has declared various initiatives and the one among them is the declaration of the period of 2021 – 2030 as the "Decade on Ecosystem Restoration" (UNEA, 2019).

1.1.2. Importance of Wetlands in Climate actions

Wetlands play a very crucial role in sustaining biodiversity in the planet. It also provides multiple ecosystem services such as flood control, drought control, climate change mitigation, improving water quality, increases groundwater, and provides livelihood for around 300 – 400 million people who depends on it for various resources (Mara, 2024). These multiple services of Wetlands contribute directly to the SDGs 1, 2, 6, 8, 9, 11, 13, 14 and 15 (Ramsar, 2018 & Seifollahi-Aghmiuni et al., 2019). What makes wetlands more vital to climate action, is its capacity to store more carbon than oceans and forests within less area density. It sequesters CO2 five times more than forests and five hundred times more than oceans (Temmink et al., 2022). It covers only 1% of the total Earth surface, but absorbs more than 20% of all the CO2 absorbed in the world by natural habitat (Temmink et al., 2022).

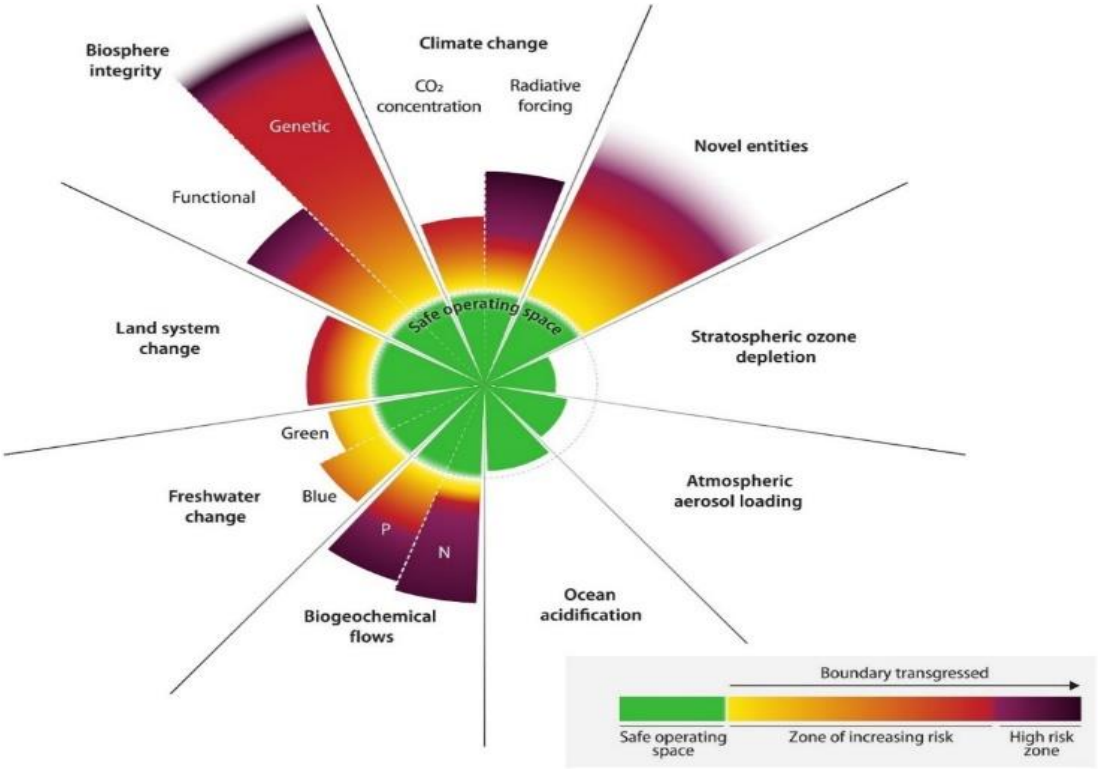

Figure 1 : Planetary Boundaries
Source: (Globaia, 2009)

1.1.3. Netherlands efforts towards Climate actions and Wetland restorations

Netherlands does actively indulge in climate actions. They have introduced "Climate Act" agreement with various plans, policies and measures during 2019 to combat climate change targeting the reduction of GHG emission by 49% in 2030 and 95% by 2050 from the 1990's level (Ministry of Economic Affairs and Climate, 2021). They have introduced several climate resilience strategies such as "Climate-resistant Friesland 2050+" with Wetterskip Fryslan initiating multiple polder restoration projects (Fryslan, 2024), Wetland restorations (Rewilding Europe, 2023), Green infrastructures (Durham, 2023) etc. Further, various decarbonization strategies such as green roofs projects (Tozer et al., 2022), carbon neutral renovation of build stocks (Visscher, 2019), regulations for industrial sector to reduce the emission (Anderson et al., 2023), carbon capture utilization and storage (CCUS) projects (NS Energy, 2020) etc. Another study by Yang et al. (2022) based on the context of Leiden, the Netherlands, points out that the annual GHG emission from the building stocks will be reduced by 90%, if all the recommended decarbonization strategies are deployed simultaneously with its fullest potential.

Netherlands has a history of more than 2000 years in climate adaptation measures through wetlands for mitigating the flood and drought risks and integrating it with man-made structures which will enhance the resilience performance of the measure (Cheong et al., 2013). They have

developed several climate resilient wetland restoration programs throughout the country including Weerribben-Wieden National Park (Mara, 2023), Marker Wadden restoration project which restoring upto 100 square kilometer of wetlands (Rewilding Europe, 2023), Peatland Meadow Program (FeanGreide Fryslan, 2024), Alde Feanen National Park (It Fryske Gea, 2024), Onlanden wetland restoration project (De Haas and Schepers, 2022), Noordrand Midden Nature Realization projects (Delta, 2023) etc. They have even decentralized the authority for nature related initiatives to respective municipalities based on their changes in nature policy (Lordkipanidze et al., 2019). Dutch postcode Lottery have granted 1.5 million euro to Wetlands International, an NGO for the welfare of wetland preservation (Nikita, 2024). Also, Netherlands is actively participating in the EU funded Waterlands project with restoring the coastal wetland of Ems-Dollard Estuary (Cordis, 2023).

1.2. Problem definition

1.2.1. Socio-technical factors that leads to hesitancy towards nature-based solutions and depletion of wetlands

Despite many benefits and potentials, globally, nature-based solutions are still not widely been utilized or implemented as a formidable solution. Particularly wetlands, which has the potential to contribute significantly towards climate actions (Mara, 2024). But, as per studies, globally 50% of the wetland restoration programs are not being successfully accomplished (Temmink et al., 2022). There are various socio-technical factors attributed as challenges towards the hindrance of its successful implementation and management. Social factors such as spatial issues (Buckingham et al., 2021), community and stakeholder related disputes (Sayer et al., 2021), stakeholder related barriers (Duraiappah et al., 2014). fund shortages (Gantioler et al., 2014), ambiguity in the practicality of nature-based solutions and the linking of its emergence from multiple scientific fields (Sowińska-Świerkosz and García, 2022), governance issues related to national and subnational levels etc. (Martín et al., 2021) etc., plays as major social challenges in the application of the nature-based solution of wetland restoration.

Apart from above, technical challenges related to the clarity of the performance measurements of NbS related projects and the dubiousness and uncertainty about its capacity to produce results (UNESCO, 2019), absence of exclusive methodology for the performance assessment (Kumar et al., 2021), lack of scientific knowledge and research gaps (Martín et al., 2021), and dearth of overarching recognized standard in assessing the multi-functional performance and a profound proof indicating the benefits of NbS (Nelson et al., 2020) etc., also hinders the adoption and its wide-range acceptance globally. Altogether, the omnipresence of these social, technical and economic challenges during the implementation and management phases of such ecological restoration practices are mostly overlooked and inadequately evaluated (Wortley et al., 2013).

These factors have profoundly impacted the preservation and conservation of wetlands and results in its gradual degradation. Since 20th century, it has been reported a loss of 64-71% of wetlands globally due to urbanization. But through active interventions of organizations like Ramsar, the rate in loss of wetland in Europe and US has been slowed down. Nevertheless, it is still remains

high in Asian region as the large-scale conversion of wetlands is still continuing due to the human interventions for land-use (Davidson, 2014). A classic example is the Sundarban wetlands which is one of the largest coastal wetlands that situated within India & Bangladesh where a major area has been converted to agricultural farms and fields (Erwin, 2008).

At present, 5% of the global annual CO2 emission is contributed due to wetland degradation (Temmink et al., 2022). This will further increase as the global population is estimated to increase 68% by 2050. This will have an effect in destroying of wetlands for the purpose of land-utilization for housing, agricultural and industrial demands which will cause the decline of biodiversity and increase poverty (Mara, 2024). According to the latest assessment, the loss of 50% of global mangroves ecosystem, a wetland category, are on the verge of collapse due to human interventions and developments which will result in the loss of 1.8 billion tons of carbon stored that values a minimum $13 billion in carbon markets, and 2.1 million lives will encounter coastal flooding risk (IUCN, 2024).

Hence, to mitigate these looming risks and disasters, it is imperative to conduct more studies at a context where the nature-based solution of wetland restorations is successfully applied and utilizes its potential towards climate actions, and to gain more knowledge about these socio-technical challenges there and what strategies and best practices they have applied to overcome these challenges and successfully implement and manage the initiative.

1.3. Research Objective

The main objective of this study is to understand how the complex socio-technical system involvement and its influences becomes a challenge in applying the nature-based solution of wetland restoration initiatives in the Netherlands, and to evaluate the strategic measures adopted by the implementors to overcome these challenges.

The Context of the Netherlands is selected since they are known as one of the pioneers in introducing and successfully implementing NbS methods (Bona et al., 2022), and due to its rich heritage in wetland conservation and restorations activities (See **1.1.3**). Approximate 13% (5514 Square kilometer) of the Netherlands comes under Nature 2000 areas (Statista, 2024). Of that, it covered over a million hectares of wetlands which includes peats, bogs, marshlands, fens and lakes (Ministerie van Economische Zaken en Klimaat, 2017). It consists of around 43 numbers of both large and small-medium scale wetlands all across the country, which is only second to Germany in the EU (Statistics Netherlands, 2009). Hence, it was quintessential to research about the wetland restoration projects implemented in the Netherlands context.

According to Cooke et al. (2019), the “Decade on Ecosystem Restoration” which is declared by UN in the period of 2021 – 2030, will serve as a platform to raise awareness among the public about the importance of ecosystem restoration and enhances the public and political support for its protection. But if we apply it by attempting large-scale restoration projects without solid evidence of effectiveness, we are then engaging in a high-risk, decade long experiment (UNEA, 2019).

Aligning to this vision of UN, this study contributes to: -

- Adopt proactive measures and strategies towards imminent challenges which will enhance the success rate of restoration initiatives.
- Address the existing knowledge and awareness gaps related to wetland restorations which will enhance universal acceptance of the nature-based solution of wetland restoration.
- Slowing down the conversion of wetlands for other land uses, especially at global south.

2015 Paris Agreement is considered to be the most important milestone in steps towards climate action. All the countries who endorsed the agreement have declared their own targets through National determined contribution (NDC) (NRDC, 2021). Countries at global north are leaps ahead in successfully implementing various methods for climate action (Bona et al., 2022). But many countries, especially global south, are lacking advanced technologies and are facing various social, economic challenges which act as a hindrance towards adopting such technologies (Maizland, 2023). Hence, addressing these factors, will encourage such countries to initiate the nature-based solution of wetland restoration to address their required demand of climate action target in a more economical and eco-friendly manner.

1.4. Research Question

The objective of the research was attained by investigating the research question: -

How do socio-technical challenges in the Netherlands, influence in effectively applying nature-based solution of wetland restoration for climate action, and what strategies applied to overcome these challenges?

The following sub-questions have been developed and answered to achieve the aforementioned objectives and ultimately addressed the research question.

- What are the key socio-technical challenges encounters during the **implementation and management** phases of wetland restoration?
- Which are the **most influential socio-technical challenges** and how they affects the effective application of wetland restoration?
- What are the key **strategies and best practices** that applied to overcome these socio-technical challenges?

1.5. Research Outline

Section 2, the literature review, delves into the benefits of the nature-based solution of wetlands for climate actions, and its related socio-technical challenges and strategies applied globally. It further elaborates about the theoretical framework “Socio-technical Systems”, and how it contributes to this study. Section 3 outlines the research design, its strategies, the data collection and analysis methods, and the limitations and ethical consideration. Section 4 presents the results and findings, Section 5, Discussion, discourses about the results, its characteristic features and its alignment with previous studies. And ultimately, section 6 derives the conclusion of the research and proposes recommendation for further investigation of the topic.

2. Literature Review and Theoretical Framework

This chapter provides the details about the literature reviews related to the research topic and subjects of the study, and it sheds light on to the theoretical framework used in this research, its potentials and scope, and the reason for incorporating it in this study etc. A deep understanding about these factors has enhanced the clarity of the purpose of conducting this research.

2.1. Literature Review

The literature review contains 5 sections. The first section explains the concept of nature-based solution and what is a wetland restoration. The second section is the detailed version of the importance of wetland restoration discoursed in the introduction chapter as it was imperative to the study to delineate further about its contribution at different global contexts towards climate resilience and decarbonization. The third section describes about the implementation and management of a wetland restoration. The fourth section defines various socio-technical challenges of wetland restorations identified through various researches and studies worldwide. And the fifth section discusses about multiple strategies adopted globally to resolve or mitigate those socio-technical challenges and to successfully accomplish wetland restoration.

2.1.1. Nature-based solution of Wetland restoration

As per UNESCO (2019), Nature Based Solution (NbS) is a method which is purely based on strategies and processes that is developed through environmental resources. It is a kind of method which uses natural resources and ecosystem to provide solutions to various factors which act as an impediment for assuring a quality and risk-free existence not just for human life, but for all living being in the planet.

Wetland restoration, a nature-based solution, is the re-construction of the physical, chemical and biological characteristics of a degraded or depleted wetlands to its natural condition (US EPA, 2023). It includes terrestrial wetlands such as peatlands, bogs, fens etc. (Archibold, 1995), coastal wetlands such as mangroves, coral reefs, salt marshes, sea weeds etc. (Bertram et al., 2021), inland wetlands which are near to rivers, lakes and streams (US EPA, 2023). They all enhance overall ecosystem and biodiversity which directly or indirectly contribute immensely to carbon storage and its regulation (Tracextech and Tracextech, 2023). And restoring and preserving it, is highly essential in the combat for climate resilience and climate change mitigation (Nikita, 2024).

2.1.2. Benefits of Wetland restoration for climate action

The main highlight of wetland restoration is that, it addresses not just the targeted issue, but delivers multiple co-benefits too in the form of ecosystem services. For eg: mangroves replanting for mitigating flood risk, provides other services including provisional and regulation services such as water purification, air quality improvement, river banks protection, soil erosion, sediment regulation and drought protection (UNESCO, 2019). Then creates natural habitat for marine species and plants, produce biomass, food and fibers, pest and nutrients controlling, recreational and eco-tourism activities etc. (Wang et al., 2023). And this NbS method possess intrinsic adaptability characteristics towards environmental changes which the grey structures fail to meet

(Vogelsang et al., 2023). A depiction of its multiple benefit factors is illustrated in (Figure 2). It is sustainable due to its natural way of solution (Keesstra et al., 2018), and is considered as a critical planning tool for enhancing the resilience of the cities towards climate change (Bona et al., 2022). And it can be developed as a worthy alternative to the majority of existing remedies practicing either individually or in a combined manner (Davies and Lafortezza, 2019), and also highly economical too (Davies and Lafortezza, 2019).

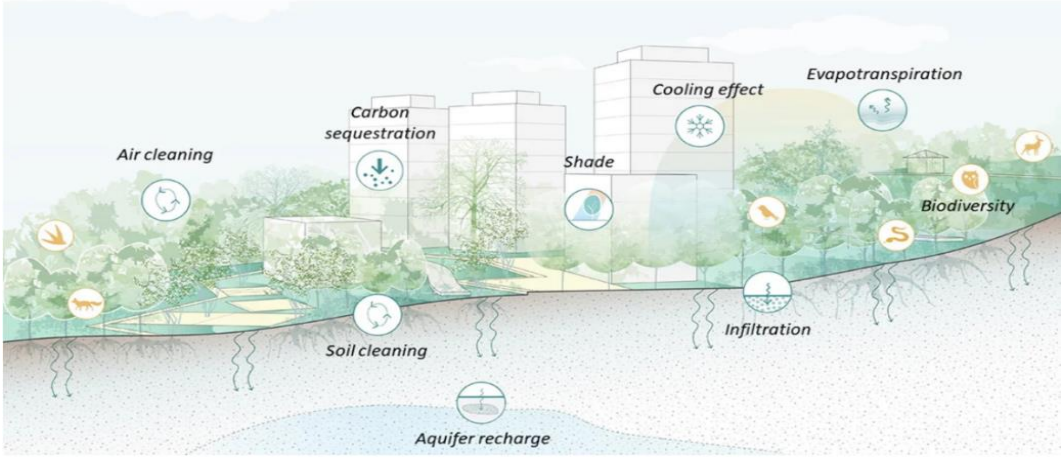

Figure 2 : NBS Multiple Benefits
Source: (Jongman et al., 2022)

2.1.2.1. Climate Resilience through Wetland restoration

As per studies, wetlands are crucial for climate resilience actions and contribute immensely to the mitigation of climate related disasters. Coastal wetland ecosystem that includes seagrasses, salt-marshes, macroalgae, mangroves etc., disperses the wave energy and raises the sea floor level through sedimentation, and buffers the effects of increased sea level and waves (Duarte et al., 2013). Also integrating it with conventional grey infrastructures such as sea-wall construction will enhance the capacity of the measure towards the intended risk (Cheong et al., 2013). Due to this, the inclusion of wetland development as an additional supportive measure with grey infrastructures are gaining relevance for the risks such as flood and drought hazards (Stark et al., 2016). Another integration method is levees, that constructed for resisting flood, which covered with thick wetland seaward grass levees to enhance its strength and resistance towards flood waves (Cheong et al., 2013).

Integrating wetlands with urban landscapes is coming into prominence nowadays due to its contribution to various social, economic, political and environmental benefits. It helps to make the cities smart and sustainable with water supply and management of waste and storm water (Subrahmanian, 2020). In sustainable cities, the presence of wetlands will act as flood regulatory measure with its catchment prowess, it enhances biodiversity in the cityscape, provides recreational and job opportunities, and cooling the city temperature, thus by reducing the effect of climate change (Alikhani et al., 2021). Also, wetlands enhance water quality of the cities, and preserves groundwater levels, soil moisture enrichment and carbon sequestration (Thorslund et al., 2017). Another study based on Bangalore, India, constructed wetlands act as natural alternative

for the treatment of waste water which have developed as a remedial measure for the increasing waste water and surface water pollution at a very low maintenance cost (Raj and Jamwal, 2024).

2.1.2.2. Decarbonization through Wetland restoration

Wetlands have high potential for carbon sequestration and emission reduction capacity (UNESCO, 2019). There are various studies globally that lays out the role of wetland restoration plays in carbon containment. It is estimated that mitigating the conversion of wetlands and restoring the degraded wetlands, has the potential to reduce the GHG emission of 1.1 to 2.6 GT CO2 annually by 2030 (Strack et al., 2022). A rewetted peatland in North Germany measured to have reduced the annual GHG emission (773 t CO_2eq), nitrogen release to (914 kg N), and increased the cooling to (1 744 kW) and biotope value (Joosten et al., 2015). The study conducted by Komulainen et al. (1999) in Finland mentions about how peatlands started to act as significant carbon sink within a few years of restoration. Waddington and Warner (2001), also studied about the reduction in carbon emission after the restoration of peatlands based in Canada.

Since the Carbon capture, utilization and storage (CCUS) and the Carbon dioxide removal (CDR) technologies are still in the initial stages, and their efficiency and diverse risks associated with these technologies are still not well researched (Wallquist et al., 2009 and Palmgren et al., 2004), the acceptability of such decarbonization technologies has always encountered public reluctance (Nicholson, 2021). Hence, restoring wetlands are seems to be an efficient, benign and economical remedy for decarbonization (Tanneberger and Wichtmann, 2011). The economic benefit can be generated through carbon credits from peatland rewetting which is already established in 2011 (Tanneberger and Wichtmann, 2011), and a methodology also developed in 2017 under verified carbon standard (Verra, 2023).

2.1.3. Implementation and management of Wetland restoration

Implementation of a wetland restoration is a process of rejuvenating the degraded wetland either to its former self or with enhanced functionalities and capacities such as restoring its ecological integrity, its natural structure and native species, its natural functions and services through understanding contextual values and ensuring participation of indigenous community and stakeholders, involving multi-disciplinary team and execute designing and operational procedures to realize the restoration (US EPA, 2023).

Management of a restored wetlands facilitates the natural functions of its ecosystem for its native marine and wildlife, maintaining its regained structure by preserving it from conversions by human interventions, conserving it through effective monitoring by developing and achieving its social, economic and environmental goals and envisage future adaptation based on dynamic societal demands (US EPA, 2023). It also includes the process of controlling the degradation factors by avoiding non-native species including persistent removal of invasive plants, weeds, algae, nutrient loading and sedimentation that affects its biodiversity balance, site alterations according to the seasonal changes (SOLitude Lake Management, 2024), and enhance its multifunctional facilities of recreations for monetary benefits and generating additional fund for its management expenses (Nile Basin Initiative, 2013).

