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Development of a GIS-based model combined with a field-laboratory approach to evaluate the ecological rewetting potential of peatlands in Austria

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List of Abbreviations

a.s.l	Above Sea Level
BD	Bulk Density
C	Carbon
C _{org}	Organic Carbon
CH ₄	Methane
CO ₂	Carbon Dioxide
DTM	Digital Terrain Model
eBOD	Digital Soil Map
EC	Electrical Conductivity
ERP	Ecological Rewetting Potential
ESS	Ecosystem Services
ET	Evapotranspiration
GIS	Geographical Information System
ha	Hectares
k _f	Saturated Hydraulic Conductivity
LOI	Loss of Ignition
LULC	Land Use Land Cover
MCDA	Multi-Criteria Decision Analysis
OM	Organic Matter
SDGs	Sustainable Development Goals
Wk.max	Maximum Water Holding Capacity
WT	Water Table

Abstract

Peatlands are peat-forming wetlands with a high capacity to store CO₂ in their bodies. The conditions of these ecosystems have been anthropogenically altered by drainage and peat extraction for fuel production and agricultural use. As a result, peatlands have changed, turning from an emission sink to an emission source. Rewetting of drained peatlands is recently studied as a reversal option.

The state of the art shows studies focused either on geographic information system (GIS) data analysis with remote sensing or field data analysis. This thesis aims to develop a combined approach for evaluating the ecological rewetting potential (ERP) of peatlands in Austria. A GIS-based multi-criteria suitability model was developed for two peatlands in the Enns Valley, integrating hydrological, soil and land-use parameters. The model was validated using field and laboratory measurements of the physical and hydrological parameters of the soil. The suitability analysis showed a higher ERP in peat-rich, little to no incline areas, particularly in one investigated peatland. The other peatland showed lower suitability values. The additional field and laboratory data indicated significant depth-related differences in the physical and hydrological parameters of the soil, supporting the spatial pattern of the GIS model.

This study shows that integrating field-based peat properties in a GIS-based ERP model effectively identifies spatial patterns of potential peatland restoration areas, highlighting hydrology as a key controlling factor. The results provide a practical, spatially explicit framework for prioritising rewetting measures and supporting peatland restoration planning in the Enns Valley.

Zusammenfassung

Moore sind torfbildende Feuchtgebiete mit einer hohen Fähigkeit CO₂ in ihrem Körper zu speichern. Diese Eigenschaften der Ökosysteme wurden durch Entwässerung und Torfabbau für die Brennstoffproduktion und landwirtschaftliche Nutzung anthropogen verändert. Infolgedessen haben sich Moore von einer Kohlenstoffsенke zu einer Kohlenstoffquelle gewandelt. Die Wiedervernässung entwässerter Moore wurde kürzlich als Umkehrungsoption untersucht.

Der aktuelle Forschungsstand zeigt Studien, die sich hauptsächlich entweder auf die GIS-Datenanalyse mit Fernerkundung oder auf die Felddatenanalyse konzentrieren. Ziel dieser Arbeit ist es, einen kombinierten Ansatz zur Bewertung des ökologischen Wiedervernässungspotenzials von Mooren in Österreich zu entwickeln. Für zwei Moore im Ennstal wurde ein GIS-basiertes multikriterielles Eignungsmodell entwickelt, das hydrologische, bodenkundliche und landnutzungsbezogene Parameter integriert. Das Modell wurde anhand von Feld- und Labormessungen der physikalischen und hydrologischen Bodenparameter validiert. Die Eignungsanalyse ergab ein höheres ökologisches Wiedervernässungspotenzial in torfreichen Gebieten ohne oder mit geringer Neigung, insbesondere bei einem der untersuchten Moore, während das andere Moor niedrigere Eignungswerte aufwies. Die zusätzlichen Feld- und Labordaten zeigten signifikante, von der Tiefe abhängige Unterschiede bei den physikalischen und hydrologischen Parametern des Bodens, unterstützen jedoch das räumliche Muster des GIS-Modells.

Diese Studie zeigt, dass die Integration von vor Ort ermittelten Torfeigenschaften in ein GIS-basiertes ERP-Modell ein wirksames Vorgehen ist, um räumliche Muster potenzieller Moor Renaturierungsgebiete zu identifizieren, wobei die Hydrologie als ein entscheidender Kontrollfaktor hervorgehoben wird. Die Ergebnisse liefern einen praktischen, räumlich expliziten Rahmen für die Priorisierung von Wiedervernässungsmaßnahmen und die Unterstützung der Planung der Wiederherstellung von Mooren im Ennstal.

1. Introduction

Peatlands are unique ecosystems characterized by the natural accumulation of organic material, referred to as peat, on their surface. Although they cover only about 3% of the global land area, peatlands store approximately one third of the world's soil carbon (C), making them highly relevant for global C cycling and climate regulation (Joosten et al., 2012). Large parts of these ecosystems, however, have been altered or degraded due to long-term drainage, peat extraction, and land-use change for agriculture, forestry, bioenergy production, and livestock grazing (Liu et al., 2018). In particular, large-scale peat mining has caused substantial and long-lasting impacts on peatland ecosystems. Fuel extraction was one of the key drivers of peatland drainage beginning in the late 19th century and peatland degradation remains a continuing issue today (EU, 2020).

Globally, an estimated 43-51 million hectares (ha) of peatlands are already degraded (Joosten, 2010; Leifeld and Menichetti, 2018). Anthropogenic disturbances such as drainage and land-use change accelerate peat decomposition and organic matter (OM) mineralization, leading to increased greenhouse gas (GHG) emissions, particularly carbon dioxide (CO₂) and methane (CH₄). Although drained peatlands account for only about 15% of the total peatland area, they contribute approximately 6% of global anthropogenic CO₂ emissions (Liu et al., 2018). In contrast, intact peatlands function as long-term C sinks by accumulating peat and removing CO₂ from the atmosphere. Under anaerobic conditions, however, peat formation can also result in elevated CH₄ emissions, which have a global warming potential approximately 30 times higher than that of CO₂ (Jauhiainen et al., 2016; Figure 1).

Barthelmes et al. (2015) suggest that these opposing effects may balance over a period of about one hundred years, resulting in peatlands functioning as climate-neutral systems. Beyond GHG dynamics, peatland conservation and restoration efforts must also address biodiversity protection and aim to reduce the high emissions originating from drained peatlands (Koppensteiner et al., 2023).

Drainage further leads to substantial changes in peatland soil physical properties, including bulk density (BD), OM content, and pore structure, which in turn affect hydrological functioning and vegetation composition (Liu et al., 2018; Rezanezhad et al., 2016). Peatlands are currently declining at a rate approximately three times faster

than global forest loss (Minasny et al., 2024). Related vegetation shifts reduce biodiversity and increase susceptibility to soil erosion. The magnitude of these changes depends on factors such as the degree of peat decomposition, pore structure, botanical composition, landscape context, and hydrological regime (Joosten et al., 2012).