2.1.4. Socio-technical Challenges in application of Wetland restoration

As per UNESCO (2019), Despite the multiple benefits and co-benefits it provides, NbS methods were always projected as a mere risk reduction process ignoring its vast capabilities and functionalities. Especially ecological restoration methods such as wetlands encounters various challenges from social, technical and economic related factors (Dumitru and Wendling, 2021). And the 12 principles of Ecosystem Approach, developed by the Convention on Biological Diversity, explicitly demonstrates that these socio-technical challenges play a crucial role in all the principles, and the project initiators must consider it to ensure successful implementation. This is due to the dynamic nature of these factors as they are strongly interrelated and interdependent to each other (Convention on Biological Diversity, 2004).

2.1.4.1. Social Challenges

Social issues have always been a formidable challenge in wetland restorations. According to Buckingham et al. (2021), a major challenge, identified globally related to the restoration is the spatial issues land use factor, is bringing together various groups of stakeholders who live or work together in and around the landscape intended to be restored. They differ not only in the usage of land but in their economic status, ethnic identity, cultural aspects, land use values and property rights. Another challenge often identified is the surrounding inhabitants and communities of the restoration location. As per Sayer et al. (2021), giving emphasis to only technical aspects during the restoration process, will often results in overlooking the interests of legitimate stakeholders that includes local communities and their cultural aspects. Besides this, conflicting interests and biased political priorities among different stakeholders always generate greater challenges in these projects (Cortina-Segarra et al., 2021), and minimal awareness among the stakeholders about the utilization of wetlands for various monetary benefits through agriculture and recreation, creates diminished interest among stakeholders (UNESCO, 2019).

Policies and regulations of a country or municipality at the location of the restoration is a critical influencing factor for all such projects. Sari et al. (2019), reiterates that the complexity of overlapping regulations among ministries and unclear authority between local and central governments, will deviate the actual implementation of regulations from the intended regulations. And lack of coordination between various levels of government sectors and disparity in aligning the legislation and policies necessary for implementation can severely hamper restoration initiatives (Buckingham et al., 2019). Also, the governance intersectoral issues has always been considered to be the major socio-economic barriers in restoration initiatives (Smith & Maltby, 2003). And, an essential prerequisite for any project including wetland restoration, is the arrangement of sufficient fund and budget for the realization of the initiative. According to Gantioler et al. (2014), A major constraint for ecological restoration in Europe is the inefficient use of financial resources such as underutilization of allocated funds according to the timelines, lack of appropriate compensation for those participating in restoration activities and environmentally harmful subsidies etc. And insufficient funding and budgetary constraints always acts as severe roadblocks that impacts wetland restoration projects (Cortina-Segarra et al., 2021 & Canning et al., 2021).

2.1.4.2. Technical Challenges

Technical challenges possess severe barriers to the successful implementation and management of a wetland restoration initiative. A major factor is the immense dominance of grey infrastructure related operational processes and technologies in the global context where decades and centuries long interconnections and integration with the economy, its market orientation, policies formulations, service rendering and strategic developments which are centered with grey infrastructure solutions (UNESCO, 2019). Another factor is failure in integrating technical with social angle. Shackelford et al. (2013) have emphasized that an ecological restoration process, besides being considering the development of required landscape context, ecological services and species development, it should also give importance to the dimension of human elements and their social and political involvement too.

Then the lack of evidences and transparency of NbS system in conducting a diligent performance assessment, which is a major challenge which acts as a hindrance in widespread adoption of NbS methods (UNESCO, 2019). Suding (2011) echoes that despite numerous restoration projects and an overall consensus that evaluation is a key to future progress, comprehensive evaluations are still rare. And the limited available data indicates that restoration outcomes are highly variable. Unless standard practice changes, we will likely remain unaware of our failure and successes, due to inadequate monitoring and absence of mechanisms to report and scale-up local level activities to the global level. This could hinder future efforts to engage in effective restorations and securing necessary resources to undertake such initiatives (Cooke et al., 2019).

Another factor is the lack of knowledge and understanding among the socio-political stakeholder's circle of how to implement an initiative of NbS method even if the stakeholders are agreeing to adopt it, and how to integrate it with the existing grey infrastructural solutions (UNESCO, 2019). Local knowledge plays an important role in this factor. Cortina-Segarra et al. (2021), emphasizes that local knowledge gained from experience and stakeholder knowledge to be considered as legitimate with scientific knowledge, to garner a more comprehensive understanding of restorations and the factors influencing its success and failures. And the knowledge regarding NbS has mostly been academic which has negatively impacted its level of acceptance among the public (Sarabi et al., 2019). Then there is a dire lack of awareness about its benefits and cost-effectiveness, its underestimated contribution towards the environment and uncertainty in their efficiencies and operationalization, and absence of a comprehensive cost and benefit analysis methods (UNESCO, 2019). According to Nelson et al. (2020), even though, the high potentiality of forming a hybrid combination, NbS are always considered as a different entity from the conventional method. This factor also considers as one of the major barriers in integrating NbS methods with conventional engineered solutions (Gunn, 2023). Adequately skilled human resources are highly essential for wetland restoration activities. But there are challenges facing by organizations related to the shortage of adequately skilled human resources for volunteering wetland restorations (Grant & Langer, 2021). Various reasons highlighted for the dearth of manpower for ecosystem services. As per Osman et al. (2023), lack of operational facilities, inadequate resources, limited benefits and conflict of interests among the members are all key human resource related challenges which needs to be addressed to attract more skilled volunteers to wetland restoration.

2.1.5. Strategies applied globally to resolve the socio-technical challenges and successfully accomplish Wetland Restorations

Various strategies and concepts have been adopted globally, to resolve these diverse socio-technical challenges. Smith and Maltby (2003), have comprehensively discoursed about such strategies based on their research of 29 case studies about the ecosystem approach concept. The measures of "Awareness and Understanding", "Participation and Societal Choice", "Benefit Sharing and Incentives", "Decentralization", "Information Management" and "Adaptive Management" have been highlighted to conduct a successful implementation and management of ecological restoration practices, including wetlands. Apart from this, there are many global literatures and studies that reiterates about such measures that enhance the resolution capacity of the arising socio-technical challenges in such initiatives.

Knowledge dissemination is a key strategy in the global arena. According to Alexander et al. (2012), Principle 1 of the 12 principles of Ecosystem approach which laid out by the Convention on Biological Diversity, acknowledges the importance of promoting communication and collaboration of different stakeholders who seek distinct cultural, economic and societal benefits from wetland restorations. And principle 3 urges stakeholders to evaluate the impacts that occurs on other ecosystems and its related context due to wetland restorations (Convention on Biological Diversity, 2004). Genç (2017) advocates that the objective of communication is not simply sharing information and raising awareness about sustainability. It aims to drive societal transformation to achieve sustainability goals and involves knowledge generation, learning and collaboratively developing solutions for sustainability challenges. According to Cortina-Segarra et al. (2021), facilitating knowledge enhancement and adaptive co-management in the identified knowledge gap areas of social integration, community assembly processes, historical land uses etc., will aid to effectively overcome the barriers of successful ecological restorations. And embracing indigenous and local knowledge fosters active involvement, values the experience and wisdom of stakeholders, upholds cultural values, and facilitates adaptive management for long-term sustainability (Reyes-García et al., 2019). Also, a proper understanding and clarity on the property rights of land and the long-term benefits from it, will enthuse the land users and related stakeholders to voluntarily undertake the roles and responsibilities of realizing restoration actions (Chang & Andersson, 2021).

Enhancing social participation is a very widely used strategy. Mathe (2014) endorses that participatory approach allows to understand the diverse interests of stakeholders, local knowledge and relevant impact categories of stakeholders in various contexts. And it also encourages communication and finding simplistic solutions for the pertinent issues. According to Trkman et al. (2015), successful process management hinges on stakeholders' cooperation. To achieve this, it is imperative to have a comprehensive understanding of the stakeholder's processes in the context, ensure to uphold their priorities and values, and incorporating their perceptions towards the process uptake. Also, ensuring restoration with adequate funding by considering the entailed socio-ecological complexity of the context, optimizing the utilization of the allocated fund and promoting the financial benefits associated with ecological restorations could act as a catalyst for increased public and private participation for investment in restoration initiatives (Cortina-Segarra et al., 2021). Moreover, establishing multi-stakeholder platforms and bridging new institutions on

a landscape scale, will create an environment for enhanced collaborations, coordination and decision-making processes that drives to overcome existing barriers (Duraiappah et al., 2014). Apart from these, introducing new schemes such as "Payment for Ecosystem Services (PES) which enables concept of raising public/private funds for large-scale wetland restorations (Canning et al., 2021), and "result based payment" method which is introduced by REDD+ based on the "carbon credits" (Angelsen et al., 2024) which all will enhance stakeholder and community participation.

Synchronization is another strategy adopted globally. Vestil (2024) asserts that well-planned distribution strategy is crucial for an organization's endeavors. It enables them to broaden their reach, make their services and benefits available to a larger audience and finally ensure their objectives attained its target efficiently and effectively. And coordination and synchronization in the governance related factors thus deemed to be one of the core decisive factors in both phases of a successful wetland restoration program. Governance becomes effective when harmonized rules and regulations encourage respectful interactions among different actors, enable them achieving their distinct goals. (Lambin et al., 2014). Lordkipanidze et al. (2016), states that if the governance is adequately flexible and intense to adapt to changing political and natural circumstances, a multi-level and multi-scale approach to governing the resilience of protected areas, can also increase the resilience of the governance itself.

Enhancement of process and skills is an acclaimed strategy to mitigate these socio-technical challenges, especially technical challenges. Nilsson and Aradottir (2013), posits that improving implementation process of ecological restorations necessitates the importance on investigating social, political and technical aspects of the restoration location, developing restoration experts who are equipped to work in diverse environments and cultures and collaborative efforts for maximizing benefits. Rezaei et al. (2021), corroborates that enhancing knowledge and skills of human resources can boost human capital productivity which drives to value-added services, enhance customer relationship and satisfaction, reduce mistakes, stimulate creativity and innovation which all leads to improve system performance. And for applying effective problem solving, it is crucial to give more focus on adopting modern training for identifying and addressing the weaknesses of employees along with enhancing their abilities, skills and their cooperation (Al-Qatawneh et al., 2019). Numminen (2023) affirms Process optimization assists organizations to identify bottlenecks, redundancies and other productivity obstacles, and by streamlining workflows and adopting best practices, organizations can enhance efficiency and increase overall output.

Diligent planning and designing are very vital in wetland restorations. Based on the studies of Sundarbans at India and Bangladesh, Mekong River delta at Vietnam, Southern Ontario at Canada, the restoration of wetlands has to be carefully diagnosed and manage efficiently as the restoration process differs according to the context of the land and respective habitat based on the climate change evolution there (Erwin, 2008). Another study conducted in USA with 25 wetland restoration organization, describes the success rate of wetland restoration can be enhanced considerably without additional costs, if small changes in design is applied that augments positive species interactions (Silliman et al., 2015). Another study by Kim (2020) based on Japan context, mentions that if planned and executed well, the man-made wetlands can deliver the similar

multiple ecosystem functions of the natural wetlands. And also aid to meet both agricultural and ecosystem conservation goals through suitable cultivation methods and supporting policy interventions (Kim, 2020). The same study also discussed about how social, economic and environmental perceptions can contribute to successfully implement agro-environmental combined programs based on the context of Korea (Kim, 2020).

Hence, the restoration initiative requires comprehensive planning, leadership, involvement of various national, sub-national institutional sectors including government, communities, citizens, NGOs, educational institutions, corporates etc., for planning, implementing and funding resources (Ramachandra, 2001). It is imperative to make the initiative successful, because conservation and restoration of wetlands encompasses substantial potential that can immensely contribute to climate change mitigation and adaptation (Duarte et al., 2013).

2.2. Research Theoretical Framework: Socio-Technical Systems (STS)

The prime motive of conducting literature review about the research theoretical framework of socio-technical systems was to identify the evolution, scope and potential of this framework, to recognize various studies conducted globally at different contexts by using this framework, and to assess how to utilize and incorporate those concepts for executing the analysis of my study in a systematic way.

The evolution of STS concept is originated during 1950s. Scott (2014) explains that, according to Talcott Parsons, who was one of the pioneers in introducing social concepts, every system has to meet 4 basic functional necessary requirements for a system to survive, they are adaptation to the physical environment, goal attainment through deploying of resources, integration with the mixed and multi-dimensional atmosphere, and pattern maintenance with achieving stability in the process (Scott, 2014). Later in 1970s, Cherns (1976), have set forward 9 multifunctional principles of various socio-technical elements, which he re-visited in 1987 with adding more principles to it based on the evolution of business commercial atmosphere during those years (Clegg, 2000). Thus, the theory kept evolving as per the changed scenarios and developments in the technology's interaction with the social dimensions.

Geels (2004), have illustrated about the socio-technical regime which is a meta-coordination of diverse systems such as technological regime which contains the technical artefacts, science regime which defines the systematic knowledge, user and market regime which describes the functioning and economic aspects, policy regime which corroborates the regulations and governance, and the socio-cultural regime which describes the ethnic and cultural interventions (Figure 3). He conducted an empirical analysis of the dynamics of these socio-technical regimes by describing about the three interrelated analytical dimensions between socio-technical systems with human actors, social groups and organizations, and the rules and institutions that overall consolidates the comprehensive socio-technical system interrelation concept. He also discusses about the enhancement of socio-technical system by merging the concepts of innovations system of production stage with the subsequent functional stage that enriched the potential scope of socio-technical system concept with including the resources of both production and functional stages.

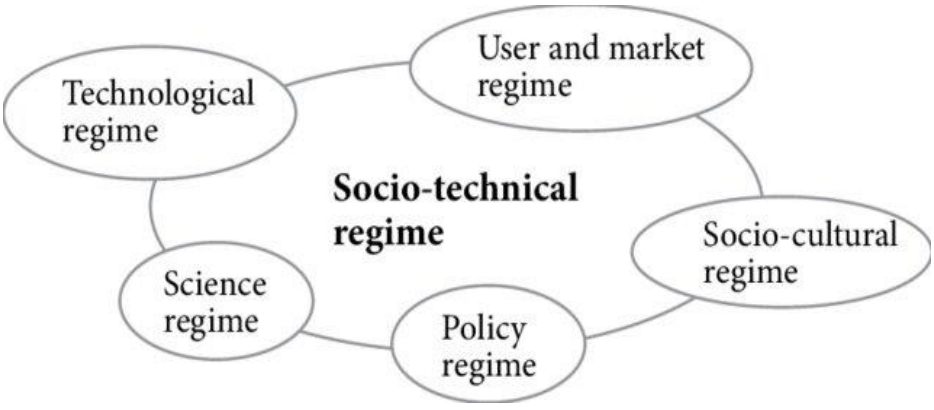

Figure 3: Meta-coordination-through-socio-technical-regimes
Source: (Geels, 2004)

Later, Davis et al. (2014) have developed STS framework which is based on the work of Leavitt in 1965 “Applied organizational change in industry: Structural, technological and humanist”, which engaging in organizational system change with a focus on the connections among individuals, tasks, frameworks, and technologies. He advocated for the interconnectedness of these elements and emphasized the importance of their collective consideration. It is expanded through various analysis and researches, and construct it with 6 interconnected components which is encapsulated with three external contexts (Davis et al., 2014). They are Goals, people, building/infrastructure, Technology, culture, and process/procedures. And the external contexts are stakeholders, regulatory frameworks and financial/economic circumstances. Any intricate organizational system which is related to either social or technical or both can be depicted using this hexagonal structure (Davis et al., 2014). (**Error! Reference source not found.**).

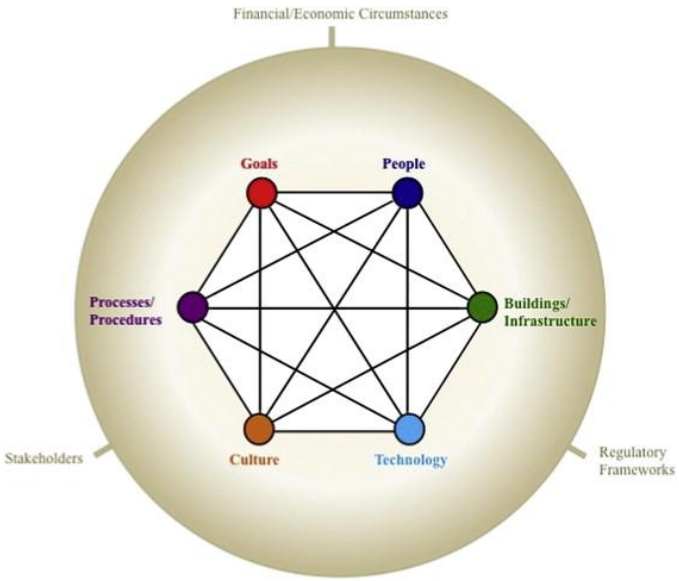

Figure 4 : STS Hexagonal framework
Source: (Davis et al., 2014)

2.2.1. Potential and scope of STS Theory Framework

According to Davis et al. (2014), the major benefit of adopting such a framework, is its ability to conduct an organized and systematic analysis of different complex systems and its related issues. This framework attempt to provide a straightforward and distinct picture of the interconnections existing in the systems. It provides a structure for examining the connections, interactions and their influences between each element existing in the system. Based on the Hillsborough football stadium disaster, the King's Cross underground fire incident and the Bradford City fire accident analysis done by Challenger and Clegg (2011), this framework has been successfully utilized to study that provided a detailed analysis about the system functioned and identified the pitfalls. This framework act as an ideal tool for investigating past incidents and outcomes through in-depth analysis which assist in predicting the future likelihood of possible challenges. This capability of

prediction can be utilized in forecasting situations which provides important contribution to the designing and management of upcoming large-scale projects (Davis et al., 2014).

Apart from this, STS multi-level regime concept is also applied for analyzing the dynamics of the transition of a niche measure to a regime measure that necessitates both societal and technological transformations (Geels, 2004). The study about the shift from industrial agriculture to organic farming and integrated production in Switzerland is an excellent example of it (Belz, 2004). It also utilizes for analyzing the failure due to the discordance in the interaction between social, technical and policy regimes. The analysis by Raven (2004) about the failure of two new ventures of manure digestion and heat pumps in the Netherlands endorses it.

Usually, the shared elements that contributes to the failure of a system are the narrow perspectives, lethargic attitudes, neglecting to absorb lessons from the previous failures, ignoring expert guidance, inadequate training and education, ineffective communication, absence of leadership, technological breakdowns, inadequately designed infrastructures, ambiguity in roles, and inadequate coordination among elements and actors. (Challenger and Clegg, 2011). Hence it is essential to adopt a framework that have the scope and magnitude to aid comprehensively in identifying these challenging elements and analyze its influence and impact occurring on a system.

2.2.2. Reason for incorporating STS Theory Framework to this study

The core reason for choosing STS framework to this study is because its aforementioned potential and scope is entirely meeting the scope of this study which necessitates an in-depth analysis of various social and technical related aspects which involves the human intervention. This framework provides a wide range of factors that encapsules all the aspects encompassing in a nature-based solution of wetland restoration initiative. Utilization of this framework enhanced the natural progression of the investigation in a systematic and scientific way that consolidated the findings of the study.

Besides this, according to the socio-technical regime concept of Geels (2004), this facilitated to understand the underlying factors of various challenges related to different regimes associated with wetland restoration and the interrelations between them that impacts its influential strength towards effective application of a wetland restoration. Also, the enhanced features of the socio-technical system through the amalgamation of production and functional stages enabled to have a profound analysis about the challenges related to implementation and how they evolve in future management stage of a wetland restoration.

Hence the study utilized the STS hexagonal structural concept of Davis et al. (2014) for the development of conceptual elements, and further incorporated the socio-technical regime concept by Geels (2004) along with it, for the development of Socio-technical challenges for the study and investigate its interrelated influences on wetland restorations.

3. Research Design

This chapter contains 4 sections with their related sub-sections. It delves into the details about the conceptual elements of the research theoretical framework adopted for the study, describes about the research strategy which consists of defining and identification of research unit, explains research boundaries, its limitations and risk management, and then details about the methodological approaches conducted for the data collection and analysis, and further explains about the ethical conduct of the research.

3.1. Research Theoretical Framework

The study conducted based on the 09 Socio-Technical system conceptual elements developed on the basis of STS hexagonal structure of Davis et al. (2014) and additionally elaborated it with the characteristics of socio-technical regime concept by Geels (2004). And these elements are investigated how they acted as challenges and influence the application of the selected NbS initiatives during its implementation and management phases.

3.1.1. Defining Conceptual elements of the Theoretical Framework

Internal Elements

According to Davis et al. (2014), These are the 6 elements which comprises inside the hexagonal framework. Each element does possess individual characteristics and purposes, but are strongly interconnected with each other which enables a system to function. The interaction between each elements forms the basement pillar of any system and decides the effectiveness of that organization's functional outcome (Davis et al., 2014).

People: It encompasses all the individuals / employees related to the organization system who interacts with the technologies and co-workers with his possessed skills and potentials in the related environment, to contribute to the attainment of the goal of that organization system (Davis et al., 2014).

It is the part of the diverse socio-cultural group regime which consists of actors, inhabitants, employees, administrators, implementors etc., who are interconnected with the other regimes for the production and functioning of the system (Geels, 2004).

Building/Infrastructure: It encapsules the overall environment of an organization system, where the people conduct the operation through utilizing technologies for the achievement of organization goals. It includes both physical and virtual environments such as physical operating spaces and artefacts, infrastructural layouts and designs, facilities and amenities provided, security and protection implemented to carry out the operation in an optimal and sustainable way etc. (Davis et al., 2014).

This element comes under the category of both socio-cultural regime and the user-market regime as it is regulated by constant interaction from both these regimes and closely dependent on the policy regime. It has equal relevance with both production and functioning phases (Geels, 2004).

Technology – It consists of all the provided technological artefacts which is being managed and handled by the people of an organization system and augments all the operations and procedures

of the system in the most optimal way. It includes machineries, software and hardware, testing and analysis tools, monitoring and controlling instruments, transporting and logistics systems, operating systems, sustainability systems, electrical and electronic properties etc., where the list would be endless (Davis et al., 2014).

The technological regime which contains hard and soft technological materialistic items, standardization, product specifications and functional attributes, technical frameworks etc., which all utilized by the other regimes, especially science regime in the production phase and user and market regime in the functional phase (Geels, 2004).

Culture: It defines the organizational culture and atmosphere where a system operates. It reflects in every aspect of the system in the form of goal designing and conceptualization, people's behavior and attitude, infrastructural layout and facilities, technological applications and its operations, process and procedures implementations and conduct (Davis et al., 2014).

A component of the socio-cultural regime that depicts the distinctive societal norms and characteristics existing among the various groups of the society and their interaction with other regimes, especially with the policy regime and the user and market regime (Geels, 2004).

Process / Procedures: It involves all the steps, plans, strategies and preparations both physically and technically which is to be followed by the people in an organization system to achieve the objectives put forward by that organization. It contains all the procedures to carry out the physical and technical operations, the internal rules and regulations, standardization and stabilization of the processes, assessments, controlling and monitoring of the procedures, auditing and evaluation processes, safety and maintenance etc. (Davis et al., 2014).

The procedure for production and functioning incorporates both the technological regime that necessitates the technical aspects for both phases, particularly for production and science regime that necessitates the required knowledge for facilitating the both phases, particularly functioning phase (Geels, 2004).

Goals: Every organization system have a set of objectives and goals which could only be able to achieve through the interconnected action of its people utilizing various technologies and tools operates in a given infrastructure (Davis et al., 2014).

Each regimes possess autonomous characteristics and hence have their own respective objective and goals. But due to the significant interrelation between them, each regimes necessitates the interaction with other regimes to accomplish their respective goals (Geels, 2004).

External Components

The below mentioned 3 numbers of external elements do have a significant influence on all the 6 internal components of an organization system. All the operational performance, procedures conduct, manpower organizing, technical applications, culture development, infrastructural implementations and objective settings etc., will be affected and aligned based on the below external factors. These factors can be enacted on micro, meso and macro level of an organization system upon the circumstances (Davis et al., 2014).

Financial / Economic Circumstances: The financial and economic aspects of an entity such as organization or a state or national and global level, can control the hexagon elements. It is based upon the dynamic scenario of related entity's economic budgeting, costing and accumulation of financial resources of an organization system. For eg: An economic crisis can impact the financial implications of an entity (micro to macro) which affects the systems related to it (Davis et al., 2014).

It is the part of user and market regime which includes the financial regime concepts such as financial institutions and its functioning, controlling of economic and commercial aspects of the market, financial supporting of the business etc. (Geels, 2004).

Regulatory Framework: It can be termed as the rules, regulations, policies, measures, procedures etc., followed by the above-mentioned entities to conduct an operation of a system or process. For eg: A change in the political scenario of a country can brings changes in its policies and regulations which adheres to new administration in charge. This will have a direct effect to all the organizations goals and objectives (Davis et al., 2014).

The policy regime consists of the governmental institutions, its regulatory frameworks and policy constructions. It is interconnected with all the other regimes for the execution of both production and functional phases (Geels, 2004).

Stakeholders: It comprises of all the parties interconnected with the related organization system which act on a basis of mutual benefit concept with the system involved. They are the customers, entities, suppliers, logistics providers, clients, dealers, service providers etc. The change in concepts or behaviors of these stakeholders can have significant impact on the related system (Davis et al., 2014).

The user and market regime that comprises of stakeholders at both stages, particularly in the functional stage. The regime encompasses the group of consumers, the market segments, market constructors and operators, commercial and financial firms etc. This regime actively interacts and dependent on all the other regimes of the comprehensive socio-technical regime (Geels, 2004).

3.1.2. Identifying potential challenges for the study

It is being noted from the literature review that there are multiple challenges prevailing related to both social and technical aspects in wetland restorations, globally. And also, there is a significant knowledge gap in the awareness about the strategies applied to resolve it. This necessitates to conduct the study about such challenging socio-technical aspects and enlightening about the resolution measures adopted for it. Hence, it is imperative to identify the potential challenges of wetland restorations globally, and investigate how they affects its effective application in the context of the Netherlands. Furthermore, to discover what strategies they applied to overcome those challenges. Therefore, based on above STS framework hexagonal conceptual elements derived from Davis et al. (2014) and its alignment with regime concept of Geels (2004), potential challenges are ascertained from the literature review section **2.1.4** about global socio-technical challenges of wetland restorations that synchronizes with both the concepts.

The infrastructure concept of a wetland restoration is the land location where the restoration project is planned. Therefore "Land use issues" mentioned in the study of Buckingham et al. (2021) is identified as a potential challenge. Similarly, for culture element and socio-culture regime, "Local communities and culture" related issues mentioned by Sayer et al. (2021), and for stakeholder element and user/market regime, "Stakeholder interventions" pinpointed by Cortina-Segarra et al. (2021), Then, for regulatory framework and policy regime concepts, "Governance regulations & policy" related issues mentioned by Sari et al. (2019), and for financial/economic circumstances and user/market regime, the issues related to "Economic & Budget limitation" stressed by Gantioler et al. (2014) has been identified.

Likewise, similar exercise was repeated for determining technical challenges as well. For process/procedures and science/technological regime, the challenges of "Process management" echoed by UNESCO (2019), and for people / technology elements and socio-culture / technology regime concepts, the "Employee competency and skills" related factors mentioned by Grant & Langer (2021), then for goals element and science / technological regime, the factors mentioned by Cooke et al. (2019) of "Performance Evaluation", and for technology element and science regime, the "Knowledge gap" issues mentioned by UNESCO (2019) has been identified. (Table 1): -

Table 1: STS Related Challenges

Section		Challenging Factors identified	STS Framework elements category	
			Hexagonal Concept of Davis et al. (2014)	Regime Concept of Geels (2004)
Social	1	Land use related issues (Buckingham et al., 2021)	Building/Infrastructure	Socio-cultural / User-market Regime
	2	Local Community & Cultural factors (Sayer et al., 2021)	Culture	Socio-cultural Regime
	3	Stakeholder interventions (Cortina-Segarra et al., 2021)	Stakeholders	User-market Regime
	4	Governance & policy factors (Sari et al., 2019)	Regulatory Frameworks	Policy Regime
	5	Economic & Budget limitations (Gantioler et al., 2014)	Financial/Economic Circumstances	User-market Regime
Technical	6	Process management (UNESCO, 2019)	Processes & Procedures / Technology	Science Regime / Technological Regime
	7	Employee Competency & Skills (Grant & Langer, 2021)	People / Technology	Socio-cultural Regime / Technological Regime
	8	Performance evaluation (Cooke et al., 2019).	Goals / Technology	Science Regime / Technological Regime
	9	Knowledge gap (UNESCO, 2019)	Technology	Science Regime

3.2. Research Strategy

The research is based on the exploratory approach which delve deep into identifying the challenges encountered by the research unit owners during the implementation and management stages of those initiatives. The research also blended with explanatory elements that elucidated the remedial measures adopted to overcome those challenges and how they proceeded the application of the initiative successfully. The study is executed by collecting and analyzing the information, observations, experiences acquired, empirical findings, knowledges attained etc., based on the STS conceptual framework elements and found the most influential challenges for the effective application of those projects in the Netherlands.

3.2.1. Research Unit

This research is focused on the NbS initiatives of Wetland restoration due to its substantial contribution towards climate resilience and decarbonization actions in the Netherlands.

3.2.2. Selection of Research Unit

The research included various large to small-medium scale wetland restoration programs which is administered by National and provincial level governments, Research universities, International NGOs etc., that is initiated for flood defense, biodiversity enhancement, drought control, habitat enrichment and decarbonization etc.

3.2.3. Research Boundaries

The research boundaries were set to ensure that the research is successfully completed as per the timeframe without compromising on the quality of any phases including data collection and data analysis. Since research period is covering from May 2024 to 2nd week of July 2024, the temporal boundaries for data collection had set from 1st week of May 2024 to 2nd week of June 2024. This was done to provide adequate time to conduct a meticulous data analysis process from the 3rd week of June 2024.

3.2.4. Limitation

Out of 14 research units which are availed for the study, 12 numbers are still in the implementation phase and yet to enter into the management phase. Hence, the intensity rating of challenges during the management phase, which discussed in the chapter **Results and Findings**, are based on the speculations and assumptions of the key interviewees reflecting their expectations for future management scenario.

Another limitation was, since the data collection was conducted during the period of May 2024 and June 2024, there were some inconveniences observed in the interviewees time availability due to the hectic schedule to gear up for the upcoming holiday season.

3.2.5. Risk Management

Proactive measures and devising of “Plan B” are always essential to successfully carry out a research study. The below mentioned steps were aided to the management of risks related to the research boundaries and limitation factors.

The research boundaries related risk was managed through expediting the data analysis by starting it from 2nd week of June 2024 itself concurrently with the ongoing data collection phase which was further extended up to end of June 2024. This strategy has paid off as more participants have been added further to the interview list, and also obtained sufficient time to conduct a conscientious data analysis for the results.

The extension of the data collection period also aided to mitigate the risk of time availability of the interviewees. And, regular engagement with the first supervisor enabled to take necessary measures to the barriers and challenges encountered during thesis progress.

And, an in-depth secondary data collection method was planned to apply through desk research based on the grey literatures including project related reports, documents, updates in website and from previous studies etc., if in any scenario, the primary data collection gets affected and becomes insufficient to conduct the data analysis.

3.3. Research Methods

This section elaborates about the methods and measures adopted to obtain the supportive secondary data in the form of desk research through literature reviews of both scientific and grey articles, for the topic aspects under study. And then describes about the methods applied for collecting the primary data required for the study, and finally, the systematic approaches conducted for the data analysis and evaluation process of the research.

3.3.1. Desk Research

Extensive literature review has been carried out based on the topic elements at global scenario such as nature-based solution of wetland restoration, its contribution to climate resilience and decarbonization, its implementation and management, the socio-technical challenges related to it, the strategies applied for its successful accomplishment, research theoretical framework, its evolution, scope and potentials, its conceptual components, and identification of challenges based on the framework that relating to the study etc.

The searching of literatures for the scientific and reliable articles were conducted at the databases of SCOPUS, ELSEVIER, RESEARCH GATE, GOOGLE SCHOLAR, SPRINGER, FRONTIERS etc. using the keywords nature-based solutions, wetland restoration, socio-technical system challenges, climate change and adaptation, and decarbonization.

Apart from the scientific articles, the literature review was conducted relying on a handful of grey articles and publications such as UN reports, EU reports, US EPA reports etc., mainly for gathering information related to updates and statistics.

3.3.2. Data collection

Primary data - The data collection process for answering all the 3 sub-questions was mainly based on obtaining primary data through qualitative approach by conducting semi-structured interviews. A total of 19 number of key personnel were interviewed who were possessed between 5 to 35 years of experience range. They are comprised in the category of initiative owners, provincial project leaders, planners, engineers, managers, supervisors, coordinators, experts etc. who are involved in

various types and scales of wetland restorations in the Netherlands. The versatility in the category of the key personnel has been phenomenal in deriving subtle observations and a multilayer viewpoint to the generated results.

The initial details of contacts have been obtained from the websites of related projects of Wetterskip Fryslan projects, Waterlands projects, Frisian Peat Meadow Projects, NGOs such as IUCN, Wetlands Organization etc. And from there, snowball sampling approach was adopted which has turned out to be successful as it was instrumental to reach to the key personnel who falls in the aforementioned categories. The key personnel were first reached via email by introducing the researcher (myself) and research objective. And once obtained with the consent for participating in the interview, an appointment was arranged according to the convenience of both parties. Further, the interview questionnaire was provided to the interviewee well in advance for their reference.

The questionnaire for the semi-structured interview was developed based on 9 potential socio-technical challenges (Table 1) derived from the literatures and STS framework and aligned it with the research sub-questions. The questionnaire was constructed as open-ended questions (See **Appendix 1**) which is the best method for extracting data for obtaining the qualitative information, observations, experiences acquired, empirical findings, knowledges attained that is being shared by the key informants. Additionally, there were some quantitative based rating scales questions which enabled to conduct the data analysis to identify the influence gravity of the challenges.

The interview was conducted either face to face at the location of the interviewee or through utilizing online medium of Microsoft Teams under University of Twente, according to the convenience of the interviewee. The duration of each interview was on an average 45 to 60 minutes. And during interviews, voice recording for face-to-face and video recording for online interviews, were captured. Both recordings were converted into transcripts with the facility of Microsoft Teams. Either way, this process was applied only with the prior intimation and consent of the interviewee through proper ethical channels.

Secondary data - obtained by conducting desk research, mainly to study about the basic details of the selected research units, such as background information, related updates, key personnel information etc. Grey literatures including organization websites, publications and newspapers were also utilized for this method.

The research units which the study has conducted are given below. (

Table 2). The list of interviewees is provided in **Appendix 2**

Table 2: Selected Research Units

Sr. No.	Research Units	Location	No of Interviewees	Application Phase
1	Alde Feanen National Park	Earnewald	2	Management
2	Alde Lune Polder west of Suwald	Suwald	1	Implementation
3	Anonymous	Anonymous	1	Implementation
4	Ems Dollard Estuary	Groningen	5	Implementation
5	Engbertsdijksvenen Peat Restoration Project	Overijssel	1	Implementation
6	Gouden Boaiem Heeg Project	Smallebrugge	1	Implementation
7	Green banks at Brasserhout	Hague	1	Implementation
8	Hegewarren Polder Project	Heggewarren	1	Implementation
9	Idzegea Project	Idzegea	1	Implementation
10	Leeuwarden Zuid Flood Defence Project	Leeuwarden	1	Implementation
11	Marker Wadden Project	Flevoland	1	Implementation
12	Nature development - Weimeren Polder	Breda	1	Implementation
13	Veen Innovatie Polder Hegewarren	Heggewarren	1	Implementation
14	Weerribben Wieden National Park	Giethoorn	1	Management

3.3.3. Data analysis

Since the data collected for the first and third sub-questions are of qualitative nature, data analysis is executed by utilizing content analysis through coding techniques by creating a codebook (Self Contribution, 2024).

For the first sub-question, separate sections have created based on the nine socio-technical challenges developed for the study (Table 1), and the contents of the interview questions from 1 to 10 incorporated to the codebook to the respective challenges section and sub-categorized it based on the implementation and management phases. This method facilitated to identify the various patterns in each challenge at implementation and how it evolves in the management phase. The challenges were then quantified with providing color codes categories of “Nil to Negligible”, “Minor to Moderate” and “Major to Catastrophic” based on each interviewee’s rating provided to each challenge for the interview questions 12 and 13. Further, applied descriptive analysis for statistical derivation of the challenge evolution. This also has facilitated to provide a systematic

analysis and description for the results and visual representations of the data including charts and tables.

For answering the second sub-question, regression analysis was conducted in Microsoft Excel to identify and quantify the strength of the influence of challenging factors towards the effective application of wetland restoration in the context of Netherlands. The figures from descriptive analysis which derived based on the rating scale interview questions of 11 and 12 were utilized for this data analysis. Each challenge rating was analyzed with conducting regression test against the effective implementation rating provided by the interviewees and this led to shed light on to the identification of most influential socio-technical challenges among those 9 STS elements. And also, further developed a relational network data matrix (Self Contribution, 2024) in Microsoft Excel and incorporated it to Gephi (0.10.1) visualization software to identify and demonstrate the interrelations between these 9 STS elements.

And for the third sub-question, the resolution strategies adopted by the key personnel are collected from the contents of the interview questions from 1 to 10, 14 and 15, and then incorporated into the codebook. Since the key personnel applied the strategies holistically to all nine socio-technical challenges during both the implementation and management phases, these strategies were classified into different categories and derived themes based on global literature from section **2.1.5**. This facilitated to discourse the result according to the themes identified and the percentage of interviewees utilized those strategies.

After incorporating all the contents, the codebook was finally applied for interrater reliability measure with a peer to evaluate the consistency of the derived patterns of the challenges and the themes of the strategies, thus by minimizing the possibilities of biases.

Please find below table for an overview of the data collection and analysis methods adopted for the research, based on the three sub-questions (Table 3): -

Table 3: Overview of data collection and analysis methods

Research sub-question	Desired information	Data collection method	Sources	Data Analysis method
1) What are the key socio-technical challenges encounters during the **implementation and management** stages of wetland restoration?	Information, observations, experiences acquired, empirical findings, knowledges attained about various types of challenges encountered and how they resolved it.	1) Desk research will be conducted to study the background information, basic details and related updates about the selected research units. 2) Semi-structured interviews with qualitative type questionnaires based on open-ended question with some additional rating scale questions.	1) Grey literatures including organization websites, publications and newspapers for conducting the desk research. 2) Participants including initiative owners, planners, designers, architects, engineers, managers, supervisors etc for conducting the interviews.	1) Content Analysis through applying coding techniques, and descriptive analysis of the intensity ratings. 2) Regression analysis to identify the strength of the challenging factors that influenced the effective application of the initiatives 3) Relational Network Data Matrix analysis and Gephi (0.10.1) software to identify and visualize the interrelation between the socio-technical challenges.
2) Which are the **most influential socio-technical challenges and how they** affect the effective application of wetland restoration?	Rating of each STS challenges during implementation and rating of the effectiveness of their initiative implementation.			
3) What are the key **strategies and best practices** that applied to overcome these socio-technical challenges?	Information, observations, experiences acquired, empirical findings, knowledges attained about various types of challenges encountered and how they resolved it.			

Please find below a schematic representation of the research process flowchart (Figure 5)

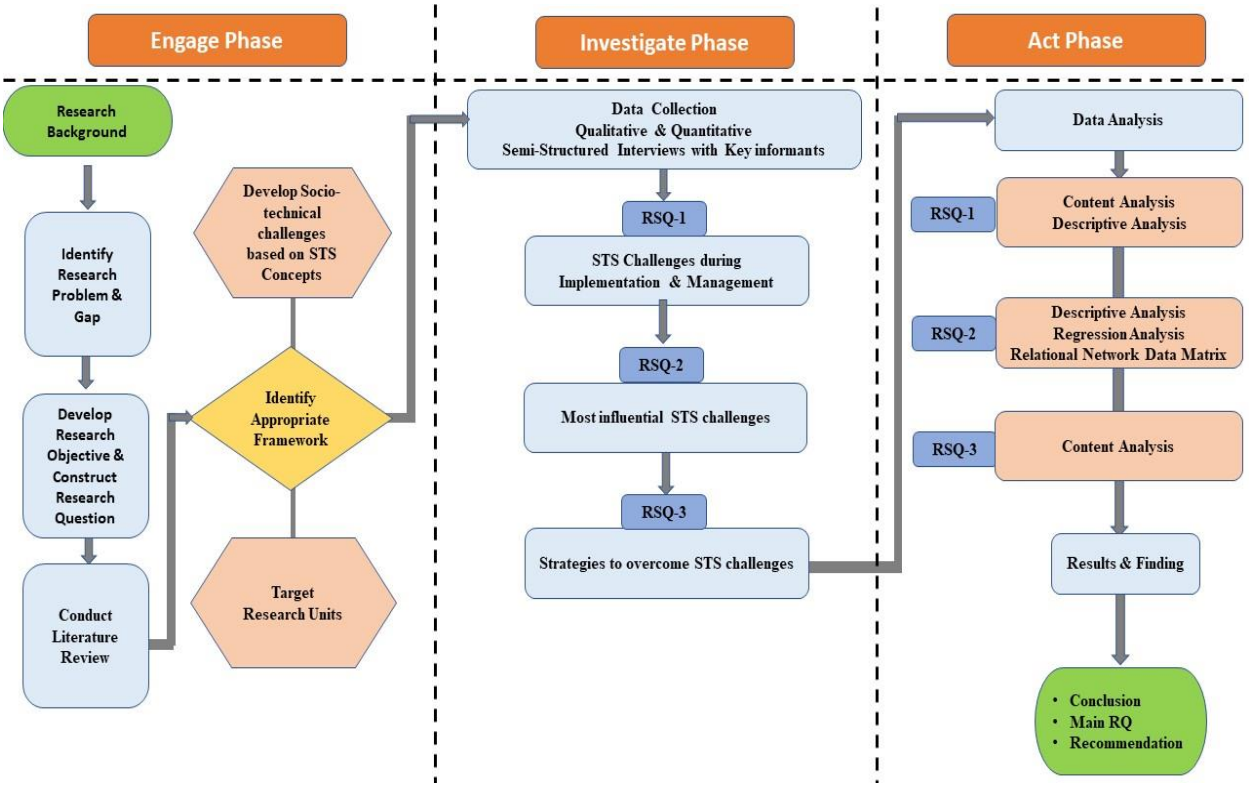

Figure 5: Research Process Flowchart
Source: (Self Contribution, 2024)

3.4. Ethical Consideration

The conduct of this research has ensured to adhere all the mandatory protocols, principles and guidelines set forth by the University of Twente Ethics Committee. It comprises from conduct of the interviews and surveys if any, handling of the data, utilization of online mediums and software, usage of one-drive facility for data storage etc. The questionnaire for the interview were submitted before Ethics Committee and obtained necessary approvals for proceeding with it. Also, it followed the guidelines such as sending prior intimation and notification about the interview questions to the interviewee, obtaining consent form from the interviewee about the interview conduct etc., has ensured.