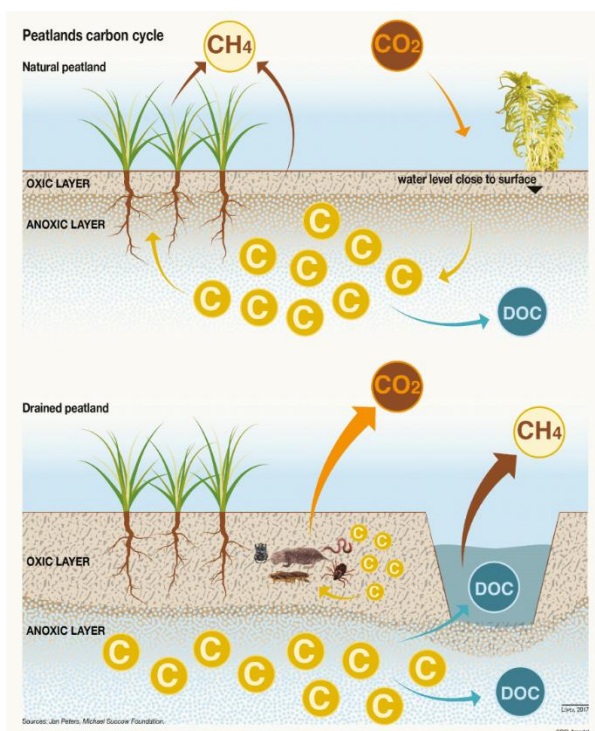


Figure 1: Simplified peatland C cycle. The upper part of the figure shows the C cycle of a natural peatland with a water table close to the surface, C accumulation in the anoxic (without oxygen) zone, showing a slow decomposition. GHG are low with a limited release of CO_2 and CH_4 . Dissolved organic carbon (DOC) flows into surrounding water body. The lower part of the figure shows the cycle of a drained peatland. The water table is lower, resulting in a higher oxic layer. Higher aerobic decomposition and peat degradation. This leads to higher GHG emissions. DOC is flowing into water body and water system. More C is released (Lopez, 2017).

Peatlands are highly diverse ecosystems with a global distribution and are influenced by a wide range of environmental conditions (Minasny et al., 2024). Persistent water saturation and limited oxygen availability provide favourable conditions for the accumulation of dead plant material and mosses as peat (EU, 2020). In natural peatlands, the water table (WT) is typically close to the surface, promoting peat formation due to anaerobic conditions. These conditions may also enhance CH_4 emissions (BMLRT, 2022). Peatlands are commonly classified based on their dominant water source, which influences nutrient availability and water chemistry and may vary spatially and temporally (IPS, n.d.). In addition, peatlands are predominantly found in regions where precipitation exceeds evapotranspiration (ET) (van Breemen, 1995).

Peatlands are generally divided into fens and bogs according to their primary water supply (Minasny et al., 2024). Differences in nutrient availability and pH are commonly used to distinguish between these two types. According to the FAO (2014), fens are defined as “a minerotrophic peatland that receives water and nutrients both from the atmosphere and from the groundwater ” (FAO, 2014, p. 1). In contrast, bogs are defined as “a peatland that receives water and nutrients exclusively from atmospheric deposition and is isolated from laterally moving, more mineral-rich soil water” (FAO, 2014, p.1).

However, due to the wide geographic distribution and ecological variability of peatlands, strict definitions are often difficult to apply. Consequently, the general term *peatland* is frequently preferred (Craft, 2016).

1.1. State of the Art

1.1.1. Properties, Hydrology and Mapping of Peatlands

According to the International Peat Society (IPS), peat is defined as “... sedentarily accumulated material consisting of at least 30% (dry mass) dead organic matter” (IPS, n.d.). In Europe, peat layers grow at a rate of approximately 1-2 millimetres per year, illustrating both the great age of peat deposits and the long timescales required for their development (EU, 2020). The physical characteristics of peat are strongly influenced by its water content, which affects hydraulic conductivity, BD and compression properties (FAO, 2014).

Peat is characterized by high total porosity, pronounced swelling and shrinking during wetting and drying cycles, and low BD. Porosity and BD are inversely correlated (Karimi, 2024). Total porosity refers to the volume fraction of soil pores filled with air or water and often exceeds 80% in peat soils (Rezanezhad et al., 2016). Peat soils also exhibit strong heterogeneity and anisotropy in their pore structure (Wang et al., 2020). Due to their high pore space, peat soils function like a sponge: they instantly absorb water, increasing in weight, but become extremely light when dry (Craft, 2016).

BD is a key regulator of peatland hydrology. Lower BD increases the water storage capacity of peat, making it one of the most important characteristics of peat soils (Karimi, 2024). BD is also commonly used to estimate other soil parameters, such as C content, total porosity and saturated hydraulic conductivity (k_f) (Qi et al., 2025; Morris et al., 2022). Hydraulic conductivity depends on pore structure and the degree of peat decomposition and therefore varies both vertically and horizontally (Morris et al., 2022; Quinton et al., 2008). Its spatial determination is particularly challenging due to this high variability (Qi et al., 2025; Morris et al., 2022; Wang et al., 2021; Ahmad et al., 2020).

Fluctuations in the WT strongly influence peat volume. A rising WT causes peat and its pore spaces to expand, which can reduce moisture retention capacity and increase water losses through ET and drainage (Kellner and Halldin, 2002). In contrast, a declining WT leads to peat shrinkage and pore closure, potentially resulting in land subsidence (Karimi, 2024).

Peatland Hydrology

Hydrology in peatlands is a fundamental driver of their characteristics, particularly regarding degradation, dominant water sources, and ecosystem development. As a controlling factor in peatlands, water and its movement play a significant role (Holden, 2006). Hydraulic conductivity describes water flow through peat and its permeability. Further important predictions about plant growth, occurrence and vegetational structure can be made by the height above the WT, which describes the distance between surface and WT (Håkan and Jeglum, 2013).

Peat humification increases with depth and is closely related to hydraulic conductivity. A higher degree of humification results in increased BD, which leads to a reduction in pore space and pore connectivity and consequently to lower hydraulic conductivity. According to Håkan and Jeglum (2013) the lowest hydraulic conductivity values are found in highly decomposed peat, whereas undecomposed Sphagnum peat exhibits comparatively high values. Seasonal WT fluctuations lead to a phenomenon often referred to as mire breathing, where peat volume changes in response to wetting and drying cycles, thereby also affecting hydraulic conductivity (Håkan and Jeglum, 2013).

The vertical structure of peatlands, as well as the vertical movement of water within the peat body, is commonly described by the acrotelm-catotelm concept, originally developed for bog ecosystems. The acrotelm is located above the mean WT and represents the biologically active layer, where the most intensive biogeochemical and hydrological processes occur. Near the surface, living and dead plant material is subject to relatively rapid decomposition. This layer is characterised by high hydraulic conductivity and a strong exchange with the surrounding environment. Photosynthesis and plant production predominantly take place within the acrotelm (Håkan and Jeglum, 2013). A fluctuating WT and the presence of air-filled pores allows plant growth and supports abundant aerobic microorganisms, resulting in high biological activity (Craft, 2016).

In contrast, the catotelm lies below the lowest WT level and remains permanently water saturated. It is characterised by anoxic conditions, low hydraulic conductivity, and reduced water flow. As a result, decomposition processes are considerably slower in the catotelm, allowing for long-term C storage within the peat body (Håkan and Jeglum, 2013; Figure 2). Due to the absence of oxygen, biological activity and hydraulic conductivity are both low, and aerobic bacteria are largely absent (Craft, 2016).

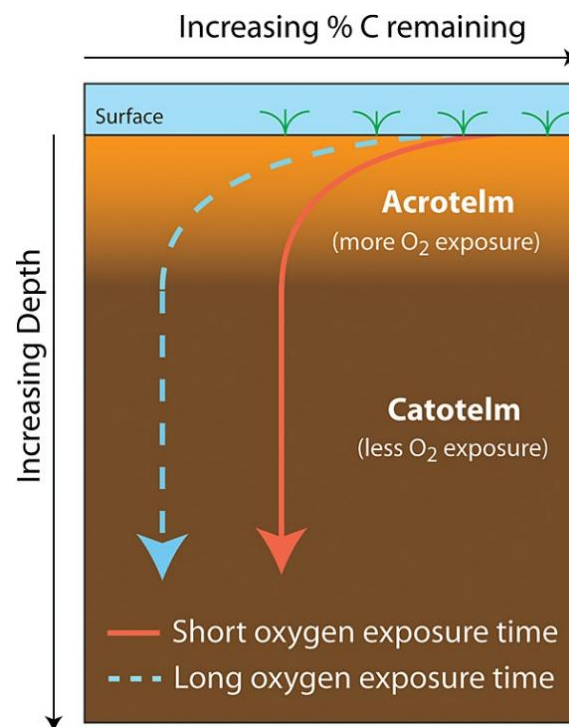


Figure 2: Illustration of the acrotelm-catotelm structure within peatlands. The acrotelm shows a shallow layer in the peat structure. With increasing depth, the acrotelm is transitioning into the catotelm. The peat has more O₂ exposure in the acrotelm than the catotelm. Slow accumulating peat (blue line) stays longer in the acrotelm and shows higher oxygen exposure and higher decomposition. Rapidly accumulating peat is staying shorter in the acrotelm and shows less oxygen exposure and less decomposition (Philben et al., 2014).

Peatland drainage unintentionally causes peat subsidence through shrinkage and oxidation of peat above the WT and compression of peat below this level. Long-term subsidence is attributed to approximately 65% shrinkage above the WT and 35% compression below it. Subsidence results in reduced saturation and increased WT fluctuations. A decreased hydraulic conductivity limits both lateral and vertical water movement within the peat deposit and can also contribute to a rise in the WT (Price et al., 2003).

Water flow within peatland systems enters through various pathways, depending on the type of peatland. Through groundwater inflow, precipitation and snowmelt, water movement occurs within the peatland both laterally and vertically. Lateral water movement is generally increased by slopes, while water movement above the peat surface is typically faster. Below the surface, water movement is reduced by the resistance of the peat body and decreases further with increasing peat depth and distance from the surface. Previous studies have also shown that climate conditions can alter groundwater flow. During droughts, water movement may shift upward, while during flooding and wet periods recharge processes can lead to downward water movement. The direction of water flow is mainly determined by water pressure, which can be resolved through measurements at different depths. From these measurements the hydraulic head can be determined, which is commonly measured using piezometers (Håkan and Jeglum, 2013).

The water balance of peatlands summarises the overall water movements within the system, including inputs, outputs and storage. It represents an important tool for predicting the effects of both anthropogenic interventions and natural changes in the hydrological system. Although the water balance equation was not explicitly applied in this thesis, several of its parameters are addressed. Precipitation includes incoming rain and snow and is measured using specific collection devices. Surface water inflow may originate from springs, channel flow or surface runoff from surrounding higher areas. In addition, groundwater inflow can enter the peatland as subsurface flow in horizontal, vertical or sloping directions, depending partly on the underlying bedrock conditions. Evaporation, as part of the water balance, is defined as the amount of water transferred from the land surface to the atmosphere through the combined processes of evaporation and plant transpiration. It describes the transition of liquid water into water vapour and is considered a key parameter in the water balance of peatlands.

However, measurements of ET are challenging because many influencing factors interact, including climate, vegetation and other site conditions. As a result, the ET cannot be easily measured in its full extent. The height of the WT also influences the ET. Annual ET can be approximately 1.5 times higher than annual precipitation, while a lower WT generally reduces ET (Håkan and Jeglum, 2013).

Peatlands function as natural water regulators, responding to both hydrological extremes such as flooding and drought (Håkan and Jeglum, 2013). WTs close to the surface respond more rapidly to rainfall events and can therefore result in peak flow conditions. In spring, water storage is generally lower than in summer (Holden, 2006). Most water flow occurs near the surface or within the acrotelm as horizontal flow, while the contribution of the catotelm to water flow is comparatively small. Streamflow is typically highest in spring due to snowmelt and lowest during the summer months because of reduced precipitation and higher ET. A deeper WT can temporarily store more precipitation in the upper peat layers before it becomes surface runoff. The interaction of these parameters makes peatlands particularly sensitive to anthropogenic impacts. Drainage reduces the water storage capacity of peatlands and lowers the WT, which in turn increases organic matter loss and leads to changes in vegetation composition (Håkan and Jeglum, 2013). In general, water movement represents a key controlling factor in peatlands and can only be fully assessed based on local data (Holden, 2006).

Peatland Mapping

Given their role as effective C sinks and providers of multiple ecosystem services (ESS), including water purification and habitat preservation, peatland degradation poses significant environmental challenges. Consequently, restoration measures, particularly rewetting, have gained importance as key strategies to reverse degradation, restore ecosystem functions and ESS, and reduce GHG emissions (Andersen et al., 2017). Peatlands therefore represent an important target within the Sustainable Development Goals (SDGs), as they contribute to objectives such as freshwater availability, flood protection, clean air, and sustainable livelihoods (Minasny et al., 2024).

Globally, approximately 88% of countries are committed to peatland protection through the Ramsar Convention on Wetlands and the International Union for Conservation of Nature (IUCN) resolution on peatlands. Nevertheless, many countries still lack sufficient information, coherent strategies, and consistent peatland mapping, while unified policies and definitions are often absent (Minasny et al., 2024). According to Montanarella (in FAO, 2014), the main challenges lie in the absence of generalized standards, limitations of remote sensing across different land uses, land ownership constraints, and varying environmental conditions affecting fieldwork.

Peatland mapping largely depends on data availability and offers significant opportunities to generate new information and integrate existing knowledge on peatland extent and condition. At the global scale, peatlands are commonly mapped either as part of land use and land cover (LULC) classifications or within wetland inventories. While datasets exist at various spatial resolutions and scales, not all peatland characteristics relevant to development and management have been mapped so far. For example, C stocks and peat thickness are often not explicitly represented (Fiantis et al., 2024; Rudiyanto et al., 2018).

Differences in mapping approaches, classification systems, and data availability result in varying peatland management strategies. Consequently, each country applies its own policies and decision-making processes regarding peatland use, conservation, and adaptation to climate change. A major step towards harmonization was the Global Peatland Assessment (UNEP, 2022), which promoted international agreements and a shared vision for peatland protection. However, peatland management and mapping remain largely regional or local responsibilities, and implementation varies considerably among countries, reflecting diverse approaches and priorities (Minasny et al., 2024).