Apart from above, the interviewee was explained about their rights, safety and ethical methods practicing for the data security. And further detailed about maintaining the identity anonymity of the interviewee, recording and transcription of the interview, and related data revelation and information sharing of the interview conducted. These data were processed according to the consent form endorsed by the interviewee.

4. Results and Findings

This chapter delineates into the results and findings of the data analysis conducted with the collected data through the interviews with experts based on the 9 socio-technical challenges developed from the literatures and STS Framework (Table 1) and the strategies they have applied to overcome those challenges. And thus by, it answers the three sub-questions through three sections which has addressed the main research question.

4.1. Sub-question 1 - Key socio-technical challenges encounters during the implementation and management of wetland restoration

This section uncovers the sub-question 1 by illustrating the findings about each socio-technical challenges and the patterns identified from the issues related to each challenge during the implementation phase and management phase of a wetland restoration initiative. A descriptive statistics analysis has been applied for a comparison of challenges perception based on the rating provided by the participants for the implementation and management phase (Table 4). The result of this section is derived from the contents based on the interview questions from 1 to 10 and ratings for the questions 12 and 13 for each respective challenges (See **Interview Questions**).

4.1.1. Land use issues

Implementation phase – Out of 19 interviewees, 79% (n=15) considers land use related issue as a challenge between "major to catastrophic" level. A further 11% (n=2) perceive land use related issue as a "minor to moderate" challenge and 11% (n=2) observes it as "nil to noticeable" challenge.

Based on the content analysis, multiple patterns of issues have been identified. They are "Conflict of Interest" that arises due to the difference in vested interests of multiple landowners that lead to resistance for the acquisition of agricultural lands through strong protests and agitation from the land owners and farmers, and obtaining collective cooperation for the implementation. Then "Insufficient financial compensation" offers to farmers to sell the land that impacts their revenue sources which restricts the project owners for negotiation. And "Resource Scarcity" issues that related to land shortage that intensify the resistance of land owners to sell their land as the implementors fails to provide replacement lands to the owners who are hesitant to accept financial compensation as mentioned by Interviewee 9, a project coordinator:

"In the Netherlands there is less ground for people & farmers. We have a very intensely use of the land and the legislation for farmers is stick stuff. We only can give them money and they don't want money. They want compensation as land".

Interviewee 4:

"A very big challenge as the farmers don't wanna loose their single square meter of their land for the project as they are skeptical of the developments and transitions going all over whether it may affect them".

The scenario of categorizing "nil to noticeable" level occurs when there are situations such as the inhabitants voluntarily raise the requisition to realize the project to resolve the degradation of their agricultural or residential lands such as subsidence issues or when the farmers also cooperate with the project to mitigate an issue that affecting their wellbeing or their smooth farming operations such as increase in water levels, and also when the implementers have their own lands or sites which are already designated nature protected areas.

Management Phase – When it enters to management phase, 68% (n=13) interviewees consider it as a "major to catastrophic" challenge, and 26% (n=5) perceive it as a "minor to moderate" challenge and 5% (n=1) observes land use as "nil to noticeable" challenge. The major pattern identified are the "Resource Scarcity" due to land availability issues, and "Future land use regulations".

Result – Overall, a major challenge marginally close to significant level in implementation phase with only a narrow decrease in management phase **(Table 4)**.

4.1.2. Local community & cultural related factors

Implementation phase – Majority of the interviewees (42%) (n=8) observes local community and cultural related factors between "major to catastrophic" level challenge, while a 37% (n=7) considers it as a "minor to moderate" challenge, and there are 21% (n=4) who recognize it as a "nil to noticeable" challenge.

The major identified patterns from the contents are "Legal appeals and objections" by the communities as protest against land acquisitions due to the anxiety about how the project affect their trade such as farming and grazing, their financial sources, and their lifestyle. Then the "Operational objections" raised by the surrounding villages related to duration of works, transporting machineries, harvest seasons etc. Another important pattern identified is the "Conflict of interest" arises due to the cultural factors such as spiritual or archeological importance of the location as highlighted by the Interviewee 6, a project coordinator:

"For some farmers, there are some cultural, spiritual heritage things which started from their great, great grandfathers, so they won't easily acknowledge the new changes".

Management Phase – While the percentage of "major to catastrophic" level has decreased to 32% (n=6), the "minor to moderate" figures has increased to 53% (n=10). And 16% (n=3) of the interviewees perceives local community and cultural related factors as a "nil to noticeable" challenge.

The most identified pattern is "Challenges will mitigate", and then "Challenges will remain same", and few participants indicated about "Anxiety from the surrounding communities" due to the unforeseen impact as expressed by Interviewee 11, a project coordinator:

"What the people are afraid of is that these are rural areas and if you change things like the plan we have, more tourism or more housing, then you attract people from the city. People are afraid

of the things they don't know if and yes, if the welfare balance is too far apart, then it doesn't work".

Result -On a whole, the local community and cultural factors will minimize from "moderate" to "noticeable" level challenge in the future management phase **(Table 4)**.

4.1.3. Stakeholder Interventions

Implementation phase – While 47% (n=9) strongly affirms stakeholder interventions as a "major to catastrophic" challenge, 42% (n=8) consider it in "minor to moderate" level. And a 11% (n=2) believes it is in the category of "nil to negligible" challenge. There are mainly two types of patterns being ascertained that are interrelated to each other. They are the "Conflict of Interest" due to the various demands and expectations of multiple stakeholders related to the initiative, and the second one is the challenge of "Gaining trust" within limited time among the stakeholders about upholding their values and interests. The perplexity of these two challenges is, while a solution is always attainable, they simultaneously have the potential to transform into unsurmountable challenges that will hinder further progression of the implementation.

Interviewee 15, a project manager, comments about the essentiality of synchronizing multiple goals of multiple sectors and striking the balance between them:

"It's a challenge, because you know the prospects of the region is also of course, apart from the farming, also in recreation and in other economical possibilities for the area and of course there's also different people that can be impacted".

Management Phase – The categorization of the challenge in management phase is, 53% (n=10) classifies it as "minor to moderate", 37% (n=7) still perceive it as "major to catastrophic" and 11% (n=2) as "nil to negligible" challenge. The patterns surfaced are "Challenges remains same", "Conflict of interests" among stakeholders, and "Challenges mitigates after implementation".

Result - Generally, as per descriptive analysis **(Table 4)**, the challenges related to stakeholder intervention is perceived as a higher moderate level challenge which is marginally closer to the major level during implementation, and decreases into a lower moderate challenge in management phase.

4.1.4. Governance related regulatory & policy issues

Implementation phase – 74% (n=14) perceives barriers related to governance related regulations and policies as a "major to catastrophe" challenge. And 26% (n=5) observes it as "minor to moderate" challenge. The major patterns of challenges derived from the content of the interviewees are: -

"Stringent Regulations" due to stricter and inflexible regulations & policies, both from the EU level and national level, that restricts the implementors to be flexible by applying pragmatic options to overcome the challenges and accomplish their works. This is also synchronized with regulation for "Operational barriers" that is related to the restrictions in carrying out the

implementation process during the breeding and holiday seasons. These types of factors will lead to further challenges due to financial losses and project delay.

Interviewee 11, a project coordinator expresses that:

"Regulations gave no space to move in a new direction that's quite frustrating. All the people in the field here they're willing to move, but there's always a regulation that says no. So, it would be nice if the regulations give more space for developing".

Other major patterns identified were "Political influences" in the decision makings and "Short-term plans". Almost all interviewees have expressed that they have encountered these types of governance challenge patterns in their project implementation. They believe that the favorable scenario for the climate actions such as wetland restorations is directly proportional to the change in administration, rules and policies as per political inclination of the ruling party. Further, the change in characteristics of these regulations every 4 years, also affect such implementation programs which is a rather long-term process.

Interviewee 4, argues that:

"It's not because we cannot implement it, it's just politics, our political figures, they are hesitating to use the instrument, to use force to do so. We have the instruments, but we hesitate to use it because of the politics and electorate".

Another major pattern identified is the "Conflict of interest" between policies which leads to multiple permits that hinders the smooth progression of an implementation program as such programs constantly involves multi-level governance sectors. It is regarded as a formidable challenge to harmonize the regulations and policies of these different parties who have their own different perspectives, goals and vested interests

Interviewee 6, a project coordinator evaluates this aspect as:

"The kind of biggest challenge is the legislation in place is undiagnostic. We have a policy to increase and improve agricultural productivity, but also a policy to reduce emissions and protect biodiversity and water. And that often means, then, that you're spending the same money to counteract the other policy that you're spending money on".

Management Phase – While 58% of participants (n=11) have expressed that governance related regulations and policies will still be a "major to severe" challenge during the management phase, 42% (n=8) observes it in the category of "minor to moderate" challenge. The major patterns identified are "Challenges will remain same", "Challenges will mitigate", "Political influences" and "Short-term Plans".

Result -The results **(Table 4)** illustrate that overall, this issue will descent from "significant" to "Major" level challenge in the management phase.

4.1.5. Economic & Budget Limitations

Implementation phase - 53% (n=10) considers economic and budget limitations as a "major to catastrophe" challenge and 47% (n=9) depicts it as a "minor to moderate" challenge. The patterns of challenges found from the content of the interviewees are the "Stringent Regulations" to flexibly utilizing the fund for negotiation purposes with the stakeholders for land use related issues, and this will lead to "Time constraints" of the fund utilization which illustrates the challenges in meeting the timeline goals by the funding organizations such as EU & National level Subsidies. Other pattern are the "Short-term plans" of the funding in the budget allocations that is inversely proportional to long-term projects like wetland restorations, the strict and complex "Administrative measures" which causes delay in obtaining the funds for the project, and the "Conflict of Interest" in the objectives between the fund raisers that impedes the possibilities of resolving fund shortages through combinations as illustrated by Interviewee 15, a project manager:

"I think one of the most main budget constraints is that all the funds that we get are specific funds. So, we get funds that are for climate and we get funds that are for nature purposes, but we're creating a process that is interdisciplinary. So, we can't make the division between measures we take".

Management Phase – 47% (n=9) of participants each apprehends it as "minor to moderate" and "major to catastrophic" level. And 5% (n=1) believes it as a "nil to noticeable" challenge. The patterns observed are "Shortage in fund" for maintenance, monitoring and future scaling up. "Challenges will mitigate" and "Challenges remains same".

Result - According to the results **(Table 4)**, the economic and budget constraints is retained as "major" challenge in both phases.

4.1.6. Process Management

Implementation phase – 37% (n=7) adjudges process management related issues as a "major to catastrophic" challenge and 53% (n=10) deems it as a "minor to moderate" challenge. While 11% (n=2) finds it as a "nil to negligible" challenge. The content analysis generated patterns are "Operational barriers" which is considered as a key technical barrier that has been echoed by most of the interviewees. This is mainly attributed to the negative effects occurring through water level enhancement of wetlands as part of restoration which affects the neighborhood agriculture and residences. Apart from land acquisition, it is one of the prime reasons for the majority of protest from the adjacent community and stakeholders. Other patterns are "Resource Scarcity" that is related to the scarcity of designated contractors and technical personnel who have the expertise and experience in wetland restorations, and "Time constraints" that relates to the restrictions for administering the implementation works during breeding and holiday seasons.

Another major pattern identified is the "Conflict of interest" arises out due to the involvement of various sectors such as farmer communities, village communities, nature & wildlife organizations, provincial authority, water board, tourism sector etc., and their required approval for necessitating the operations of implementation. This is being accentuated by Interviewee 5, a project leader:

"It was a big challenge as it need to get so many experts, organizations, government bodies to bring together for the realization of the project".

And, Interviewee 11, a project coordinator:

"We always have to be aware of what we do. If it does affect the neighbors or the other stakeholders, and that's always given a little bit of tension because they want this and we want that, that gets a little friction".

Management Phase – In this phase, 42% (n=8) addresses it as a "major to catastrophic" challenge, 53% (n=10) views it as a "minor to moderate" challenge and 5% (n=1) assesses it as a "nil to negligible" challenge. The patterns obtained are "Operational barriers" for future maintenance and upscaling works, "Challenges will mitigate" and "Challenges remains same".

Result - The result **(Table 4)** directs that process management related factors perceives as a higher "moderate" challenge during both implementation and management phase.

4.1.7. Employee competency & skills

Implementation phase – Most of the interviewees (58%) (n=11) indicated employee competency & skills related challenges as "minor to moderate" category and 37% (n=7) ropes it in "major to catastrophic" category. And 5% (n=1) claims it as a "nil to noticeable" challenge. The detected challenge patterns are "Resource Scarcity" due to the lack of social skills to engage with the surrounding inhabitants and communities of the initiative location and convincing them about the importance of nature etc., which are deemed as very vital in such programs. And also, issues related to the dearth of technical knowledges arises when multi-sector level employees participate in wetland restoration programs. Another pattern is "Conflict of Interest" in the perspectives between the senior employees who have profound on-field experience and the juniors who have latest knowledge but devoid of pragmatic experience.

Interviewee 14, a portfolio manager of peatlands lays out the importance of social skills:

"Most of the people has background in ecological or biological science, not with the social science background. so that it's a struggle when you want to deal with people and need to manage stakeholders, to engage and motivate them".

Management Phase – 58% (n=11) still opted it as "minor to moderate", 32% (n=6) for "major to catastrophic" and 11% (n=2) for "nil to noticeable" challenge. The patterns are "Challenges remains same", "Challenges mitigates after implementation" and "Shortage of socio-technical skilled employees".

Result - The generated results **(Table 4)** states that the challenges related to employee competencies and skills is counted as a "moderate challenge" in both phases.

4.1.8. Performance Evaluation

Implementation phase – While 37% (n=7) considers performance evaluation is a "major to catastrophic" challenge, 53% (n=10) evaluates it as a "minor to moderate" challenge. The remaining 11% (n=2) observes it as a "nil to noticeable" challenge. The major patterns recognized are "Complexity of measuring multiple aspects" due to the mixed characteristic of wetlands and the multiple goals associated with its restoration. It involves the combined goals of water retention, carbon sequestration, biodiversity enhancement etc. which is deemed to be a humungous task to evaluate the success of its respective goals. The absence of a comprehensive standardization is also a major factor. And this complexity leads to other two identified patterns such as "Expensive process" which most of the interviewees confirmed the same and challenge related to "Timeframe limitation for the goals" that specified by the EU and the national government as most of the wetland restorations are long-term process, it is always a challenge to evaluate its performance in short-term and convince the higher authority. This is being highlighted by Interviewee 1, a program manager:

"These projects are long-term result oriented, hence short-term testing may not provide the desired result which made difficult to convince whether the project is effective during short time frame".

Management Phase – 74% (n=14) of the interviewees perceives it as "minor to moderate", whereas 21% (n=4) still categorize it in-between "major to catastrophic" level. And 5% (n=1) views it as a "nil to noticeable" challenge. The patterns derived are "Challenges will mitigate" and "Challenges remains same".

Result - The result **(Table 4)** points out that performance evaluation will minimize from "moderate" to "noticeable" level in the future management phase.

4.1.9. Knowledge Gap

Implementation phase – 58% (n=11) opted knowledge gap as a "minor to moderate" challenge, and another 37% (n=7) outlines it as a "major to catastrophic" challenge. And 5% (n=1) assess it as "nil to negligible" challenge. The emphasized patterns are the challenges related to the knowledge gap in "Transforming wetlands into source of income" which mentions about not capitalizing the various options of revenue generation from wetlands through carbon credits, green financing etc. And then the "Skepticism and inexperience" develops due to the unawareness of the benefits and necessity of the restoration initiatives which drives to protest and uncooperativeness that is mentioned by the Interviewee 10, a project manager:

"The inexperience of flooding issues in the past makes them to resist the implementation and questions the requirement of the dyke now. And they don't see the necessity of it. So that's a big problem".

A contrasting pattern to this also identified "Conflict of interest" between the farmers and the implementor, that highlights even though people acknowledge the benefit of the restoration program, they are hesitant to relinquish their priorities. Another one is the knowledge gap in

"Convincing about the importance of the project" and "Limitation in knowledge transference" that hinders the prospects of initiating more wetland restoration programs which mainly attributed to the limitations in transferring the knowledge of science and ecosystem to common people.

Management Phase – In this phase, 79% (n=15) of the participants evaluated knowledge gap as a "minor to moderate" challenge and 21% (n=4) chosen it in "major to catastrophic" category. The patterns are "Challenge will mitigate in future" and "Challenge remains same".

Result - The result **(Table 4)** ascertains that the challenges related to knowledge gap overall reflects as a "moderate" in both phases.

Table 4: Descriptive Statistics of Challenges Comparison

STS Challenges	Implementation			Management			Overall
	Category	Mean	Std. Dev	Category	Mean	Std. Dev	Mean
Land Use related Issues	**Major**	**6.42**	2.09	**Major**	**6.26**	2.16	**6.34**
Local community & Cultural factors	Moderate	4.84	2.27	Noticeable	4.42	1.95	4.63
Stakeholder Interventions	Moderate	5.42	2.01	Moderate	4.84	1.77	5.13
Governance & policy factors	**Significant**	**6.74**	1.85	**Major**	**5.95**	2.12	**6.34**
Economic & Budget Limitations	**Major**	**5.84**	2.29	**Major**	**5.63**	2.63	**5.74**
Process management	Moderate	5.21	2.46	Moderate	5.16	2.06	5.18
Employee Competencies and Skills	Moderate	5.11	2.21	Moderate	4.89	2.00	5.00
Performance Evaluation	Moderate	5.00	2.03	Noticeable	4.42	1.89	4.71
Knowledge Gap	Moderate	4.95	1.99	Moderate	4.63	1.30	4.79

Overall, according to result, the key socio-technical challenges in both implementation and management phases of the wetland restoration are issues related to "Land use", "Governance regulations and policies" and "Economic & Budget Limitations" which categorizes between "major to catastrophic" levels. They are followed by "Process management" and "Stakeholder Interventions which are considered as higher "moderate" with marginally closer to the "major" category according to overall mean. And the remaining challenges categorized between "moderate to noticeable" levels with minimal variances between both phases.

4.2. Sub-question 2 - Most influential socio-technical challenges and how they affect the effective application of wetland restoration.

This section will address the second sub-question of discovering the most influential among the nine socio-technical challenges that affects the effective application. The result of this section is derived from the ratings based on the interview questions 11 and 12 (See **Interview Questions**).

Here, the findings are generated solely on the values of implementation phase. And the values of management phase were excluded for two key reasons. Firstly, there was a limitation related to the availability of research units in the management phase (See **Limitation**). Secondly, implementation is a one-time process, with its effectiveness rating will always remain constant. In contrast, the management process is continuous and dynamic, with its effectiveness rating and the intensity of the challenges varies over time based on the changes in community demands, stakeholder requisitions, policy reforms, technological innovations and other factors. Therefore, the influential challenges were derived based only on the implementation phase ratings.

4.2.1. Descriptive analysis rating of intensity of the socio-technical challenges during implementation

As per the descriptive analysis **(Table 4)** based on the rating provided by the interviewees, "Governance regulations and policies" is rated as a significant level challenge, followed by "Land use issues" and "Economic and Budget constraints" which are considered as "Major" level challenges. The challenges such as "Stakeholder Interventions", "Process Management" are included in the higher "Moderate" level which is marginally closer to "Major" category. The remaining challenges "Employee Competency", "Performance Evaluation", "Knowledge Gap" and "Local community and Cultural factors" are distinctly categorized as "Moderate" challenges. The respective ratings are illustrated in the below graph.

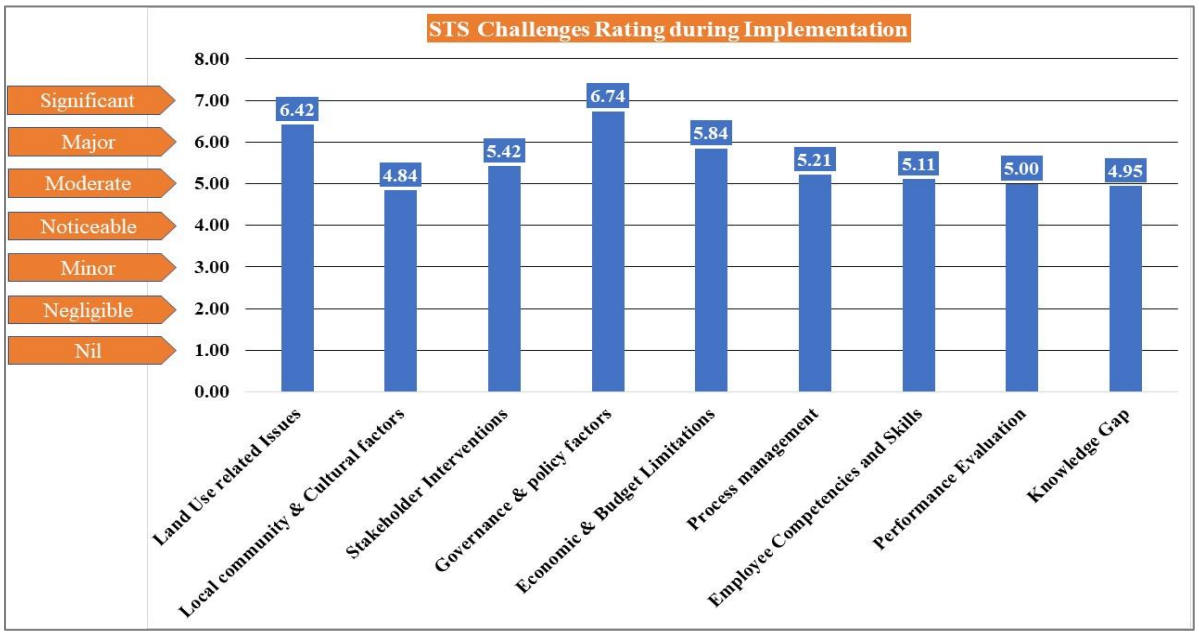

Figure 6: STS Challenges Rating during Implementation
Source: (Self Contribution, 2024)

4.2.2. Regression Analysis of socio-technical challenges against effective implementation

To consolidate this rating, a regression analysis is conducted to evaluate its statistical significance and the correlation strength of these challenges against effective implementation. According to the results, "Land use issues" emerged as the most influential challenge against effective

implementation with correlation coefficient value of "0.58", and coefficient determination of "0.34" with the P-Value of "0.01". It is followed by "Process Management" with correlation coefficient value of "0.46", and coefficient determination of "0.21" with the P-Value of "0.05", and "Governance Regulations and Policies" with correlation coefficient value of "0.42", and coefficient determination of "0.17" with the P-Value of "0.08".