1.1.2. Peatland Rewetting in Austria

Around 90% of all peatlands in Central Europe have been or are currently used for peat extraction, agriculture, and forestry (Joosten, 2010). As a response, national peatland strategies have been developed and implemented in collaboration with stakeholders like nature conservation organisations, science and the economic sector, actors of the federal states and federal ministries and governments. The overall goal is a consistent and integrated management of peatlands across all sectors in Europe (Nordbeck and Høgl., 2024).

In Austria, the *Peatland Strategy 2030+* was developed. This programme addresses peat soils and mires and defines objectives such as the conservation and restoration of intact, damaged, and drained mires and their associated ESS. In addition, it promotes the sustainable use of peat soils in order to minimise GHG emissions, increase water retention capacity, raise public awareness of the importance of peatlands, and strengthen the need for action (BMLRT, 2022) (Figure 3).

Due to the great age and slow development of peat, restoration measures require long periods of time before changes in ecosystem functioning become visible. For successful restoration or measurable improvements in conservation status, long-term perspectives must therefore be considered. One example is the LIFE programme, which was established in 1992 and forms part of the peatland protection framework in Austria. Sustainable peatland restoration must take all key peatland parameters into account, including peat, water, and vegetation (EU, 2020).

Austria, alongside Germany, is among the countries with the most recently developed peatland strategies, published in early 2022. The strategy identifies remaining research gaps and open questions and explicitly refers to the SDGs of the UN Agenda 2030. Overall, it places a strong emphasis on interdisciplinary collaboration, nature conservation and science stakeholder involvement, and the establishment of a peatland working group. Funding for the implementation of the peatland strategy is provided through the EU LIFE programme as well as the Austrian Biodiversity Fund (Nordbeck and Hogl, 2024).

Rewetting is understood as the restoration of a stable WT close to the land surface to counteract the negative environmental impacts caused by peatland drainage. The procedures required to achieve rewetting conditions in degraded peatlands vary depending on site-specific conditions. In general, hydrological interventions aim to reduce water losses from the peatland, increase water storage within the peat body, or enhance water supply to the site. These measures can be implemented through adjustments to the hydrological settings, provided that other peatland parameters can also be modified accordingly (FAO, 2014). Rewetting restores stable, near-surface WT and re-establishes waterlogged conditions that are essential for peat accumulation and C sequestration (Ahmad et al., 2020).

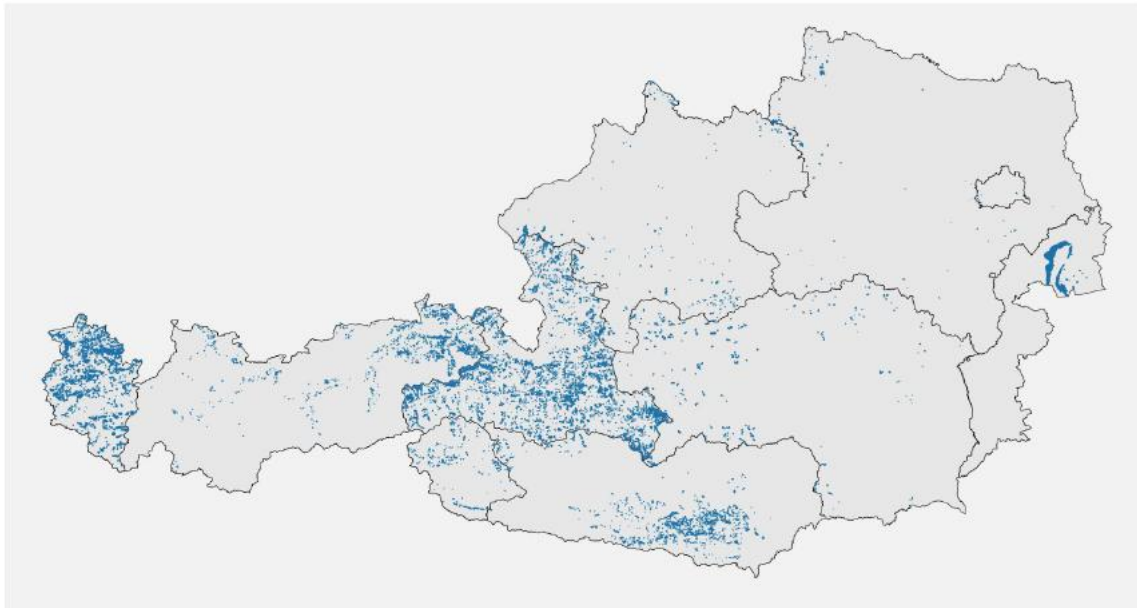


Figure 3: Peatland distribution in Austria (BMLRT, 2022).

Within the MOIST project, focussed on peatland degradation, peat soils represent the central research focus. The aim of the project is to identify suitable rewetting areas in order to improve climate change adaptation measures. Rewetted peatlands function as CO₂ sink and should therefore be placed under protection. In addition, the management of surrounding areas is crucial for long-term peatland maintenance. These objectives are addressed within the Biodiversity Strategy, the Austrian Peatland Strategy 2030+, and EU-level regulations, which aim to safeguard peatland ESS and biodiversity. A standardised procedure for the Alpine region would significantly reduce implementation challenges. Currently, research efforts often focus on single aspects of the rewetting potential, whereas an interdisciplinary approach would reduce uncertainties regarding peatland status, climate mitigation potential, and ecosystem resilience (AGES, 2024).

For long-term sustainable rewetting, the consideration of soil properties, topography, geomorphology and hydrology is essential for project success. In addition to these natural factors, land-use practices, agricultural management, soil compaction caused by machinery, historical land use, and land ownership must also be considered (Qu et al., 2018; Pakalne et al., 2021). According to Qu et al. (2018), all of these factors should be integrated into a GIS model to identify suitable rewetting areas, assuming that both anthropogenic and natural influences affect restoration potential. A coordinated rewetting campaign would further enhance the effectiveness of rewetting potential maps by enabling immediate comparison between sites (Qu et al., 2018).

In Alpine regions, additional challenges arise from complex ownership structures, heterogeneous topography, and variable hydrological conditions. Hydrological monitoring prior to the implementation of rewetting measures would be beneficial, as it would provide baseline water level data and allow for comparison with post-rewetting dynamics. However, challenges in site prioritisation are not limited to hydrological aspects alone but also stem from the lack of integrated and interdisciplinary approaches (Pakalne et al., 2021).

Despite numerous ongoing strategies addressing peatland rewetting and long-term restoration outcomes, a reliable combined approach integrating GIS-based modelling with validated field data is still lacking. Furthermore, rewetting strategies should be developed at the landscape scale to ensure successful and sustainable peatland restoration. Existing studies are predominantly either GIS-based or field-based, while combined approaches are not yet applied systematically. Consequently, the need for consistent validation, monitoring, and management frameworks, especially at national and international levels, is increasing, along with the integration of GIS models and on-site measurements to ensure effective peatland rewetting (BMLRT, 2022).

This thesis focuses on the development of a GIS-based model that integrates natural and anthropogenic factors and enables validation using field data, including BD, k_f , maximum water holding capacity (Wk_{max}), loss of ignition (LOI), electrical conductivity (EC), pH, peat decomposition degree, and peat thickness. The aim is to produce a suitability map for peatland rewetting sites that is validated using data collected during a field campaign. This approach directly addresses the identified research gap and is implemented through a GIS analysis using a suitability modeller based on multi-criteria decision analysis (MCDA).