The challenges such as "Employee Competency", "Economic and Budget Limitations", "Stakeholder Interventions" etc., despite being demonstrated some notable correlation strength towards effective implementation, but could not attained the statistical significance in both thresholds of 90% and 95% confidence levels. And remaining "Local Community and Cultural factors", "Knowledge Gap" and "Performance Evaluation" have shown the least influence rates among the challenges. The regression analysis figures are denoted in the below table.

Table 5: Regression Analysis of STS Challenges Vs Effective Implementation

STS Challenges	Correlation Coefficient	Coefficient of Determination	P-Value
Land use related issues	**0.58**	0.34	**0.01**
Local Community & Cultural factors	0.10	0.01	0.69
Stakeholder interventions	0.15	0.02	0.55
Governance & policy factors	**0.42**	0.17	**0.08**
Economic & Budget limitations	0.15	0.02	0.54
Process management	**0.46**	0.21	**0.05**
Employee Competency	0.32	0.10	0.19
Performance evaluation	0.05	0.00	0.84
Knowledge gap	0.10	0.01	0.69

4.2.3. Relational Network Data Matrix Analysis for identifying Interrelation between influential challenges

Strong interrelations and interdependence between these challenges has been reflected from the content analysis of this study while identifying the influence degrees of the investigated nine socio-technical challenges. To visually demonstrate the complexity of interrelation between these socio-technical challenges, a relational network data matrix (Figure 7) has been developed and incorporated in Gephi (0.10.1) software.

Challenges	Land use related issues	Local Community & Cultural factors	Stakeholder interventions	Governance & policy factors	Economic & Budget limitations	Process management	Employee Competency	Performance evaluation	Knowledge gap	Total Connections
Land use related issues	0	1	1	1	1	1	0	0	0	**5**
Local Community & Cultural factors	1	0	1	1	1	1	0	0	1	**6**
Stakeholder interventions	1	1	0	1	1	1	0	1	1	**7**
Governance & policy factors	1	1	1	0	1	1	0	0	0	**5**
Economic & Budget limitations	1	1	1	1	0	1	1	1	0	**7**
Process management	1	1	1	1	1	0	1	1	1	**8**
Employee Competency	1	1	1	0	0	1	0	1	1	**6**
Performance evaluation	0	0	0	0	1	1	1	0	1	**4**
Knowledge gap	1	1	1	1	0	1	1	1	0	**7**

Figure 7: Relational Network Data Matrix
Source: (Self Contribution, 2024)

- **Relational network question**: Which are the challenges that co-influences each other the intensity strength of the corresponding challenge?
- **Value Indication**: "1" indicates co-influence / interrelation towards the respective challenge in the column, and "0" indicates neutral / nil relation towards it.

The result derived 9 nodes (Challenges) and 55 edges (Connections) between them. And from the matrix, “Process management” is evaluated as the most interrelated and interdependent challenge with maximum number of relations (n=8) to other challenges. Its intensity strength depends upon the resolution of land use issues, the resistance of local communities and stakeholders, favorable regulations, sufficient fundings and employee skills to facilitate the processes, proper monitoring and evaluations, and adequate technical knowledge.

It is closely followed by “Economic and Budget Limitations” (n=7). Its intensity is connected with the intensity of land use issues, discretion of local community, stakeholders and policy reforms, the affordability of the expenses of process management, skillful employees and knowledge dissemination.

The next strongly interrelated challenge is the “Stakeholder Interventions” (n=7), They are also interrelated to land use issues, community demands, the status of governance regulations, budget constraints and process management. And the deficiency of performance evaluation and technical awareness.

“Knowledge Gap” (n=7) is another strongly interconnected challenge. The intensity of the knowledge gap can have direct influence on the intensity of land use issues, community and stakeholder resistances, policy issues, challenges related to process management, employee skills and performance evaluation.

Rest of the challenges also had shown sufficient interconnections which all of them are related with at least 50% of the associated challenges. They are “Employee Competency” (n=6), “Local Community and Cultural factors” (n=6), “Land use issues” (n=5), “Governance Regulation and Policies” (n=5) and “Performance Evaluation” (n=4) is being the least connected challenge.

The Gephi diagram of the STS challenges interrelations has been depicted in (Figure 8).

Result - Therefore, overall, based on the three different analyses, it can be evaluated that “Land use issues”, “Governance regulations and policies” and “Process management” are the three most influential socio-technical challenges that can directly affect the effective application of a wetland restoration in the Netherlands. The first two have both emerged as major to significant level challenge with the descriptive analysis ratings, attained statistical significance with regression analysis, and also shown interrelation with minimum 50% of the other socio-technical challenges. And “Process management” identified as the most interrelated challenge, demonstrated statistical significance in regression test and achieved a high moderate intensity rating as well.

Even though, despite not proven statistical significance in regression, “Economic and Budget Limitations” and “Stakeholder Interventions” have shown profound influential strength through good intensity rating and interconnections. The remaining challenges varies depending on the dynamics of these above-mentioned challenges resistance.

Therefore, this strength of influence of these socio-technical challenges and the strength of its intricate interrelations do impact the effective application of a wetland restoration. The reasons for how they affect, are explicated in **Discussion**.

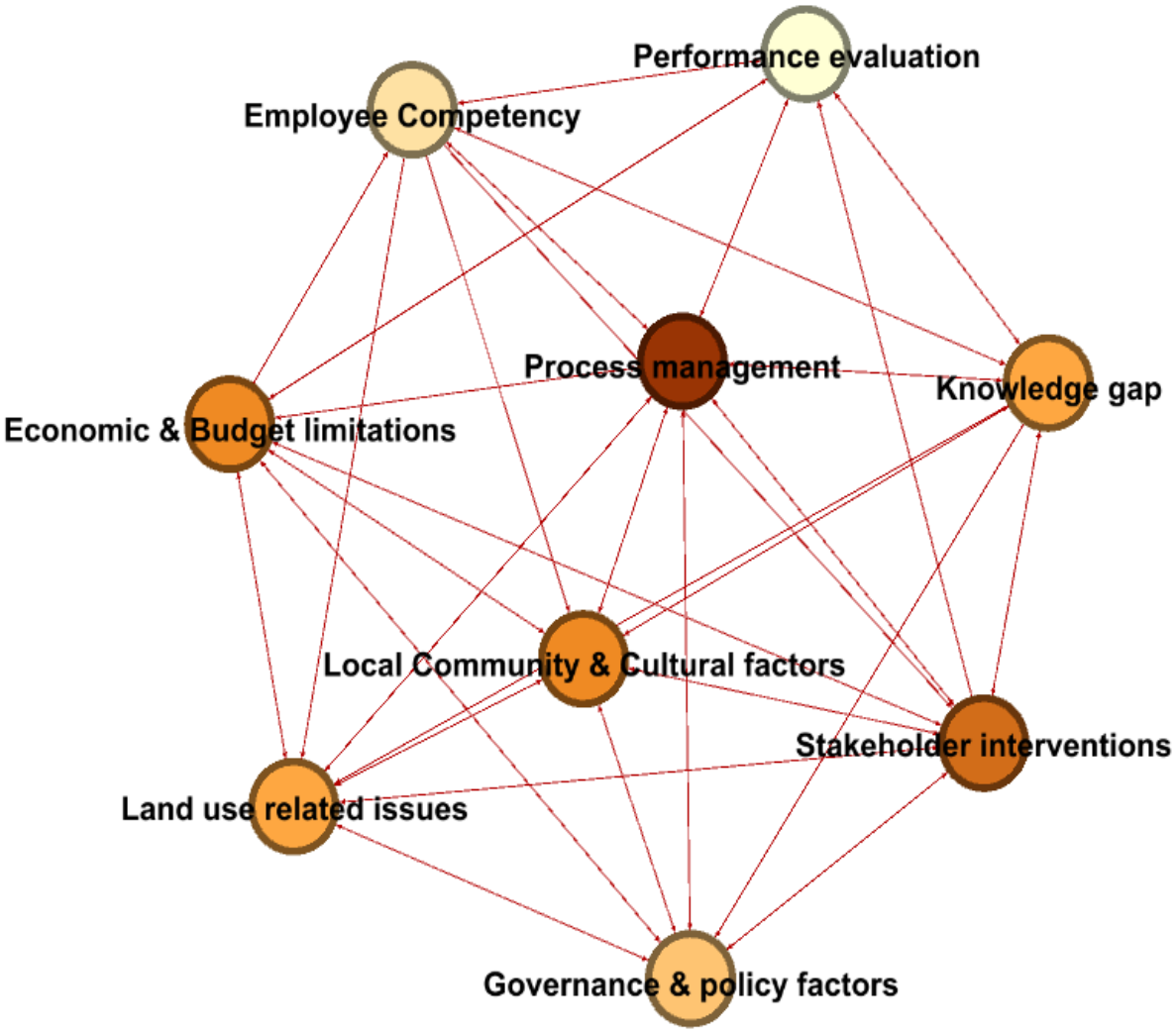

Figure 8: STS Challenges Interrelations
Source: (Self Contribution, 2024)

4.3. Sub-question 3 - Key strategies and best practices that applied to overcome these socio-technical challenges

This section will explicit the third sub-question by uncovering the core strategies and best practices holistically applied by the participants to overcome the socio-technical challenges that encountered during both the implementation and management phases of their wetland restoration, the weightage based on the application of these approaches by the participants in their respective projects, and the challenges it addressed. The result of this section is derived from the contents based on the interview questions from 1 to 10, 14 and 15 (See **Interview Questions**), which are classified into different themes that deduced from the global literature.

4.3.1. Participatory Approach

89% (n=17) of the participants have reiterated it as an extremely successful approach in multiple circumstances of their project application, especially implementation. They applied this approach to resolve challenges related to land use issues, local communities and cultural factors, stakeholder interventions, governance regulations and policies, and process management related issues.

According to the interviewees, this strategy emphasizes the values of "co-creation" that brings together all the stakeholders, and encourage their active participation in the project. They urge that ensuring multi-level involvement from diverse sectors of the system not only fosters public cooperation, but also enhance the success rate of the initiative as the stakeholder will complement each other with their relevant expertise and knowledge with the context. For example, incorporating farmers is beneficial in rewetting the land as mentioned by Interviewee 6, a project coordinator:

"I would say that the best people to do this restoration are the farmers who have been doing the opposite of this restoration i.e, digging the drains, because basically all they need to do is the opposite of what they've been doing for the last 50 years".

Interviewee 8, a project director opines:

"if we really work with communities, you'll see that they have all kind of ideas and they know sometimes better than we do. They know the place because they walked there every day. So, we have to incorporate their opinions and in lot of cases it makes the plan better".

Another participatory approach is the "building up together" concept that includes the stakeholders, especially the surrounding community and the land users as part of the designing of the project. This will enhance their trust on the implementors in upholding their values and cultures and develop the project with mutual benefits. Interviewee 1, a program manager, emphasized:

"We invite them to think with this how their area should be developed".

Interviewee 11, a project coordinator, highlights*:*

"Try to listen to the people, to get to know what they want actually and try to resolve in the way they want. That is a very good strategy".

Another method of applying this concept is the balancing of top-down and bottom-up layers of the nexus between higher authorities and grassroot stakeholders which is colloquially called as the "Sandwich approach" by Interviewee 14, a portfolio manager of peatlands, that propagate a balanced state of the system which has the flexibility of applying either approaches according to the circumstances.

According to many interviewees, the best tactic to ensure the participation and cooperation of stakeholders, especially the land users, in the project, is to derive plans that will become beneficial to them either through economical or non-economical means. Couple of interviewees mentioned about "Green Investments" and also "Result-based payment" method, a relatively new strategy that encourages land users to cooperate with the implementation without losing their lands and generate revenue through carbon credits from the investors involved in this nuanced system.

4.3.2. Integrated & Balanced Distribution

68% (n=13) of interviewees have applied this strategy in their initiatives at various challenging situations. It is mainly applied for resolving economic and budget limitations, stakeholder interventions and land use issues.

Many interviewees have elucidated about the importance of integrating different aspects and equitable distribution of benefits to overcome the socio-technical challenges. According to them, it functions as a key aspect for meeting the inadequacies of finances by combining various projects together and integrate the funds allocated for its designated objectives as mentioned by Interviewee 2, a program manager:

"We strive to mix all the sectoral goals and means that are bounded to the aim. So, we have to bundle that. Therefore, we ask to make it possible that we can bundle all the goals and the means, so as an integrated financial structure".

They validate that this strategy will be successful if the objectives share a common characteristics and potential for amalgamating the goals for a common purpose. Interviewee 8, a project director explains:

"It's not only about wetland restoration, but it's all also about carbon neutrality. It's also about biodiversity goals. It's about water quality goals, so we have to combine all kind of governmental goals or policies that are put it in one place and also the money that is available from these different policies".

They endorse that it also acts as an arbitrary mean for the implementors in mitigating disputes related to the land acquisitions and legal resistance from the land owners, and also building consensus between the stakeholders for the issues arises due to the conflict of interest that affects them both economically and culturally as remarked by the Interviewee 13, a freshwater ecologist:

"It's always in combination with other stakeholders in the area. So, then all the different stakeholders come together and they try to create some kind of win-win situation. Make a balance between the stakeholder's interest plus the national interest, EU goals, of preserving the nature".

According to the participants, this strategy can also be further applied in other aspects as well such as combining government policies and regulations, associating the wetland restoration initiative with healthcare benefits etc. And it also underscores the essentiality of providing sufficient time to stakeholders to contemplate on their priorities and arriving a consensus on the disputes. These practices are highly effective in mitigating the challenges related to conflict of interest among stakeholders.

4.3.3. Flexibility in Compensation & Regulations

According to 79% (n=15) of the interviewees, this strategy acted as a crucial decisive factor between the resolution of multiple disputes and the smooth implementation of their projects. This strategy had direct impact in the issues of governance regulations and policies, land use issues,

process management, economic and budget limitations, local community and cultural factors and stakeholder interventions.

The interviewees unequivocally accentuates that the flexibility in regulations related to the emerging issues provides the marginal space for the implementors and the middlemen who interact with the stakeholder issues with multiple options to resolve the issues as pointed out by Interviewee 4:

"The most successful one is the thing you can offer. So, if we take a certain square meter of their property to make the waterway broader, and we give him the opportunity to compensate that service by muting other smaller waterways in their land which are not using. And then I can win those square meter and to use it in the business. The most effective strategy is to give room for compensation".

Another viewpoint from Interviewee 5, a project leader:

"The diminished value of the land from farming land to nature protection land, have to be compensated to the land owners, that will enable them to retain it as nature development land".

According to interviewees, it necessitates intervention from the higher authorities including national and EU level with ample adjudications to amend the regulations according to the contextual circumstances. This enhances the optimal utilization of the fund, mitigates compensation issues of land acquisitions and process management challenges of time restriction for administering the operations. It furnishes policies that symmetrically upholds the cultural aspects of the communities as well as the stakeholders interest viabilities.

Another valid opinion aroused was adopting long-term funding programs for wetland as stated by Interviewee 6, a project coordinator:

"It needs to have secure long-term commitment from the government as long as it can be. Healthcare is always funded. Education is always funded. Restoration should be always funded. It's an investment in your society in the same way education and healthcare".

Other major measures reported by the interviewees were leniency in restrictions for swapped lands according to the priority of the land user, planning of projects in city outskirts with minimal regulations and in vulnerable areas where inhabitants encounter issues with pollution, flood and drought etc., which will stimulate the inhabitants to voluntarily cooperate in realization of the project to mitigate effects of flood and drought. An interesting experience shared by Interviewee 8, a project director:

"A polluted area that we used wetland restoration as a part of flooding and as part of the cleaning the soils, to immobilize the pollution and that's in combination with recreation. Now there are 1.4 million visitors this area has each year because it's crowded area city area".

4.3.4. Process Optimization

This strategy has been endorsed by 84% (n=16) of the interviewees which they applied to counter the operational issues related to challenges in process management and performance evaluation of their initiatives.

The key informants vouch that optimizing the operational resources and its functional attributes have comprehensively contributed in mitigating all the socio-technical challenges that are interrelated to process management. They point out various measures such as ensuring the land availability prior to the project initiation, finalization of the planning, obtaining adequate skills and competencies among the team related to social and community engagements, clarity in evaluations and monitoring etc. And ensuring participation of various specialized organizations to incorporate their knowledge and objectives for the management of the project, also proved to be successful. Interviewee 3, a project supervisor endorses that:

"Handed over the management to wildlife conservation organizations was a good move as such organizations have necessary budgets for doing such activities which comes handy with mutual benefits".

Interviewee 5, a project leader:

"We handed over the work through public participation of the companies specialized to handle these kinds of works and chose the best and appropriate ones".

Many interviewees emphasized the significance of initiating small-scale or pilot projects in the location instead of directly commissioning large-scale projects. This will provide a holistic experience of all the factors that has the potential to become major challenges during large-scale project. This will enable the implementor to take proactive measures accordingly. Interviewee 2, a program manager explains:

"We did a lot of small projects and pilots in it to see what worked and to get system knowledge and how to do interventions in it to improve the quality, and gather support as well".

Similar measure has been stressed by Interviewee 19, a peatland expert:

"We're actually working on setting up a production facility in one of our own stables here. And we hope that if we can get that going and can prove that it works, we can actually attract the money."

Apart from these, A major opinion was the importance of understanding the technical measures to mitigate the negative effects in the surroundings through water level enhancement. Interviewee 8, a project director observes that:

"One of the aspects is that you really need to know your water system. How does this water system function at the moment? And if I change something make it wetter, how does it function in the future then? That's really a thing that we always try to figure out".

It further lays out the importance of developing methods to carry out the operational works during wet period which will reduce the disruptions to the neighborhood due to it. Additionally, they highlighted the importance of prioritizing the processes based on the gravity of requirement of the stakeholders during the planning stage itself and adhere to that plan without diversions unless catastrophic situations arise. This also facilitated optimal utilization of the financial, technical and manpower resources simultaneously ensuring to secure stakeholder's priorities.

Another significant observation was about the necessity and possibilities of developing an exclusive framework and a comprehensive measurement, reporting and verification (MRV) system with appropriate standards and methods for accurate evaluations of initiative objectives like water quality, carbon sequestration, biodiversity enrichment etc., for the wetland restoration programs. They accentuate that it will mitigate the multiple disputes related to the benefits generating from the wetlands and ensuing "conflict of interests" issues related to it as Interviewee 11, a project coordinator reflects:

"If you see the improvement of the nature, if you see the water storage is improving, and if you see the results of the changes you make, then it lowers the barriers".

4.3.5. Communication of knowledge

100% (n=19) have pinpointed the significance of communication of knowledge as a vital aspect in challenge mitigation. It directly addresses all the patterns related to knowledge gap and performance evaluation challenges and indirectly contributes to resolve the remaining STS challenges.

All the participants unanimously claims that it serves as the bridging tool between the project initiators and related stakeholders. It states that, effective communication about the objectives and the inevitability of realizing the project, to the stakeholders such as land users, community, government administrators etc., could expedite the resolution of all the barriers and challenges confronting the project. They have to be well updated about the comprehensive benefits to them from the initiative, both individually and as community including social benefits such as recreation, financial benefits such as income generation, wellbeing benefits such as flood and drought controls, environmental benefits such as carbon sequestration etc. According to Interviewee 14, a portfolio manager of peatlands:

"Promote using a very simple language when you are trying to certain groups of society and people. They usually ask is what it's in there for me? What are the benefits of this wetland restoration? This is like the key questions that you will have to explain. It's how we try to bring a community-based restoration approach".

Interviewee 16, a project technical manager:

"You have to talk a lot to help people to see what's the value of nature, why this is special and why we need to develop it. We have to communicate more to make people's ambassador of that nature".

Because this transformation of stakeholders into nature's ambassadors is highly essential for successful application of an initiative. The stakeholders can be enlightened only with effective knowledge transference about the positive social, economic and environmental benefits contributes by the project to them. And also, based on the experience of some participants, while promoting about the positive benefits of developing nature, it is also necessitating to inform in advance, about the imminent negative impacts occurring due to the project and the precautionary measures adopting to mitigate it. This will provide sufficient time and knowledge to them to ascertain the right decisions on it.

Various aspects have been perceived in communication of knowledge as it is highly essential to winning the trust of the surrounding inhabitants. And to attain this, it has to be communicated effectively by providing assurance for the resolutions of the problems and anxieties they encounter due to the project. Interviewee 9, a project coordinator emphasizes that:

"The strategy is that we try to listen to the farmers that we hear their story, their problems. We try to invest in the relationships with the farmers. I think that's the most important thing we have to do. And try to see how we can change things in the water system to make improvement and resolution in the problems they raised".