The developed model can be applied across Austria, adapted for Alpine regions, or transferred to other countries, as the spatial datasets required for the GIS analysis are generally widely available.

1.2. Research Framework, Research Question and Hypotheses

To establish a conceptual framework for this thesis, key findings from the literature on peatland restoration and ERP were synthesized. Previously peat thickness, groundwater level, degree of decomposition, slope and land use were consistently identified as critical parameters influencing the rewetting success.

In recent studies, the role of peatlands is frequently discussed in connection with hydrology, which plays a central role in these ecosystems. Rewetting is considered one of the most effective restoration measures, as it directly targets the hydrological site conditions necessary for peatland functioning. Based on the importance of hydrology in peatlands, the assessment of current site conditions and the potential for ecological rewetting becomes possible, although successful restoration generally requires longer time periods (Stachowicz et al., 2025). According to Wetlands International, rewetting primarily focuses on hydrological adaptation and improvements within peatlands. This measure can be implemented in many peatland systems, as it mainly involves stopping water extraction and implementing water retention measures such as dams or small barriers (Elenius et al., 2025; Greifswald Mire Centre & Wetlands International European Association, 2023). Low WTs represent one of the main causes of peatland degradation and drainage (Convention on Wetlands, 2021).

Furthermore, the main drivers of rewetting success were analysed in the study by Elenius et al. (2025). These include the WT level prior to restoration measures and the restoration of natural watercourses, both of which influence the hydrological functioning of peatlands. Additional factors include proximity to water bodies and the intensity of drainage. Topography also plays an important role, as it influences the selection of suitable locations for rewetting measures (Elenius et al., 2025; Convention on Wetlands, 2021). Peatlands with slopes below 2% generally demonstrate a higher ERP (Tanneberger et al., 2021). In this case, topography is negligible for the GIS model, as the study area is located on a broad valley floor where slopes are minimal. Further influencing factors relate to soil type and land use, whereas climate plays a comparatively smaller role in determining rewetting success (Elenius et al., 2025; Convention on Wetlands, 2021).

Ecological and soil physical properties are closely linked to these hydrological conditions. Bulk density (BD) generally increases with depth, while hydraulic conductivity (kf) decreases due to reduced porosity and changes in peat structure

(Whittington et al., 2007). These variations are especially pronounced in the acrotelm, where hydrological regulation is most active. Long-term drainage can alter peat properties, leading to increased BD, reduced porosity and hydraulic conductivity, and greater WT fluctuations. This ultimately reduces the peatland's ability to buffer hydrological extremes and lowers the potential for a successful rewetting process with a stable WT (Greifswald Mire Centre, 2023). As mentioned above, WT is one of the main factors contributing to peat degradation and is therefore a key hydrological parameter influencing site conditions (Elenius et al., 2025). Another important parameter affecting hydrology and water storage in peatlands—and influenced by WT fluctuations as well as BD—is the k_f value (Håkan and Jeglum, 2013). BD has already been the subject of numerous studies and is widely regarded as a key regulator in peatland hydrology (Karimi, 2024); however, it is not treated as the primary regulator in this context.

According to Barthelmes et al. (2015), peat thickness is strongly correlated with ERP, with peat layers over 30 cm being considered more suitable for rewetting. In addition, less decomposed peat exhibits higher ERP compared to more strongly decomposed areas due to greater porosity and water retention capacity (Schuhmann and Joosten, 2008). A stable WT level close to the surface is targeted, ideally between –10 and 0 cm (Wichtmann et al., 2016).

Land use and protection status further influence restoration suitability. Areas under low-intensity use, particularly nature reserves, tend to show higher ERP due to limited anthropogenic disturbance (Price et al., 2016). From a hydrological perspective, favourable conditions for rewetting include a high mean groundwater level, high water retention capacity, and limited WT fluctuations. These factors directly influence peatlands, whereas climate and land use exert more indirect effects (Joosten et al., 2017).

Despite the increasing use of GIS-based suitability models in peatland restoration planning, field-based validation of these models remains limited. In the MOIST project, a comparable approach was applied: existing datasets were compiled and combined with remote sensing data and a catalogue of relevant parameters. This provided a basis for identifying potential rewetting areas suitable from pedological, hydrological, and nature conservation perspectives. The results were subsequently validated and complemented through field investigations (AGES, 2024). It can therefore be assumed

that spatial datasets and remote sensing information broadly correspond with field data, or at least exhibit similar spatial patterns. However, this assumption is examined in this thesis, as it represents a critical research gap. A GIS-based analysis alone may overlook site-specific ecological and hydrological conditions essential for successful rewetting. This thesis addresses this gap by combining GIS-based suitability modelling with detailed field and laboratory measurements to evaluate the ERP of peatlands.

Based on the identified research gap, this thesis addresses the following research question:

How can a combined GIS-based development of a suitability model and a field-laboratory approach be used to map and evaluate the ecological rewetting potential (ERP) of peatlands in Austria?

Based on the above mentioned literature review, the dominant controlling parameters on peatland functioning are hydrological and soil related, especially regarding WTs and the kf value. Their influence on peatlands is significant and more direct than climate and land use parameters. Simultaneously, the limited validation of GIS-based models shows the need for a consistent verification with field data. Therefore, the following hypotheses (H) were formulated:

H1: Hydrology and soil related criteria have stronger influence on the ERP than climate and land use criteria.

H2: Hydrological parameters, particularly WT dynamics and kf, significantly influence the ERP of peatlands.

H3: Field and laboratory measurements correspond spatially with GIS-identified high-suitability areas.

These hypotheses reflect the key predictors of peatland rewetting success identified in the literature, including peat thickness, degree of decomposition, groundwater conditions, slope, land use, and protection status (Barthelmes et al., 2015; Schuhmann and Joosten, 2008; Tanneberger et al., 2021; Wichtmann et al., 2016; Price et al., 2016). Restoration measures require integrated knowledge of hydrology, ecology, and socio-economic processes to achieve both climate mitigation and the recovery of ecosystem services. Scientifically, without restoring WT levels and peat-forming

vegetation, restoration goals cannot be achieved without continued carbon losses (Joel and Glina, 2026).

Although simultaneous rewetting and post-restoration monitoring were initially planned, time constraints limited the study to model development and pre-restoration validation. Nevertheless, the results provide a geoecological evaluation of peatland conditions and identify areas with high potential for future rewetting measures (White and Fennessy, 2005). The subsequent chapters present the study area, materials and methods, results, and discussion, concluding with a synthesis of findings and final conclusions.

2. Materials and Methods

2.1 Study Area

This thesis is site-specific and focuses on two peatlands, Irdning and Wörschach, located in the Enns Valley in Styria (Figure 4). There are five sites distributed over both peatlands. The peatland areas and sampling sites were selected as part of the AMooRe project, which provides the framework for this work. Two sites are located in the Irdning peatland, site 1 and 2. Sites 3, 4 and 5 are located in the Wörschach peatland. The five sites are presented by the purple stars in the map; field sampling is shown by the black circles (Figure 4). The ERP of these peatlands is assessed. Access permissions had already been secured, and climatic and hydrological datasets were available, which facilitated the analysis.