Aligning to this, Interviewee 11, a project coordinator comments that:

"Try to listen to the people, to get to know what they want actually and try to resolve in the way they want. That is a very good strategy".

Similarly, it is also fundamental to communicate with the contractors about the practicalities of the underlying macro and micro goals of the project and their contribution to realize it. Also striking a balance between them and the employee mix with their specific skills and experience required for the project is of paramount importance. Interviewee 19, a peatland expert lays out the importance of this factor:

"I think, a very important one in this is practical learning that we need to keep a good record of what we're doing. I think it is very important to combine scientific knowledge with practical knowledge, because we're somewhere in between".

And adept technical knowledge for surmounting the ensuing operational related challenges, is a vital aspect for dodging the imminent agitations related to it. Hence, training and synthesizing a network of experienced team and contemporary manpower resource is also a crucial factor. Interviewee 10, a project manager, highlights the essentiality of such network:

"We have a great network in our province and with the companies, so you know where some kind of knowledge is and when you know you need these skills, you search for them and get them".

Apart from above, the EU initiative of raising awareness among the national level, political level and related organizations etc., plays a major role in mitigating the challenges of knowledge gap. This is being stated by Interviewee 8, a project director:

"The nicest thing about this EU projects is, they are defining this knowledge gaps and try to solve it with 20 different organizations from 10 different countries in Europe".

Besides this, majority of the participants underlined the significance of ongoing researches about additional options to raise income and benefits from the wetlands such as paludiculture, green deals, green investments, carbon credits etc., all these actions will contribute holistically in overcoming the challenges encounters during the implementation and management of wetland restoration projects as highlighted by Interviewee 7, a development manager:

"If people recognize better way of life, better way of living for themselves and their surroundings due to the project implementation, they will probably more willing to accept it and also put effort in it".

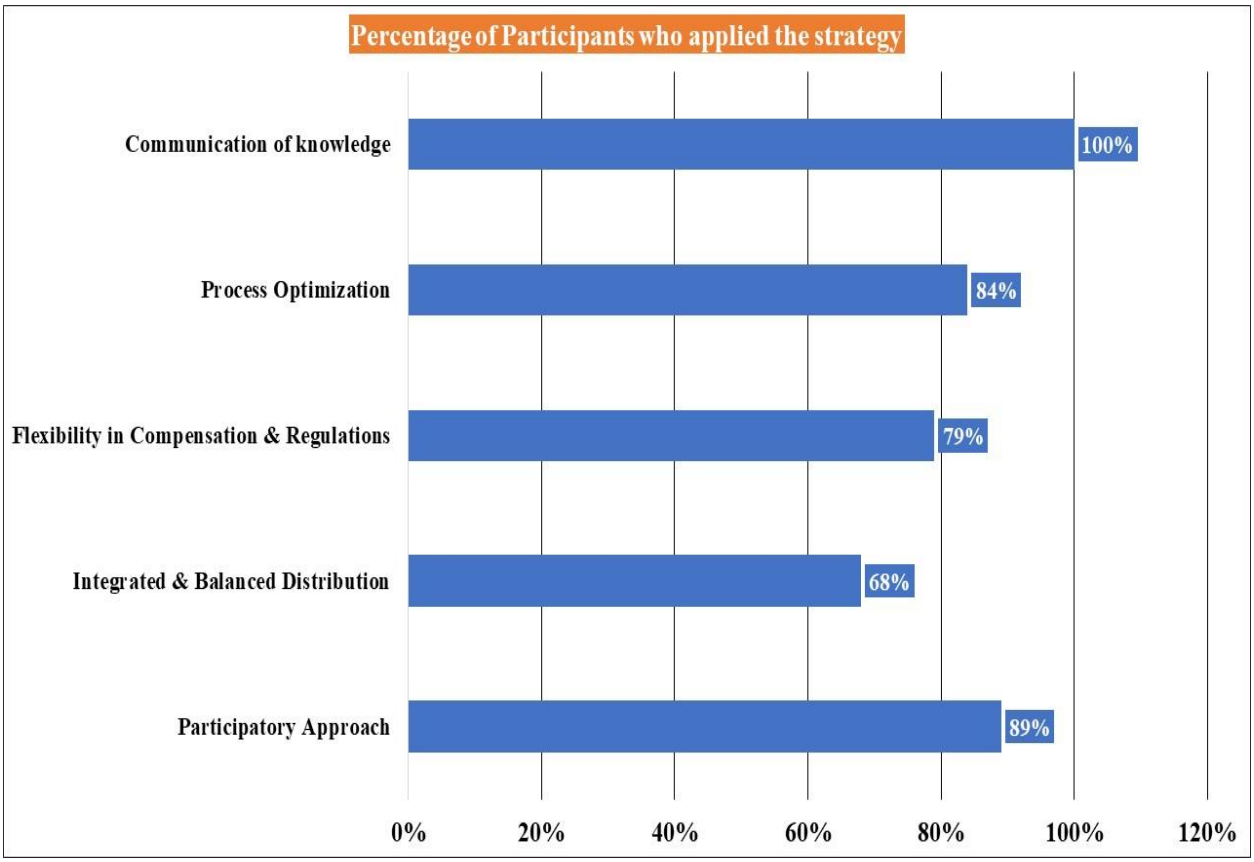

Figure 9: Percentage of Participants who applied the strategy
Source: (Self Contribution, 2024)

Result - Altogether, based on the illustrated graph, the most applied key strategies to overcome the socio-technical challenges encountered during the application of wetland restoration in the Netherlands, are "Communication of Knowledge", followed by "Participatory approach", "Process optimization", "Flexibility in compensation and regulations" and "Integrated and balanced distribution" respectively. And the average success rate of the overall application of these strategies, as applied by the participants, received the rating "7", which is categorized as "Effective".

5. Discussion

This chapter discusses about the nuanced intricacies in the results of investigated 3 sub-questions, their consistency with previous studies and finally how it assimilates to answer the main research question. It discourses the reasons for the major identified patterns of the socio-technical challenges and its metamorphosis from implementation to the management phase. It further highlights how the strength of influences of the key socio-technical challenges and its intricate interrelations affects the effective application of the wetland restoration. And finally, it elucidates about the success in the combined application of the identified key strategies for the resolution of socio-technical challenges.

5.1. Major recurrent patterns among Challenges during Implementation and Management phases, and its reasons

This section discusses about the major challenge patterns that was reminiscent in majority of the nine socio-technical challenging elements investigated during its both implementation and management phases. They are the core reason that transforms those potential elements into formidable and influential challenges in a wetland restoration.

5.1.1. Implementation Phase

The major recurrent patterns which were identified among the key socio-technical challenges are "Conflict of Interest", "Resource Scarcity" and "Stringent and biased regulations".

5.1.1.1. Conflict of Interest

Wetland restoration is an initiative that demands extensive social involvement process. From the beginning to its realization, it necessitates the active participation of diverse range of actors from multiple sectors. The implementors have to confront with literally every social aspect related to restoration process. For example, in land-use itself, there will be different types of utilization that ranges from commercial related to health related, cultural related, recreational related, agricultural related etc., based on its owner's specific priorities and objectives. Even if it is a public area, there will be multiple interest groups comprises of adjacent communities and inhabitants, farmers group, vendors group, tourism sector, provincial authorities, nature and wildlife organizations etc.

Apart from these, in project initiation itself, the implementors have to deal with the various partners who have their own specific goals to participate in the initiative, and the multiple regulations and policies related to each sector of the governance authorities. For example, in wetland restoration, there is always the presence of diverse sectors of nature conservation, wildlife preservations, real-estate interests, tourism sector, water bodies authorities, agricultural authorities, fisheries board etc. These all entities have their own vested interests and objectives which are shaped based on their political and nationalistic agendas. These heterogeneous objective intricacies of multiple stakeholders have been evident in the previous study of Duraiappah et al. (2014) too. And as mentioned in section **4.1.5**, these interests, diverse objectives and short-sighted outlooks reflects in the approval of budgets allowance for the restorations as well. And this leads to the restriction in utilization of the funds of these diverse sectors as a combined fund, even if it is implementing in the same location.

Even for technical related challenges such as process management, performance evaluation, employee skill related and scientific knowledge related issues, this conflict of interest has become a key reason to act as a barrier against the initiatives. Since the technical attributes and artefacts are handled with human interventions, the influence of social challenges reflects in the utilization of technologies as well. This influential factor has been highlighted in the study of Shackelford et al. (2013) as well. In fact, the other mentioned challenging patterns in section **4.1.6**, such as operational barriers and time constraints are aroused due to this variance in the interest and priorities factor of the diverse sectors involved. If it is affecting their goals, resistance is bound to happen. Similarly, in the case of employee skills, the conflict of interest in applying the procedures and tactics between the employees who are differentiated with practical experience, updated knowledges, social and technical competencies etc., all such factors raise challenges.

Besides this, even though indirect, the involvement of various entities in a wetland restoration such as hydrology related, biodiversity related, disaster related, decarbonization related, recreation related etc., and the realization of their individual goals makes the performance evaluation of the initiative a humongous task. Moreover, the absence of a comprehensive framework or model and dearth of scientific knowledge for the application of a wetland restoration project impacts the harmonization of the interest of the stakeholders involved in the project. It is to be noted that this conflicting interests among different stakeholders, has been observed in the previous study of Cortina-Segarra et al. (2021), based on the European context.

5.1.1.2. Resource Scarcity

It is another recurrent pattern that triggers into challenges for many of the socio-technical factors. One is the land scarcity facing in the Netherlands at present, for acquiring it for a wetland restoration process implementation. In many cases, the existing land users are ready to vacate if they have provided with a replacement land, but this turns out to be a challenge as there is only limited idle lands available for utilizing it as an exchange land in negotiation during arbitration process. And, over the time, there appears shortage of manpower with adept social and technical skills in the environmental related projects is reflected due to unattractive benefits. Especially, social interactive skill is of paramount importance in such projects for handling various stakeholder resistance and agitations from different stakeholders including land owners, communities and governance authorities. It is also highly essential for disseminating the knowledge about the pros and cons of the wetland restorations among these stakeholders. Also, limited availability of experienced contractors to undertake the project implementation and management is an issue. This skill shortage in wetland restorations were also reflected in the previous studies of Grant and Langer (2021) and Osman et al. (2023).

Time constraints is another issue facing by the implementors in various factors as mentioned in section **4.1.5,** related to the utilizing of EU fund and national subsidies that will lapse if the project fails to reach the required progression. Gantioler et al. (2014) has mentioned about this inefficient fund utilization in their study of ecological restorations in Europe. Such delays occurs when the implementation process is stalled due to legal tussles with land issues unresolved on time. And delay in project realization can also occur due to the time constraints for the operations mentioned in the section **4.1.6**, which covers around 7 months in a year. Effectively, it giving only

approximate 5 months for the work execution which also further affect by increased rainfall during that period. And as mentioned in the section **4.1.8**, another scarcity is the absence of a comprehensive standardization for wetland restoration. Suding (2011) has highlighted about this shortcoming in the study of ecological restoration.

5.1.1.3. Stringent and biased regulations

The above mentioned two patterns are directly and indirectly influence the emergence of this pattern. The reasons of conflict of interest from various sectors, and the scarcity in the land, budget and time due to the short-term visions by the governance sectors leads to the development of stringent and biased regulations and policies related to the wetland restorations. As mentioned in the section **4.1.4**, the multiple sectoral interference and top-down approaches impedes the coordinators to garner more options in challenge mitigations. For example, flexibility in financial compensation for land acquisitions that could become crucial in resolving land disputes. The intersectoral issues related to the governance has been reported in the research of Smith & Maltby (2003) as well. Another factor is the issues related to the political influences on the nationally centralized system, which is also mentioned in the investigation of Cortina-Segarra et al. (2021). This restricts the project administrators to furnish the regulations and policies based on the contextual relevance by weathering off the biased political inclinations in the utilization of funds and resources. And it also hinders the implementors to utilize the law enforcement instruments in dire strait situations such as protest arose only due to the political whims and devoid of substantial claims.

5.1.2. Management Phase

Firstly, due to the limited availability factor of research units in the management phase, as mentioned in the section **Limitation**, the patterns of the challenges are being addressed as an articulation of expectations and underlying presumptions of the participants. Secondly, overall, most of the challenges are having a metamorphosis when it comes to the management phase from the implementation phase. Hence, major recurrent patterns which were identified among the key socio-technical challenges during the management phase are “Challenges will mitigate”, “Challenges will remain same”.

5.1.2.1. Challenges mitigate

Majority of the challenges are appeared with diminished intensity in the management phase. The prime reason for the alleviation of strength among the challenges is because the corrective measures for the resolution have been already applied to accomplish the implementation. For example, local community and cultural factors. It reduces from moderate to noticeable in the management phase because most of their concerns and demands have already been addressed and ensure their cooperation during implementation phase itself and also people will get accustomed to the new changes in the surrounding.

Similarly, stakeholder intervention is perceived as a higher moderate level challenge that was marginally closer to the major category in implementation phase. But expresses a possibility of relief in future management as observed for local community and cultural factors due to the familiarity to the challenges and the benefits started to obtain with the participation of the project.

Despite this, the challenge related to the "conflict of interest" among the stakeholders are anticipated to persist in the future as well.

According to the relational network data matrix, process management is identified as the most interrelated and interdependent element among the STS challenges. Hence, even though a good number of participants perceives it as a major level challenge, most of the participants believes that the alleviation of other challenges will automatically diminish the challenges related to process management in the management phase.

Another notable mitigation is performance evaluation that perceived as a moderate challenge in implementation due to its intricacies in the evaluation process. But it subdued to noticeable level in the management phase as most of the participants vouches that the complexity of the performance evaluation will reduce in future as they believe the ongoing development in standardization of evaluation process will mitigate the challenge in management phase.

And, the mitigation of challenge related to knowledge gap is mainly attributed to the fact that people garner more knowledge with increased visibility of positive impacts of wetland restoration and negative impacts of climate change. This will mitigate their resistance.

5.1.2.2. Challenges remains same

There are challenges that will remains unaltered in the management phase. This occurs mainly due to the speculation demands and the ambiguity in future scenarios. Land use related issues is one of them. The intensity of the land use related issues remains as a higher major level challenge in both phases of a wetland restoration. Even though, the acquisition issues, and resistance from communities and stakeholders related to the land use have already resolved in the implementation phase, the challenge is bound to resurface in the management phase in another dimension. This is mainly attributed to the expected change in the future land use regulations due to the increasing demand of land-use for other purposes such as food and dairy production, livestock farming and residential expansion requirements. This will severely affect the upscaling of wetlands restorations which again give rise to the pattern of "conflict of interest" and "resource scarcity" as the stakeholders are rather hesitant to relinquish their activities than embracing the global initiatives for biodiversity enhancement or climate resilience until it becomes a necessity for their survival or wellbeing.

Governance regulations and policies is a significant challenge in the implementation phase due to the interference of the emphasized patterns in section **4.1.4**. It reduced to major level as a fair number of hurdles settles down once the implementation phase is complete, because the required regulations and policies have already been developed. But even though it expects a rather smooth management process compared to the previous phase, the ambiguity factor in the future scenarios due to the political inclinations and short-term plans in the policies, re-emerges the patterns of "operational barriers", "stringent and biased regulations" and "conflict of interest".

And, Economic and budget limitations remain as a major challenge in both phases. The raising of fund is not really a major challenge as necessary funding is available through subsidies from EU & National government. However, the related factors that highlighted as patterns in the section

4.1.5 will remain static until a substantial change occurs in the outlook of budget management. This prompted to retain it as a formidable challenge in the management phase too.

Also, Employee competency and skills is termed as a moderate challenge in both phases. Despite the dearth of socio-technical skilled employees have been identified, it will not escalate as most of the participants anticipates such issues will be resolved in the coming years by enhancing the pool of such skills through engaging more youngsters into the environmental field with increased training and benefits.

5.2. Influence of socio-technical challenges on effective application of wetland restoration

Socio-technical challenges plays a crucial and decisive role in the effective application of a wetland restoration. Their influence is particularly significant for two main reasons. First, the influential strength of these challenges often acts as a formidable barrier to the successful implementation and management of restoration projects. Second, the strong and complex interrelations between these challenges can significantly affect the variation in the intensity of their influence.

5.2.1. Strength of Influence

Influential Strength of a challenge towards a wetland restoration, is the factor that decides whether it is a major to catastrophic level challenges or minor to moderate level challenge or nil to negligible level challenge. It varies based on several factors such as the geographical location of the project implementation, the socio-economic and political environment of that location, knowledge and outlook of surrounding communities towards restoration practices, and acceptance of its broader objectives of climate actions and biodiversity etc. As per the result of this research which was based on the socio-technical challenges in the context of the Netherlands, Land use related issues, Governance regulations and policies, and Process management are indicated as the most influential challenges that affects the effective application of wetland restoration.

Similar to global scenario, as mentioned by Buckingham et al. (2021), Land use related issues and its effects on multiple stakeholders, is a major influential challenge in the Netherlands context too. The main reasons are the challenge patterns mentioned in the section **4.1.1** as they are directly impacting the multiple land users of the location and their source of living and culture. This prompts the affected land users to resist the implementation through social protests and legal actions against it. The existing resource scarcity issues related to the shortage of available land for relocation and insufficient compensation, exacerbates these conflicts. These issues significantly impact the restoration process which necessitates the implementors to put considerable efforts to resolve the issues. In some cases, it may lead to complete stoppage of the restoration processes until the social and legal tussles resolved.

And the crucial intriguing factors which made governance regulations and policies a significant influential challenge during implementation is its complexity in acting as a balancing platform to simultaneously safeguard multiple objectives from the sides of affecting stakeholders, political pressures and the implementor's objectives. It has to find an equilibrium in developing diverse policies supporting each entity that may act as trade-off factors with others. Consequently, majority of the instances, it is the implementation that becomes at the receiving end which necessitates

adjustments in its objectives, timelines and operational methods. This complexity of overlapping policies and regulations that affects the effective implementation, is resounded in previous study of Sari et al. (2019) as well. Finally, these trade-offs gave rise to the challenge patterns mentioned in the section **4.1.4,** such as stringent regulations and operation barriers that aims to support the affecting stakeholders which comprises of land users, farmers, adjacent communities etc. The diverse interests of these stakeholders and their influence in the central authorities also obtain the support of the political outlooks which persuades the governance authorities to compromise the restoration objectives. Hence, the policies developed related to it also will be short-visioned that have direct implications on the economic and operational aspects of the wetland restoration projects.

Another key influential challenge identified is the process management. Literally, this challenge encompasses the amalgamation of both social and technical characteristics in the challenge patterns that mentioned in the section **4.1.6**, such as operational barriers that triggered due to the inadequacy of technical artefacts to mitigate the challenges related to the water level management which itself generated by the diverse interest through social interference as it affects the surrounding resources of the inhabitants. The ensuing challenge patterns related to it are the resource scarcity that indicates the technical in-adeptness of the manpower necessitates for the restoration process, and the time constraints in the execution of the operational processes that arises out of the policy development based on the socio-political influences of the affecting stakeholders. The emphasizing of this combined characteristic has been evident in the previous literature of Shackelford et al. (2013) too**.** This social and technical combination factor elevates the influence of the challenges related to the process management, which will affect the effective wetland restoration, both directly and indirectly.

5.2.2. Strength of Interrelation

This section illustrates how the interrelations and co-influential characteristics between the challenges plays a key role in both raising and diminishing the strength of the influence of the challenges it is connected with. A variation in one challenge will triggers a chain reaction on other related challenges either positively or negatively. For example, based on the relational network data analysis of section **4.2.3,** process management is adjudged as the most interrelated among the nine socio-technical challenges studied. The major challenge pattern of the process management reported in the section **4.1.6** are “Operational barriers”, “Resource scarcity”, “Time constraints” and “Conflict of Interest”. Let’s look how these challenge patterns are interconnected and influences each other.

Process management necessitates the participation and cooperation of stakeholders from various sectors and communities right from the adjacent inhabitants, the location land users such as farmer communities, nature clubs, wildlife organizations, project partners, governance authorities etc. This multisector involvement triggers the “Conflict of interest” between them as each stakeholders have their own priorities related to the project. The resistance arises out of it will act as a significant hindrance towards the process initiation. To develop a truce between the stakeholders and to weather off ensuing political pressure due to it, the governance authorities introduce regulations of “Time constraints” with restrictions on carrying out the operational works without hampering

the interests of the affecting stakeholders. This regulation will cut down the operational flexibility of the implementors to carry out the operational process during the breeding and holiday seasons. This leads to the challenge pattern of "Operational barriers" as they have to make additional technical arrangements to conduct the process in wet season apart from the arrangements to diminish the negative effects occurring through water level enhancement of wetlands as part of restoration which affects the neighborhood agriculture and residences. And this scenario leads to "Resource scarcity" due to the limited availability of technically adept contractors and personnel who possess both the experience of conducting the process in wet season and water management.

Similarly, this chain reaction characteristics, due to the interrelation factor, can also diminish the influence intensity of the challenges. For example, in another scenario related to the land use, a leniency in governance regulations in compensation flexibility, will empower the employees to exhibit their negotiation skills and competency with more options to resolve the land use issues. This will indirectly diminish the resistance of the local community and stakeholders towards the process implementation.