The Wörschach peatland covers approximately 284 ha at the eastern edge of Wörschach and represents the largest peatland in the Enns Valley. It consists of roughly 256 ha of bog area and 28 ha of fen area. Historically, peat extraction began around 1840 and shifted to mechanised methods in 1922 for a brief period before reverting to manual extraction, which ceased a few years later (Gemeinde Wörschach, n.d.).

Today, the Wörschach peatland is designated as a bird protection area and a Flora-Fauna-Habitat site. It is located at an elevation of approximately 640 m a.s.l. and is part of a Natura 2000 protected area covering around 401 ha. The peatland is characterized by its proximity to the Enns River and by a heterogeneous landscape

composed of bogs and fens, floodplains, and extensively used wet meadows. These diverse land-use types contribute to the site's high ecological value. The Wörschach peatland displays geomorphological features shaped by glacial overprinting, resulting in a broad valley floor with gentle slopes (Land Steiermark, n.d.).

Dominant peatland types within the study area include raised bogs, transitional mires, and fens. The prevailing soil types are alluvial soils, gleysols, and brown soils developed on siliceous bedrock, particularly within the floodplain and southern areas, respectively (BMLUK, 2014).

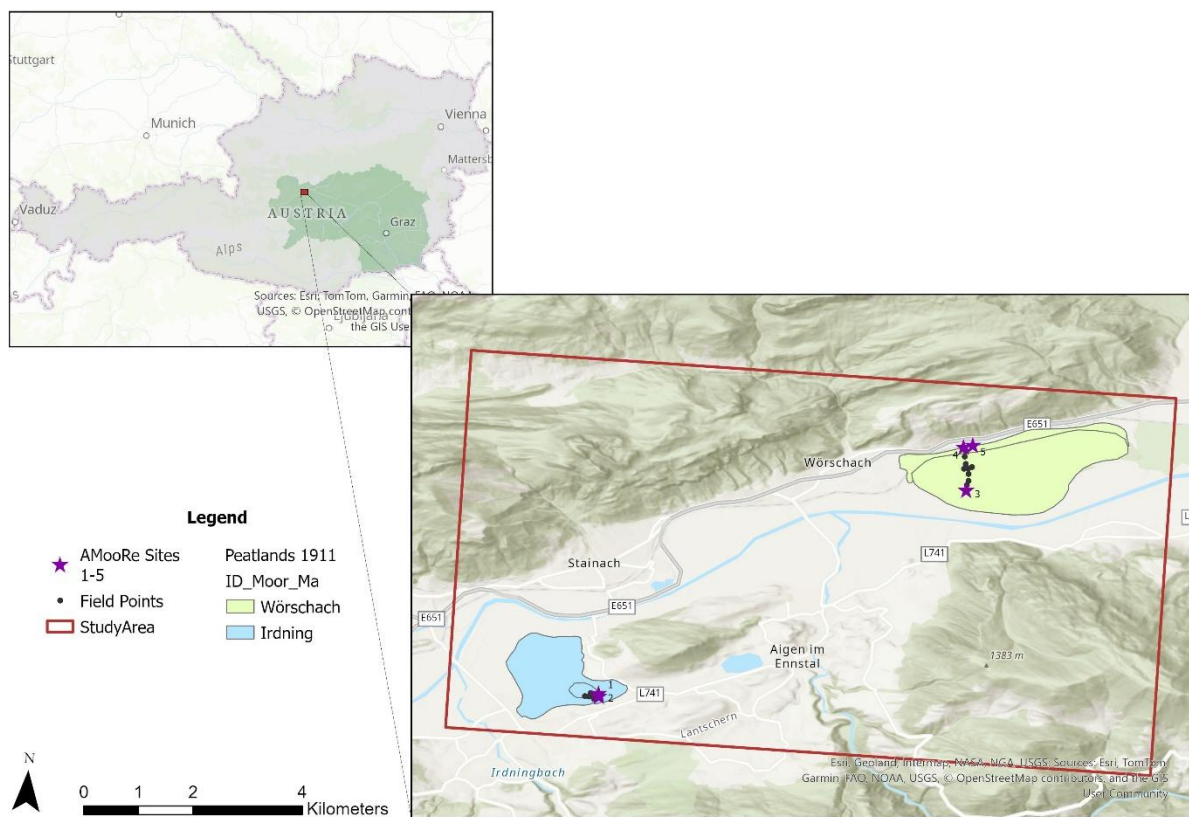


Figure 4: Study area in Styria. The blue and light green areas in the map show the peatlands in the Enns valley. Within the peatlands, black circles map the field sampling, purple stars illustrate the sites selected within the AMooRE project. The red frame limits the study area (own mapping, 2025).

The Irdning peatland covers an area of approximately 267 ha and was first subjected to drainage measures in 1925. This peatland has been strongly influenced by anthropogenic activities, particularly drainage and agricultural use, which have shaped its current conditions (Amt der Steiermärkischen Landesregierung, 2007).

The peatland is also part of the Natura 2000 conservation network, highlighting its ecological significance and the ongoing efforts to protect its habitats in accordance with European environmental directives. Irdning forms part of the Birds Directive site (Land Steiermark, n.d.).

Situated within the wider Enns River valley ecosystem, the Irdning peatland is characterized by soils that are influenced by hydrological dynamics and historical land management practices. Peatland types within the Irdning peatland are predominantly fens, with smaller areas of transitional mires, while the dominant humus form is peat (BMLUK, 2014).

2.2 GIS Suitability Model Workflow

In order to evaluate peatland areas with regard to their suitability for rewetting and the potential long-term effects, several factors must be considered to ensure successful management and restoration outcomes (Karimi, 2024). Accordingly, a four-step analytical workflow was applied to the dataset. This workflow includes (1) the acquisition and preparation of relevant spatial data, (2) clipping all datasets to the extent of the study area and harmonizing polygon and raster data to a common spatial framework (mask), (3) deriving variables such as slope and Euclidean distance to surface water, and (4) transforming the base criteria through reclassification, applying criteria-specific weight and combining them to identify suitable locations and restoration potentials (ESRI n.d.; White and Fennessy, 2005).

Preparing the Base Criteria

The prepared datasets forming the base criteria for the suitability model (Figure 5) including slope (derived from the digital terrain model, DTM), distance to flow streams (calculated using Euclidean distance to streams), land use, soil water content, humus type, pH value, permeability and soil thickness. In addition, field and laboratory data were incorporated, including k_f , BD, W_k , max, pH, EC, LOI, precipitation, evapotranspiration, degree of decomposition and peat thickness. All datasets were composed and prepared for analysis using the suitability modeler in ArcGIS Pro 3.3, a GIS software, later ArcGIS Pro 3.3.5 due to storage constraints.

The selection of these criteria is based on the objective of identifying areas with potential for ecological rewetting within the study area. Their overall selection serves the purpose of addressing this goal (ESRI, n.d.; White and Fennessy, 2005). A projection adjustment was performed by reprojecting all spatial layers to ETRS 1989, the standard reference system for geodata in Europe. Subsequently, all datasets were clipped to the extent of the study area, encompassing both peatlands. Raster layers were generated either by converting polygon datasets or by clipping existing rasters using a common mask (ESRI, n.d.).