Therefore, overall, the interrelation strength of each challenge towards others will act as a key triggering factor that impacts the influential strength of a challenge either negatively or positively. Consequently, this will influence the effective application of a wetland restoration through the level of influences and barriers it raises. These identified interrelations, complexities and their dynamic characteristics has also been explicitly mentioned in the ecosystem approach framework guidelines of UNEP (Convention on Biological Diversity, 2004) and in the study of Geels (2004) about the interrelation between socio-technical regimes.

5.3. The Success of the combined application of the strategies

The key strategic themes that are identified from the cluster of actions and measures adopted by the participants in the Netherlands, to resolve the socio-technical challenges in their respective projects, are Participatory Approach, Integrated & Balanced Distribution, Flexibility in Compensation & Regulations, Process Optimization, and Communication of knowledge. This is evidently consistent with the previous studies, especially of Smith and Maltby (2003).

It is to be noted that all the participants have not relied only on one strategy, instead they applied multiple strategies in a combined manner that enhanced the success in resolving the issues pertaining to the challenges as some issues necessitates such combinations. For example, communication of knowledge and participatory approach are used combinedly by many participants for the resolution of challenges related to the land use, local community and cultural factors, and stakeholder interventions. They applied it to communicate about the benefits of the project, understand their concerns and by winning their trust, the communities will start to cooperate with the projects by providing their local knowledge and inputs. This will make their works easier and ultimately reap mutual benefits. This combined application of knowledge enhancement and adaptive co-management has been manifested in previous studies of Cortina-Segarra et al. (2021), Chang & Andersson (2021) and Mathe (2014) to resolve similar issues.

For resolving the issues related to the process management, such as operational barriers, time constraints etc., the stakeholder's diverse interests have to be studied and necessary actions to be taken. In such scenarios, the combination of communication of knowledge and process optimization were utilized that enabled to ensure their cooperation and sharing of their experience in optimizing the actions. This combination is also applied in the research of Trkman et al. (2015). And, this combination along with the integrated & balanced distribution strategies has been applied to resolve the fund shortage issues and also the time constraint issues of process management. Similar approach has been adopted by Cortina-Segarra et al. (2021) and Vestil (2024) previously.

Governance regulations and policies related issues are encountered mostly with the combination of flexibility in compensation & regulations, communication of knowledge and participatory approach. An efficient communication about the pros and cons of the projects and the ensuing challenges and barriers in it, leads to the proper understanding by the governing and political authorities about it. This facilitates enhanced collaboration, transparency and trust between the implementors and governing authorities which will leads to adapting the regulations with necessary flexibilities to resolve the challenges arise out of stringent regulations. This method of harmonized regulations has been observed in the studies of Lambin et al. (2014), and its requirement of its flexibilities are resembled in the research of Lordkipanidze et al. (2016) as well.

And, the fusion of participatory approach, with communication of knowledge, integrated & balanced distribution, and flexibility in compensation & regulations strategies has been endorsed by many participants through deriving methods of generating income for the land owners and other stakeholders that facilitates to resolve or mitigate multiple challenges related to resistance from land users that leads to legal tussles, stakeholder apathies that drives to discontinuation of the project, and upholding community cultural activities. The ideas of "Result-based payment", "Green Investment", "Carbon Credits" has been echoed by many of them. Such ideas have also been reflected in the research of Angelsen et al. (2024) and Canning et al. (2021) who discussed about methods of "Result-based payment" and "Payment for Ecosystem Services" respectively.

And as mentioned by the participants, the process optimization through the introduction of MRV (measurement, reporting and verification) system and exclusive frameworks for the wetlands restoration, conservation and preservation practices, and applying it with mixing the communication of knowledge through updated trainings also will facilitate the resolution of issues related to the reported employee skills shortcomings and performance evaluation complexities. Al-Qatawneh et al. (2019) and Numminen (2023) have emphasized the significance of these strategies in identifying critical bottleneck situations and productive barriers, and an effective measure in problem solving.

6. Conclusion and Recommendation

6.1. Conclusion

Climate change is the direct or indirect reason for the imbalance of the earth systems which affecting the human wellbeing and survival on earth. It results in environmental catastrophes including floods, droughts and global warming through greenhouse gas emissions. This study investigates on the background of the lack of widespread application of Nature-based solutions, especially wetland restorations, for tackling such catastrophes around the world despite its proven potential. The objective of this study was to understand how the complex socio-technical system involvement and its influences becomes a challenge in applying the nature-based solution of wetland restoration initiatives in the Netherlands, and to evaluate the strategic measures adopted by the implementors to overcome these challenges.

The exploratory research mixed with explanatory elements, adopted the socio-technical systems framework (STS) developed by Davis et al. (2014) aligning with the socio-technical regime concept of Geels (2004). It enabled the research to evaluate the wetland restoration initiatives of the Netherlands, based on the 9 socio-technical elements of STS framework such as land use, local community and cultural factors, stakeholder interventions, governance regulations and policies, process management, employee skills and competencies, performance evaluation and knowledge gap. The investigation applied mixed method by collecting both qualitative and quantitative data from the key personnel associated with wetland restoration programs in the Netherlands through interviews. A meticulous data analysis of content, descriptive, regression and relational network data analysis has been conducted to derive the findings based on the three sub-questions raised which ultimately answered the main research question.

Based on the derivation of results of exploring the key socio-technical challenges encountered during the implementation and management phase of wetland restorations, issues related to “Land use”, “Governance regulations and policies” and “Economic & Budget Limitations” are the three key socio-technical challenges that categorizes between “major to significant” levels in both implementation and management stages of a wetland restoration. The prime reason derived is the conflict of interest due to the increasing demand in the utilization of already scarce land properties for other sources such as agriculture, industries and real estate, the short-lived regulations and policies which undergoes fluctuations every four years according to the political priorities of the government administration, and the fugitive and inflexible plans for fund utilization. This poses as a severe challenge to initiatives such as wetland restorations which normally a long-term implementation process and necessitates continuous maintenance. Challenges related to “Process management” and “Stakeholder Interventions are considered as higher “moderate” with marginally closer to the “major” category during implementation phase, have minimized into lower “moderate” category in view of diminished intensity through resolutions once the implementation is complete. And rest of the challenges remains between “moderate to noticeable” categories with minimal variances demonstrated between both phases. The results further discussed how each challenge evolves from implementation to management stage based on the change in perception of stakeholders.

The most recurrent patterns identified among these challenges are “Conflict of Interest” between stakeholders, governance levels, employee levels etc., then “Resource Scarcity” that related to land scarcity, financial shortages, insufficient social skills, technical inadequacies, knowledge deficiencies, time constraints etc., and “Stringent & biased regulations” that related to inflexible and short visioned regulations and policies, operational constraints, top-down approaches and complex administrative measures.

As per the results of three different analysis of exploring the most influential among the socio-technical challenges and how they affect the effective application of the wetland restoration in the context of the Netherlands, overall, “Land use issues”, “Governance regulations and policies” and “Process Management” emerged as the most influential challenges towards effective application with sufficient statistical significance. Both “Economic and Budget Limitations” and “Stakeholder Interventions” also have demonstrated profound influential strength through good intensity rating and interconnections despite not being statistically significant. The remaining challenges vary based on the resistance dynamics of these above-mentioned challenges.

The result also further illustrates that these socio-technical challenges influence the effective application of the wetland restoration through their identified strong influence on the process, which is driven by the dynamic characteristics of strong interrelations and interdependence exhibited between each other. A variation in one challenge will invariably affect the persistence of other challenges, either positively or negatively.

According to the discourse of the result for identifying the key strategies and best practices applied to overcome these socio-technical challenges, the major themes resonate by participants are “Communication of knowledge” that propagates the importance of effective communication and knowledge transference in various aspects related to stakeholders, human resources, political and governance level etc. the “Participatory approach” which encourages the concepts of co-creation and building-up together values, “Process optimization” that described various optimization measures of its operational activities and its functional attributes, “Flexibility in Compensation & Regulations” that stressed the essentiality of flexibility in various regulations and policies, and “Integrated & balanced distribution” strategy that endorses the significance of tactical combination and equity distribution of resources benefits. It further corroborates the importance of combined application of these measures in weathering off such challenges. It also highlights the significance of adopting innovative measures such as “Result-based payment” and “Green investments” for enhancing stakeholder involvement and minimizing land-use disputes. It also put forth the essentiality of developing exclusive framework and a comprehensive measurement, reporting and verification (MRV) for the wetland restoration program.

Overall, the derivation of these three sub-questions unequivocally answers the main research question and attained the core objective of this study which was to find out how these aforementioned socio-technical challenges influence in effectively applying the nature-based solution of wetland restoration for climate action in the context of the Netherlands and identify the best strategies to overcome those socio-technical challenges.

To conclude, only 10% of the planet is considered as bio-reserved or protected areas and for the rest of areas, the presence of human interference is inevitable (Smith & Maltby, 2003). Therefore, these socio-technical challenges are always will be abreast with these ecosystem initiatives such as wetland restoration and they significantly influence the application processes at varying degrees based on specific demands of the diverse contexts due to their complex interrelation and interdependence.

6.2. Recommendation for future study

While the scope of this study investigates only on the wetland restorations of the Netherlands, it is recommended to conduct a similar study in different contexts, particularly in global south, which will provide diverse outlook and multiple variants of the same challenges. And, even though a panacea solution is impractical, it will contribute to gain new insights and numerous strategic options that successfully applied to resolve such challenges in that context.

Another recommendation is, during the data analysis phase, it has been reflected that there are differences in the strength of the influence of challenges between the large-scale and small-medium scale wetland restoration projects. For instance, "Land use" was not that a major challenge for large scale wetland restoration projects whereas for small to medium scale wetland restoration projects, it was perceived as the critical barrier. The major reason behind is, these large-scale projects implementation often takes place at either nature reserved areas owned by the government itself. Hence the issues related to the acquisition of the lands are minimal in these projects. Whereas for small-medium scale projects, which normally occurs close to residential surroundings, the project owners have to weather off the solid resistance from the stakeholders of the land and to find resolutions for it. Similar kind of variation was evident in other challenges as well. But since the scope of this study didn't diverge the research unit on the basis of scale and magnitude of the projects, and due to time limitations, the researcher did not delve deep into this nuanced aspect even though it ignited the researcher's curiosity. Hence, it is highly recommended to conduct exploratory research about this nuanced aspect which will provide valuable insights into developing exclusive strategies for different scale wetland restoration projects.

Overall, these studies will contribute to develop effective strategic framework for resolving socio-technical challenges in wetland restorations, and its universal application, globally.

Reference

Alexander, S., McInnes, R., & Scientific and Technical Review Panel. (2012). Ramsar Scientific and Technical Briefing Note no. 4. In Society for Ecological Restoration & Society of Wetland Scientists, Ramsar Convention on Wetlands [Report]. https://www.ramsar.org/sites/default/files/documents/library/bn4-en.pdf

Alikhani, S., Nummi, P., & Ojala, A. (2021). Urban Wetlands: A review on ecological and Cultural values. Water, 13(22), 3301. https://doi.org/10.3390/w13223301

Al-Qatawneh, N. a. W., Al-Tarawneh, S. J., Al-Qatawneh, N. a. W., & Al-Adaileh, R. M. (2019). The impact of knowledge management processes on operational performance as mediated by IT agility. International Review of Management and Marketing, 9(1), 36–43. https://ideas.repec.org/a/eco/journ3/2019-01-5.html

Anderson, B., Cammeraat, E., Dechezleprêtre, A., Dressler, L., Gonne, N., Lalanne, G., Guilhoto, J., & Θεοδωρόπουλος, K. (2023). Designing policy packages for a climate-neutral industry: A case study from the Netherlands. Ecological Economics, 205, 107720. https://doi.org/10.1016/j.ecolecon.2022.107720

Angelsen, A., Hermansen, E., Rajão, R., & R, V. D. H. (2024, April 2). Knowledge | CIFOR-ICRAF. CIFOR-ICRAF. https://www.cifor-icraf.org/knowledge/publication/7064/

Archibold, O. W. (1995). Terrestrial wetlands. In Springer eBooks (pp. 319–353). https://doi.org/10.1007/978-94-011-0009-0_10

Belz, F. (2004). A transition towards sustainability in the Swiss Agri-Food Chain (1970–2000): using and improving the multi-level perspective. In Edward Elgar Publishing eBooks. https://doi.org/10.4337/9781845423421.00016

Bertram, C., Quaas, M. F., Reusch, T. B. H., Vafeidis, A. T., Wolff, C., & Rickels, W. (2021). The blue carbon wealth of nations. Nature Climate Change, 11(8), 704–709. https://doi.org/10.1038/s41558-021-01089-4

Bona, S., Silva-Afonso, A., Gomes, R., Matos, R., & Rodrigues, F. (2022). Nature-Based solutions in urban areas: a European analysis. Applied Sciences, 13(1), 168. https://doi.org/10.3390/app13010168

Buckingham, K., Arakwiye, B., Ray, S., Maneerattana, O., & Anderson, W. (2021). Cultivating networks and mapping social landscapes: How to understand restoration governance in Rwanda. Land Use Policy, 104, 104546. https://doi.org/10.1016/j.landusepol.2020.104546

Buckingham, K., Ray, S., Granizo, C. G., Toh, L., Stolle, F., Zoveda, F., Reytar, K., Cristales, R. Z., Ndunda, P., Landsberg, F., Matsumoto, M., & Brandt, J. (2019, January 10). The road to restoration. World Resources Institute. https://www.wri.org/research/road-restoration

Canning, A. D., Jarvis, D., Costanza, R., Hasan, S., Smart, J. C., Finisdore, J., Lovelock, C. E., Greenhalgh, S., Marr, H. M., Beck, M. W., Gillies, C. L., & Waltham, N. J. (2021). Financial incentives for large-scale wetland restoration: Beyond markets to common asset trusts. One Earth, 4(7), 937–950. https://doi.org/10.1016/j.oneear.2021.06.006

Challenger, R., & Clegg, C. W. (2011). Crowd disasters: a socio-technical systems perspective. Contemporary Social Science, 6(3), 343–360. https://doi.org/10.1080/21582041.2011.619862

Chang, K., & Andersson, K. P. (2021). Contextual factors that enable forest users to engage in tree-planting for forest restoration. Land Use Policy, 104, 104017. https://doi.org/10.1016/j.landusepol.2019.05.036

Cheong, S., Silliman, B. R., Wong, P., Van Wesenbeeck, B. K., Kim, C., & Guannel, G. (2013). Coastal adaptation with ecological engineering. Nature Climate Change, 3(9), 787–791. https://doi.org/10.1038/nclimate1854

Cherns, A. (1976). The principles of sociotechnical design. Human Relations, 29(8), 783–792. https://doi.org/10.1177/001872677602900806
Clegg, C. W. (2000). Sociotechnical principles for system design. Applied Ergonomics, 31(5), 463–477. https://doi.org/10.1016/s0003-6870(00)00009-0
Convention on Biological Diversity. (2004). The ecosystem approach. Secretariat of the Convention on Biological Diversity. https://www.cbd.int/doc/publications/ea-text-en.pdf
Cooke, S. J., Bennett, J. R., & Jones, H. P. (2019). We have a long way to go if we want to realize the promise of the "Decade on Ecosystem Restoration." Conservation Science and Practice, 1(12). https://doi.org/10.1111/csp2.129
Cordis, C. (2023, August 31). Restoring Europe's damaged wetlands. CORDIS | European Commission. https://cordis.europa.eu/article/id/446072-restoring-europe-s-damaged-wetlands
Cortina-Segarra, J., García-Sánchez, I., Grace, M., Andrés, P., Baker, S., Bullock, C., Decleer, K., Dicks, L. V., Fisher, J. L., Frouz, J., Klimkowska, A., Kyriazopoulos, A. P., Moreno-Mateos, D., Rodríguez-González, P. M., Sarkki, S., & Ventocilla, J. L. (2021). Barriers to ecological restoration in Europe: expert perspectives. Restoration Ecology, 29(4). https://doi.org/10.1111/rec.13346
Davidson, N. (2014). How much wetland has the world lost? Long-term and recent trends in global wetland area. Marine and Freshwater Research, 65(10), 934. https://doi.org/10.1071/mf14173
Davies, C., & Lafortezza, R. (2019). Transitional path to the adoption of nature-based solutions. Land Use Policy, 80, 406–409. https://doi.org/10.1016/j.landusepol.2018.09.020
Davis, M. C., Challenger, R., Jayewardene, D., & Clegg, C. W. (2014). Advancing socio-technical systems thinking: A call for bravery. Applied Ergonomics, 45(2), 171–180. https://doi.org/10.1016/j.apergo.2013.02.009
De Haas, T., & Schepers, M. (2022). Wetland Reclamation and the Development of Reclamation Landscapes: A Comparative framework. Journal of Wetland Archaeology, 22(1–2), 75–96. https://doi.org/10.1080/14732971.2022.2072097
Delta, W. B. (2023, July 7). Natuurrealisatie Noordrand Midden. Waterschap Brabantse Delta. https://www.brabantsedelta.nl/noordrandmidden
Duarte, C. M., Losada, Í. J., Hendriks, I. E., Mazarrasa, I., & Marbà, N. (2013). The role of coastal plant communities for climate change mitigation and adaptation. Nature Climate Change, 3(11), 961–968. https://doi.org/10.1038/nclimate1970
Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. VTT's Research Information Portal. https://doi.org/10.2777/244577
Duraiappah, A. K., Asah, S. T., Brondizio, E. S., Kosoy, N., O'Farrell, P. J., Prieur-Richard, A., Subramanian, S. M., & Takeuchi, K. (2014). Managing the mismatches to provide ecosystem services for human well-being: a conceptual framework for understanding the New Commons. Current Opinion in Environmental Sustainability, 7, 94–100. https://doi.org/10.1016/j.cosust.2013.11.031
Durham, P. (2023, June 30). Sustainable infrastructure projects in the Netherlands | TECHNIA. TECHNIA. https://www.technia.com/blog/sustainable-infrastructure-projects-in-the-netherlands/
Erwin, K. L. (2008). Wetlands and global climate change: the role of wetland restoration in a changing world. Wetlands Ecology and Management, 17(1), 71–84. https://doi.org/10.1007/s11273-008-9119-1
FeanGreide Fryslan. (2024). VeenweideProgramma 2021-2030 | Veenweide. Veenweide. https://veenweidefryslan.frl/programma/veenweideprogramma-2021-2030

Fryslan. (2024, April 16). Fryslân Klimaatbestindich 2050+. Fryslan. https://www.fryslan.frl/fy/fryslan-klimaatbestindich-2050
Gantioler, S., Rayment, M., Brink, P. T., McConville, A., Kettunen, M., & Bassi, S. (2014). The costs and socio-economic benefits associated with the Natura 2000 network. International Journal of Sustainable Society, 6(1/2), 135. https://doi.org/10.1504/ijssoc.2014.057894
Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems. Research Policy, 33(6–7), 897–920. https://doi.org/10.1016/j.respol.2004.01.015
Genç, R. (2017). The Importance of Communication in Sustainability & Sustainable Strategies. Procedia Manufacturing, 8, 511–516. https://doi.org/10.1016/j.promfg.2017.02.065
Globaia. (2009). Planetary Boundaries — Globaïa. Globaïa. https://globaia.org/boundaries
Grant, A., & Langer, E. R. (2021). Wildfire volunteering and community disaster resilience in New Zealand: institutional change in a dynamic rural social-ecological setting. Ecology and Society, 26(3). https://doi.org/10.5751/es-12474-260318
Gunn, N. (2023, April 11). Benefit and costs of nature based solutions. WTW. https://www.wtwco.com/en-eg/insights/2023/04/benefit-and-costs-of-nature-based-solutions
It Fryske Gea. (2024, June 12). Eropuit in de natuur van de Alde Feanen | It Fryske Gea. https://www.itfryskegea.nl/natuurgebied/nationaal-park-alde-feanen/?gad_source=1&gclid=CjwKCAjw-O6zBhASEiwAOHeGxeSqX39iTSGFtEcD_jsumC97nhnk0KtXN4twcZsfKnzufauuDiNqvRoC2gwQAvD_BwE
IUCN. (2024, May 22). More than half of all mangrove ecosystems at risk of collapse by 2050, first global assessment finds. https://www.iucn.org/press-release/202405/more-half-all-mangrove-ecosystems-risk-collapse-2050-first-global-assessment
Jongman, B., Sotomayor, R. T., & Wang, X. (2022, May 19). Nature-based solutions for resilient cities and restoring local biodiversity. World Bank Blogs. https://blogs.worldbank.org/en/sustainablecities/nature-based-solutions-resilient-cities-and-restoring-local-biodiversity
Joosten, H., Brust, K., Couwenberg, J., Gerner, A., Holsten, B., Permien, T., Schäfer, A., Tanneberger, F., Trepel, M., & Wahren, A. (2015). MoorFutures®: integration of additional ecosystem services (including biodiversity) into carbon credits. Standard, Methodology and Transferability to Other Regions,Vol. 407, BfN, Bonn-Bad Godesberg 2015, P. 120. https://www.cabdirect.org/cabdirect/abstract/20153280712
Keesstra, S., Nunes, J. P., Novara, A., Finger, D. C., Avelar, D., Kalantari, Z., & Cerdà, A. (2018). The superior effect of nature based solutions in land management for enhancing ecosystem services. Science of the Total Environment, 610–611, 997–1009. https://doi.org/10.1016/j.scitotenv.2017.08.077
Kim, S. (2020). Sustainable agricultural practices of rice fields as human-made wetlands – focusing on cases in Japan and Korea. Wetland Research Vol.10, 27-36. https://www.jstage.jst.go.jp/article/wetlandresearch/10/0/10_WR010005/_pdf/-char/en
Komulainen, V., Tuittila, E., Vasander, H., & Laine, J. (1999). Restoration of drained peatlands in southern Finland: initial effects on vegetation change and CO2 balance. Journal of Applied Ecology, 36(5), 634–648. https://doi.org/10.1046/j.1365-2664.1999.00430.x
Kumar, P., Debele, S., Sahani, J., Rawat, N., Martí-Cardona, B., Alfieri, S. M., Basu, B., Basu, A. S., Bowyer, P. K., Charizopoulos, N., Gallotti, G., Jaakko, J., Leo, L. S., Loupis, M., Menenti, M., Mickovski, S. B., Mun, S., González-Ollauri, A., Pfeiffer, J., . . . Zieher, T. (2021). Nature-based solutions efficiency evaluation against natural hazards: Modelling methods, advantages and