The Suitability Modeler in ArcGIS Pro is a tool designed for MCDA. It integrates spatial data layers, primarily raster datasets, by combining defined suitability criteria and their respective weights. This process results in a suitability map customized to a specific objective, in this case the identification of areas with high ERP. The tool enables interactive adjustment of criteria and their relative importance, providing immediate visual feedback through linked maps, charts, and tables. This dynamic approach supports transparent analysis and informed decision-making by illustrating how individual factors influence the overall suitability (ESRI, n.d.).

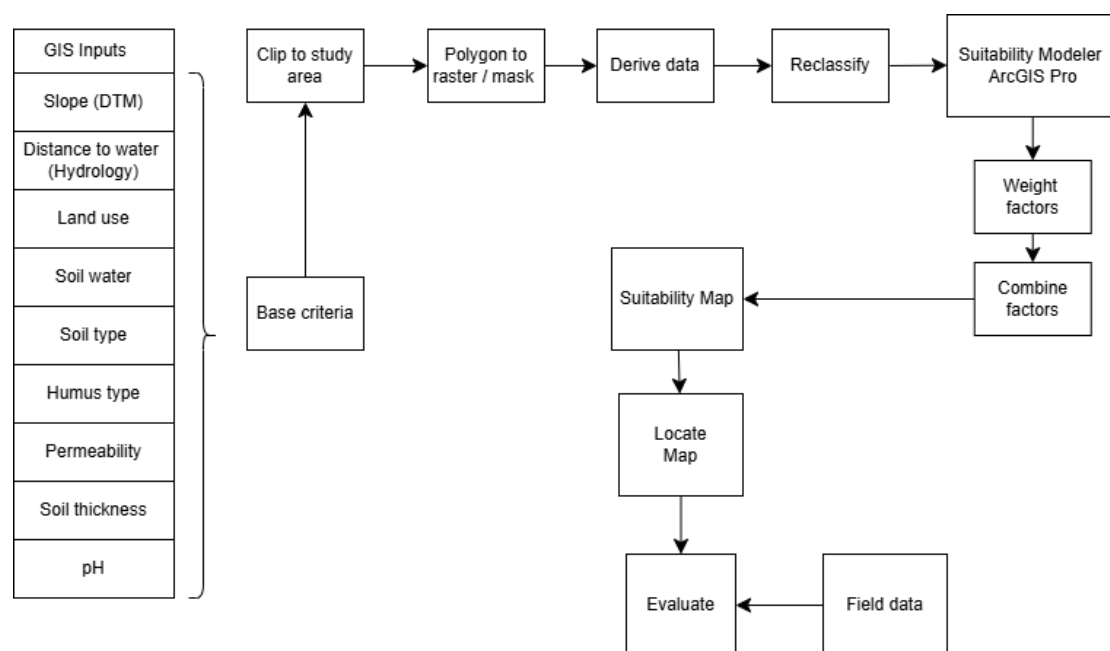


Figure 5: Workflow chart of the GIS model development with the Suitability Modeler in ArcGIS Pro (own figure, 2025).

Reclassifying the Criteria

Following the workflow chart outlined in Figure 5, the second major step in the GIS analysis involves reclassifying of the selected criteria. Each criterion has its own valuation scheme, so they must be reclassified to a common scale to ensure comparability in the suitability model. This process transforms the values of each criterion into a uniform scale ranging from 1 to 5, where higher values correspond to greater suitability.

For example, within the land use layer, wetlands are assigned a value of 5, representing high suitability, while infrastructure and built-up areas receive a value of 1, indicating low suitability. Similarly, for the slope criterion, areas with less than a 2% incline receive the highest suitability values, while steeper slopes are assigned lower values. Once reclassified, these criteria can be combined using the common suitability scale (ESRI, n.d.; Appendix C).

As an example, the digital cadastral map (DKM) 2022 land use layer is reclassified based on the following categories: water courses, standing waters, wetlands, forest land, perennial cropland, annual cropland, grassland, built-up areas (sealed and partly sealed), parks and gardens, roads and railways, industrial and business areas, and mining sites (dumps, landfills, etc.) (Table 1). Further details on the reclassification of other GIS layers can be found in the Appendix C.

Table 1: Reclassification of the land use layer DKM 22 (own table, 2025).

Classes	Land Use
Class 5	Wetlands, standing waters, water courses
Class 4	Forest land, perennial cropland
Class 3	Grassland, annual cropland
Class 2	Parks and gardens; others
	Building land – sealed and partly sealed;
Class 1	roads, railways etc., industrial and business areas;
	mining areas, dumps, landfills

Weighing the Criteria

The third step involves assigning each criterion a weight that reflects its relative importance within the suitability model. The weighting is based on the assumed relevance of each factor for rewetting. After standardizing the criteria, the weighted layers are combined using a weighted sum method to calculate an overall suitability value for each raster cell. The resulting suitability map is then categorized into classes ranging from “very suitable” (5) to “unsuitable” (1), with higher values indicating greater suitability.

All criteria are summed in percentages, and the sum of all nine criteria must equal 100% for the model to function properly. Not all criteria are weighted equally, as some have a greater influence on the suitability for rewetting. This evaluation ensures that the most important criteria are given higher weights (ESRI, n.d.).

The ranking of the criteria (Table 2) is based on the literature and previous studies on rewetting potential as well as own assessment, with an emphasis on soil and hydrological conditions of the peatlands to estimate their ERP. To clarify the classification and ranking process, the criterion with the highest weight, “humus type,” was examined. The categories for this criterion were created and ranked according to the suitability value.

Table 2: Ranked humus types used for the suitability value (own table, 2025).

Category	Suitability Value
Mull	1
Moder mull	2
Mull + moder mull + gleyic mull (heterogeneous)	3
Gleyic humus / anmoor mull	4
Peat	5

Locating the Criteria

Once the criteria are weighed, the suitability map is generated, identifying areas most suitable for rewetting based on the selected factors. This map provides insights into potential intervention zones.

While the model can accommodate specific spatial requirements, such as those needed for flora or fauna (e.g., habitat size or distances between habitats), no such constraints were applied in this study. The map itself already highlights areas where rewetting is most feasible (ESRI, n.d.). To assess the accuracy of the suitability model, field validation was conducted.

2.3 Spatial Analysis

2.3.1. GIS Data

The spatial analysis is the foundation for evaluating the ERP of peatlands in Austria. Using GIS data, several datasets were integrated, including the hydrological network, the eBOD soil map, land use information, and the DTM. The eBOD is a web-GIS application that provides access to specific soil properties, cultivation information, and consultation tools. It contains 18 layers based on soil data (BMLUK, 2014). Werni (2015) found that the eBOD values generally match field measurements, though there are some discrepancies, especially when compared to soil physical data. These differences arise from the estimation of certain parameters.

In addition to the primary parameters used in the GIS model, ET was also visualized using data from the GeoSphere Austria Data Hub (winfore-v2-1d-1km dataset, GeoSphere Austria, 2020). Precipitation data, sourced from the SPARTACUS v2.1 daily dataset (GeoSphere Austria, 2020), was included as a reference.

Further, data on WTs were integrated, measured by the Elli Track system at each AMooRe project site. Elli Track features include data logging, sensor management, status reporting, and data export. The long-term data from this system provides insights into WT fluctuations and precipitation patterns, which are crucial for understanding ecological restoration efforts (Leiderdorp Instruments BV, n.d.).