limitations. Science of the Total Environment, 784, 147058. https://doi.org/10.1016/j.scitotenv.2021.147058
Lambin, E. F., Meyfroidt, P., Rueda, X., Blackman, A., Börner, J., Cerutti, P. O., Dietsch, T., Jungmann, L., Lamarque, P., Lister, J., Walker, N. F., & Wunder, S. (2014). Effectiveness and synergies of policy instruments for land use governance in tropical regions. Global Environmental Change, 28, 129–140. https://doi.org/10.1016/j.gloenvcha.2014.06.007
Lordkipanidze, M., Boer, C. D., & Bressers, H. (2016). Assessing governance context to increase drought resilience: The case of the Drents-Friese Wold National Park. International Journal of Water Governance, 4, 69–92. https://doi.org/10.7564/14-ijwg70
Lordkipanidze, M., Lulofs, K. R., & Bressers, H. (2019). Towards a new model for the governance of the Weerribben-Wieden National Park. Science of the Total Environment, 648, 56–65. https://doi.org/10.1016/j.scitotenv.2018.08.121
Maizland, L. (2023, December 6). Global climate agreements: successes and failures. Council on Foreign Relations. https://www.cfr.org/backgrounder/paris-global-climate-change-agreements
Mara. (2023). Restoring Europe's wetlands for climate resilience: a call to act. https://www.rewet-he.eu/news/iucn-nl-has-published-video-weerribben-wieden-peatland-netherlands
Mara. (2024, January 29). REWET and the World Wetlands Days 2024. https://www.rewet-he.eu/news/world-wetlands-day-2024-care-nurture-and-support-wetlands-and-people
Martín, E. G., Costa, M. M., Egerer, S., & Schneider, U. A. (2021). Assessing the long-term effectiveness of Nature-Based Solutions under different climate change scenarios. Science of the Total Environment, 794, 148515. https://doi.org/10.1016/j.scitotenv.2021.148515
Mathe, S. (2014). Integrating participatory approaches into social life cycle assessment: the SLCA participatory approach. ˜ the œInternational Journal of Life Cycle Assessment, 19(8), 1506–1514. https://doi.org/10.1007/s11367-014-0758-6
McKay, D. I. A., Staal, A., Abrams, J. F., Winkelmann, R., Sakschewski, B., Loriani, S., Fetzer, I., Cornell, S., Rockström, J., & Lenton, T. M. (2021). Updated assessment suggests >1.5°C global warming could trigger multiple climate tipping points. Science 377. https://doi.org/10.1002/essoar.10509769.1
Ministerie van Economische Zaken en Klimaat. (2017, September 20). Protected nature areas. Nature and Biodiversity | Government.nl. https://www.government.nl/topics/nature-and-biodiversity/protected-nature-areas#:~:text=The%20Netherlands%20has%20over%20a,fens%2C%20peat%20bogs%20and%20lakes.
Ministry of Economic Affairs and Climate. (2021, March 18). Het Akkoord. Klimaatakkoord. https://www.klimaatakkoord.nl/klimaatakkoord
Nelson, D. R., Bledsoe, B. P., Ferreira, S., & Nibbelink, N. P. (2020). Challenges to realizing the potential of nature-based solutions. Current Opinion in Environmental Sustainability, 45, 49–55. https://doi.org/10.1016/j.cosust.2020.09.001
Nicholson, S. (2021). Carbon removal and the dangers of extractivism. In Routledge eBooks (pp. 189–203). https://doi.org/10.4324/9781003127611-14
Nikita. (2024, March 18). Wetlands International receives €1.5 million grant from Dutch Postcode Lottery. Wetlands International. https://www.wetlands.org/wetlands-international-receives-e1-5-million-grant-from-dutch-postcode-lottery/
Nile Basin Initiative. (2013). Wetland Management Strategy. In Nile Basin Initiative. https://swm-programme.info/documents/20142/1184079/EGY_PO_WE_20131211.pdf/be9d6c53-544d-3bd8-25b3-7fc962801e04?version=1.0&t=1652276169077&

Nilsson, C., & Aradottir, A. L. (2013). Ecological and Social aspects of ecological restoration: New challenges and opportunities for northern regions. Ecology and Society, 18(4). https://doi.org/10.5751/es-06045-180435
NRDC. (2021, February 19). Paris Climate Agreement: Everything you need to know. https://www.nrdc.org/stories/paris-climate-agreement-everything-you-need-know
NS Energy. (2020, June 16). Porthos Carbon Capture and Storage Project, Rotterdam, Netherlands. https://www.nsenergybusiness.com/projects/porthos-carbon-capture-and-storage-ccs-project/
Numminen, L. (2023, September 22). Process Optimization Explained - Methods, Benefits & Tools. Workfellow. https://www.workfellow.ai/learn/what-is-process-optimization#:~:text=Process%20optimization%20helps%20businesses%20identify,Enhanced%20quality%20and%20consistency.
Osman, A., Boateng, I., Ansah-Mensah, K., & Owusu, A. B. (2023). Wetland restoration challenges and eco-volunteerism. Journal for Nature Conservation, 73, 126411. https://doi.org/10.1016/j.jnc.2023.126411
Palmgren, C., Morgan, M. G., De Bruin, W. B., & Keith, D. W. (2004). Initial public perceptions of deep geological and oceanic disposal of carbon dioxide. Environmental Science & Technology, 38(24), 6441–6450. https://doi.org/10.1021/es040400c
Raj, A. V., & Jamwal, P. (2024). Assessing resilience of natural treatment system to variable contaminant loads in an urbanizing catchment. Journal of Water Process Engineering, 58, 104774. https://doi.org/10.1016/j.jwpe.2024.104774
Ramachandra, T. V. (2001). Restoration and management strategies of wetlands in developing countries. Electronic Green Journal, 1(15). https://doi.org/10.5070/g311510435
Ramsar. (2018). Scaling up wetland conservation, wise use and restoration to achieve the Sustainable Development Goals. https://www.ramsar.org/sites/default/files/documents/library/wetlands_sdgs_e.pdf
Raven, R. (2004). Implementation of manure digestion and co-combustion in the Dutch electricity regime: a multi-level analysis of market implementation in the Netherlands. Energy Policy, 32(1), 29–39. https://doi.org/10.1016/s0301-4215(02)00248-3
Rewilding Europe. (2023, September 28). Marker Wadden | Rewilding Europe. https://rewildingeurope.com/rew-project/marker-wadden-restoration-project/
Reyes-García, V., & Benyei, P. (2019). Indigenous knowledge for conservation. Nature Sustainability, 2(8), 657–658. https://doi.org/10.1038/s41893-019-0341-z
Rezaei, F., Khalilzadeh, M., & Soleimani, P. (2021). Factors affecting knowledge management and its effect on organizational performance: Mediating the role of human capital. Advances in Human-computer Interaction, 2021, 1–16. https://doi.org/10.1155/2021/8857572
Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., Von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Bravo, D., . . . Rockström, J. (2023). Earth beyond six of nine planetary boundaries. Science Advances, 9(37). https://doi.org/10.1126/sciadv.adh2458
Rockström, J., Steffen, W., Noone, K. J., Persson, Å., Chapin, F. S., Lambin, É. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., De Wit, C. A., Hughes, T. P., Van Der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., . . . Foley, J. A. (2009). A safe operating space for humanity. Nature, 461(7263), 472–475. https://doi.org/10.1038/461472a

Sarabi, S. E., Han, Q., Romme, A. G. L., De Vries, B., & Wendling, L. (2019). Key Enablers of and Barriers to the uptake and Implementation of Nature-Based Solutions in Urban Settings: A review. Resources, 8(3), 121. https://doi.org/10.3390/resources8030121

Sari, D. A., Sayer, J., Margules, C., & Boedhihartono, A. K. (2019). Determining the effectiveness of forest landscape governance: A case study from the Sendang landscape, South Sumatra. Forest Policy and Economics, 102, 17–28. https://doi.org/10.1016/j.forpol.2019.01.014

Sayer, J., Boedhihartono, A. K., Langston, J. D., Margules, C., Riggs, R. A., & Sari, D. A. (2021). Governance challenges to landscape restoration in Indonesia. Land Use Policy, 104, 104857. https://doi.org/10.1016/j.landusepol.2020.104857

Scott, J. (2014). A Dictionary of Sociology. In Oxford University Press eBooks. https://doi.org/10.1093/acref/9780199683581.001.0001

Seifollahi-Aghmiuni, S., Nockrach, M., & Kalantari, Z. (2019). The potential of wetlands in achieving the sustainable development goals of the 2030 agenda. Water, 11(3), 609. https://doi.org/10.3390/w11030609

Shackelford, N., Hobbs, R. J., Burgar, J. M., Erickson, T. E., Fontaine, J. B., Laliberté, E., Ramalho, C. E., Perring, M. P., & Standish, R. J. (2013). Primed for change: Developing ecological restoration for the 21st century. Restoration Ecology, 21(3), 297–304. https://doi.org/10.1111/rec.12012

Silliman, B. R., Schrack, E., He, Q., Cope, R., Santoni, A., Van Der Heide, T., Jacobi, R., Jacobi, M. D., & Van De Koppel, J. (2015). Facilitation shifts paradigms and can amplify coastal restoration efforts. Proceedings of the National Academy of Sciences of the United States of America, 112(46), 14295–14300. https://doi.org/10.1073/pnas.1515297112

Smith, R., & Maltby, E. (2003). Using the ecosystem approach to implement the Convention on biological diversity: key issues and cases studies. https://doi.org/10.2305/iucn.ch.2003.cem.2.en

SOLitude Lake Management. (2024, June 9). What is Wetland Management? Definition, Strategies and Techniques. SOLitude Lake Management: Full-Service Lake and Pond Management. https://www.solitudelakemanagement.com/what-is-wetland-management-definition-strategies-techniques/#:~:text=Most%20effective%20approaches%20integrate%20the,the%20plant%20in%20multiple%20ways.

Sowińska-Świerkosz, B., & García, J. (2022). What are Nature-based solutions (NBS)? Setting core ideas for concept clarification. Nature-Based Solutions, 2, 100009. https://doi.org/10.1016/j.nbsj.2022.100009

Stark, J., Plancke, Y., Ides, S., Meire, P., & Temmerman, S. (2016). Coastal flood protection by a combined nature-based and engineering approach: Modeling the effects of marsh geometry and surrounding dikes. Estuarine, Coastal and Shelf Science (Print), 175, 34–45. https://doi.org/10.1016/j.ecss.2016.03.027

Statista. (2024, June 4). Land area of Natura 2000 sites in the European Union 2021, by country. https://www.statista.com/statistics/1392807/land-area-of-natura-2000-sites-by-country-european-union/#:~:text=Premium%20statistics-,Land%20area%20of%20Natura%202000%20sites,European%20Union%202021%2C%20by%20country&text=The%20total%20land%20area%20of,second%2C%20at%20over%2071%2C000%20km%C2%B2.

Statistics Netherlands. (2009, February 3). Extensive wetland area in the Netherlands. Statistics Netherlands. https://www.cbs.nl/en-gb/news/2009/06/extensive-wetland-area-in-the-netherlands#:~:text=A%20relatively%20large%20area%20in,areas%20covering%20817%20thousand%20ha.

Strack, M., Davidson, S. J., Hirano, T., & Dunn, C. (2022). The potential of Peatlands as Nature-Based Climate Solutions. Current Climate Change Reports, 8(3), 71–82. https://doi.org/10.1007/s40641-022-00183-9

Subrahmanian, A. T. . R. R. (2020, November 2). Water Urbanism- Integrating Urban Wetlands into Urban Landscape for Sustainable Development. https://archives.palarch.nl/index.php/jae/article/view/5527

Suding, K. N. (2011). Toward an era of restoration in ecology: successes, failures, and opportunities ahead. Annual Review of Ecology, Evolution, and Systematics, 42(1), 465–487. https://doi.org/10.1146/annurev-ecolsys-102710-145115

Tanneberger, F., & Wichtmann, W. (2011). Carbon credits from peatland rewetting - Climate - biodiversity - land use. https://www.iucn-uk-peatlandprogramme.org/sites/www.iucn-uk-peatlandprogramme.org/files/12.06.27.5%20Carbon%20credits%20from%20re-wetting_FTanneberger_0.pdf

Temmink, R. J. M., Lamers, L. P. M., Angelini, C., Bouma, T. J., Fritz, C., Van De Koppel, J., Lexmond, R., Rietkerk, M., Silliman, B. R., Joosten, H., & Van Der Heide, T. (2022). Recovering wetland biogeomorphic feedbacks to restore the world's biotic carbon hotspots. Science, 376(6593). https://doi.org/10.1126/science.abn1479

Thorslund, J., Jarsjö, J., Jaramillo, F., Jawitz, J. W., Manzoni, S., Basu, N. B., Chalov, S., Cohen, M. J., Creed, I. F., Goldenberg, R., Hylin, A., Kalantari, Z., Koussis, A. D., Lyon, S. W., Mazi, K., Mård, J., Persson, K., Pietro, J., Prieto, C., . . . Destouni, G. (2017). Wetlands as large-scale nature-based solutions: Status and challenges for research, engineering and management. Ecological Engineering, 108, 489–497. https://doi.org/10.1016/j.ecoleng.2017.07.012

Tozer, L., Bulkeley, H., Van Der Jagt, A. P., Toxopeus, H., Xie, L., & Runhaar, H. (2022). Catalyzing sustainability pathways: Navigating urban nature based solutions in Europe. Global Environmental Change, 74, 102521. https://doi.org/10.1016/j.gloenvcha.2022.102521

Tracextech, & Tracextech. (2023, November 10). Nature Based Solution Projects for Carbon Offsets | NBS projects. Blockchain for Food Safety, Traceability and Supplychain Transparency. https://tracextech.com/nature-based-solution-projects-for-carbon-offsets/

Trkman, P., Mertens, W., Viaene, S., & Gemmel, P. (2015). From business process management to customer process management. Business Process Management Journal, 21(2), 250–266. https://doi.org/10.1108/bpmj-02-2014-0010

UNEA. (2019). New UN Decade on Ecosystem Restoration offers unparalleled opportunity for job creation, food security and addressing climate change. UN Environment. https://www.unep.org/news-and-stories/press-release/new-un-decade-ecosystem-restoration-offers-unparalleled-opportunity

UNESCO. (2019). The United Nations World Water Development Report 2018. In The United Nations world water development report. https://doi.org/10.18356/dc00fb4d-en

US EPA. (2023, November 1). Basic Information about Wetland Restoration and Protection | US EPA. https://www.epa.gov/wetlands/basic-information-about-wetland-restoration-and-protection#:~:text=Wetland%20restoration%20is%20the%20manipulation,rebuilding%20a%20former%20wetland%3B%20and

Verra. (2023, September 15). VM0036 Methodology for Rewetting Drained Temperate Peatlands V1.0 - Verra. https://verra.org/methodologies/vm0036-methodology-for-rewetting-drained-temperate-peatlands-v1-0/

Vestil, M. (2024, June 6). The importance of understanding distribution strategies. Mike Vestil. https://www.mikevestil.com/entrepreneurship/business-planning/the-importance-of-understanding-distribution-strategies/

Visscher, H. (2019). Innovations for a carbon free Dutch housing stock in 2050. IOP Conference Series: Earth and Environmental Science, 329(1), 012003. https://doi.org/10.1088/1755-1315/329/1/012003

Vogelsang, L. G., Weikard, H., Van Loon-Steensma, J., & Bednar–Friedl, B. (2023). Assessing the cost-effectiveness of Nature-based Solutions under climate change uncertainty and learning. Water Resources and Economics, 43, 100224. https://doi.org/10.1016/j.wre.2023.100224

Waddington, J. M., & Warner, K. D. (2001). Atmospheric CO2sequestration in restored mined peatlands. ÉCoscience/Écoscience, 8(3), 359–368. https://doi.org/10.1080/11956860.2001.11682664

Wallquist, L., Visschers, V., & Siegrist, M. (2009). Lay concepts on CCS deployment in Switzerland based on qualitative interviews. International Journal of Greenhouse Gas Control, 3(5), 652–657. https://doi.org/10.1016/j.ijggc.2009.03.005

Wang, B. J. R. T. S. X., Wang, B. J. R. T. S. X., & Wang, B. J. R. T. S. X. (2023, October 2). Nature-based solutions for resilient cities and restoring local biodiversity. World Bank Blogs. https://blogs.worldbank.org/sustainablecities/nature-based-solutions-resilient-cities-and-restoring-local-biodiversity

Wortley, L., Hero, J., & Howes, M. (2013). Evaluating Ecological Restoration Success: A Review of the literature. Restoration Ecology, 21(5), 537–543. https://doi.org/10.1111/rec.12028

Yang, X., Hu, M., Zhang, C., & Steubing, B. (2022). Key strategies for decarbonizing the residential building stock: Results from a spatiotemporal model for Leiden, the Netherlands. Resources, Conservation and Recycling, 184, 106388. https://doi.org/10.1016/j.resconrec.2022.106388

Appendix 1

Interview Questions

A small brief about yourself, your expertise, wetlands restoration projects you involved or studied about. And based on it, kindly give an insight for the below socio-technical challenges occurs in its implementation.

1. What are the main **infrastructure** related challenges such as land use related issues / arguments / negotiation associated with implementation of wetlands? How it arises? And how can it be resolved?
2. What challenges normally faces from the side of **community & related cultural factors**? How do we resolve it?
3. What are the major concerns raise by the **stakeholders** while implementation? How it become a challenge? How you overcome it?
4. How **government related regulatory & policy issues** arise as a challenge during the implementation period? How we can resolve it?
5. How does **financial & budget constraints** affect the smooth implementation process? How you find solution for it?
6. What are the main **operational procedures** related challenges occurring due to practicality or technical issues? What you do to overcome it?
7. Do you face any challenges related to the **competency & skills** related issues of the employees? What are they? What steps you do to resolve it?
8. How do you **evaluate the performance** of the initiative? Do you see it as a major technical challenge? What strategy you will apply to resolve it?
9. Was **knowledge gap** a major issue in successfully implementing the initiative? How you overcome it?
10. Of these, which are the challenges you perceive that will still face in smoothly managing / operating the initiative in future? How do you plan to overcome it?
11. How would you rate the overall effectiveness of the implementation of the projects you have been part of or you know about, based on the rating scale of 1 to 10?

Extremely ineffective 1	Very ineffective 2	Ineffective 3	Somewhat ineffective 4	Neutral 5	Somewhat effective 6	Effective 7	Very effective 8	Extremely effective 9	Unprecedentedly effective 10

12. Kindly give a rating for each barrier according to the strength of impact it makes during **implementation** phase of the initiative on a scale of 1 to 10 (below mentioned)?
    1. No barrier at all – This didn't act as a barrier or challenge.
    2. Negligible barrier – That can be ignored.
    3. Minor barrier – That possess only a slight challenge, but manageable.
    4. Noticeable barrier – That can be overcome with minimum effort.
    5. Moderate barrier – A barrier that requires attention, but can resolve afterwards.
    6. Major barrier – A barrier that requires some attention and effort to resolve.
    7. Significant barrier – A barrier that can delay the successful implementation
    8. Critical barrier – A blockade barrier that have to be resolved before proceeding with implementation
    9. Severe barrier – Extremely challenging barrier that poses threat to the success of implementation
    10. Catastrophic barrier – A barrier that leads to the complete failure if not addressed on emergency basis.

Land use related issues (1 – 10)	Community & Cultural factors (1 – 10)	Stakeholder interventions (1 – 10)	Governance & policy factors (1 – 10)	Economic & Budget limitations (1 – 10)	Process management (1 – 10)	Employee Competency (1 – 10)	Performance evaluation (1 – 10)	Knowledge gap (1 – 10)

13. Similarly, kindly give a rating for each barrier according to the impact it can make in future for successfully **managing** the initiative?

Land use related issues (1 – 10)	Community & Cultural factors (1 – 10)	Stakeholder interventions (1 – 10)	Governance & policy factors (1 – 10)	Economic & Budget limitations (1 – 10)	Process management (1 – 10)	Employee Competency (1 – 10)	Performance evaluation (1 – 10)	Knowledge gap (1 – 10)

14. According to the experience & observations with the project you know, what strategies have been the most successful in overcoming the related challenges? Can you describe the strategies that contribute the successful implementation?
15. Kindly give a rating on a scale of 1 to 10, how would you rate the overall effectiveness of the strategies applied for overcoming those challenges?

Extremely ineffective 1	Very ineffective 2	Ineffective 3	Somewhat ineffective 4	Neutral 5	Somewhat effective 6	Effective 7	Very effective 8	Extremely effective 9	Unprecedentedly effective 10

Appendix 2

Raw Data

- List of Interviewees
- Interview Transcripts.
- Codebook.

https://drive.google.com/drive/folders/1svpDl-BQTt2MhI-EXeTs_YBhhzVs5669?usp=sharing