Additional differentiation was achieved by including more parameters, summarized in Table 3. The data was primarily sourced from official data repositories, portals (data.gv.at), specialized maps (eBOD, eHYD), and relevant literature (Koppensteiner et al., 2023; Tiemeyer et al., 2017).

By integrating a digital elevation model, hydrological network, land use and climate data, and laboratory results, the ERP of the study areas was assessed. The data were standardized and adjusted for resolution. Then the criteria were weighted, with a focus on hydrological and soil properties, to ensure that the model accurately reflects factors that influence water availability and storage.

Table 3: Main criteria including data sources and projection used in the ArcGIS Pro Suitability modeler (own representation, 2025).

Layer	Description
Land use	land use polygons derived from DKM (digital cadastral map) 2022, ETRS89 / UTM 33N, transformed into a 10 x 10m raster for the analysis data from: ÖROK, Federal Environment Agency
Streams	water routes shapefile lines of Styria based on ALS (airborne laser scanning) data 2025 , ETRS89/WGS84 transformed into raster file for analysis, data from: data.gv.at
Elevation	DTM (digital terrain model) raster layer based on ALS with a 10x 10m resolution
Soil type	transformed into ETRS89 projection, data from: data.gv.at shapefile polygons derived from eBOD (digital soil map) 2016, 1x1m resolution, ETRS89
Soil water	transformed into a raster file for analysis, data from: eBOD shapefile polygons derived from eBOD (digital soil map) 2016, 1x1m resolution, ETRS89
Permeability	transformed into a raster file for analysis, data from: eBOD shapefile polygons derived from eBOD (digital soil map) 2016, 1x1m resolution, ETRS89
Soil thickness	transformed into a raster file for analysis, data from: eBOD shapefile polygons derived from eBOD (digital soil map) 2016, 1x1m resolution, ETRS89
Type of humus	transformed into a raster file for analysis, data from: eBOD shapefile polygons derived from eBOD (digital soil map) 2016, 1x1m resolution, ETRS89,
pH	transformed into a raster file for analysis, data from: eBOD shapefile polygons derived from eBOD (digital soil map) 2016, 1x1 m resolution, ETRS89

2.3.2. Field Sampling and Data Collection

Fieldwork was conducted twice in 2025, once in May and once in August. Samples were collected during both campaigns and used for this thesis. Data for kf, BD, and Wk.max from sites 2–5 were obtained from a Bachelor's thesis (Nussbaumer, 2025), stemming from the fieldwork in May. All soil physical parameters were measured for sites 1–5, while kf, BD, and Wk.max were measured specifically for site 1 (Figure B2).

The fieldwork was conducted in the two peatlands. All five sites are part of the LIFE AMooRe project, and their locations and coordinates are known and documented. During the field campaign, air temperatures were around 25 °C, with sunny conditions and occasional cloud cover. There had been no recent precipitation prior to sampling, and consequently the peatlands were relatively dry.

Sampling followed the scheme shown in Figure 6 and was conducted in accordance with ÖNORM L 1051 (2021). The depth specifications in Figure 6 were adopted and implemented for all sampling. Soil samples were collected using a punch-in tool for cylindrical soil sampling to ensure undisturbed samples. The sampling cylinders had an inner diameter of 56 mm. For peat sampling, a cube was extracted using a spade for the first depth interval (10–20 cm). The second cube was taken using the same procedure for the 20–30 cm depth interval. In total, ten cylindrical samples were collected, with five samples per depth interval. Vegetation was removed prior to sampling. At the first depth, three cylindrical samples were taken as replicates, while at the second depth two cylindrical samples were collected as replicates. This resulted in four to six samples per depth and ten samples per site, which across five sites yielded a total of 50 samples. The samples were sealed with lids on both sides, placed in plastic soil sample bags, and tightly closed to preserve in situ conditions. Careful sampling was required to prevent compaction and structural alteration of the peat. After sampling, all sampling holes were refilled.

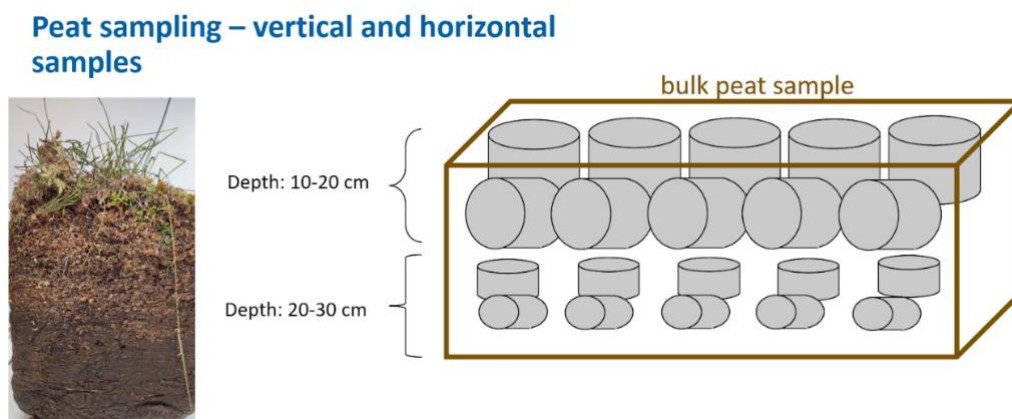


Figure 6: Overview of a peat sampling technique – vertical and horizontal samples (Müller, 2024).

The second part of the field campaign focused on assessing the degree of peat decomposition and peat thickness to complement the GIS data, hydrological information, and laboratory measurements, and to capture spatial variability within the peatlands. As peat thickness had not been measured precisely across the entire

peatland areas, and given its importance for the evaluation, transects were established prior to sampling. These transects were designed to capture spatial variability in peat thickness and degree of decomposition across the peatland extent.

In the Wörschach peatland, a transect was established across the southeastern part of the site. A total of ten sampling points were measured at intervals of approximately 150 m, reflecting the larger size of the peatland. The transect primarily followed a north–south direction, with an additional three points sampled along the east–west axis. In the Irdning peatland, six sampling points were recorded at distances of 50 m, with four points along the east–west axis and two points along the north–south axis.

The same procedure was applied at all sampling points. Equipment used included a Pürkhauer, a hand spade, a measuring tape, and a hammer. Peat thickness was determined using the Pürkhauer, with measurements not exceeding a depth of one meter (Figure B5). The degree of peat decomposition (Figure B6) was assessed using the von Post scale (Figure B1), classifying peat samples on a scale from H1 to H10 (Table A7). Throughout the field campaign, observations were documented in a field notebook, and GPS coordinates were recorded using a mobile device. Measurements were conducted once at each point and repeated only if the initial attempt was unsuccessful. Peat thickness measurements were relatively consistent due to standardized hammering, while a printed reference sheet was used for the von Post classification to ensure consistency.

After returning from the field, the sealed and airtight soil samples were stored in a laboratory refrigerator at 8 °C to preserve field conditions and prevent alteration prior to laboratory analysis.

2.3.3. Laboratory Analysis

To minimize disturbance to the peatlands, cylindrical samples collected during the first field campaign were used for all laboratory analyses, and all sampling locations were restored and closed after sampling. All measurements were conducted using calibrated devices, and analyses were repeated where necessary to ensure data quality.

Physical parameters including BD, Wk.max, kf, pH, EC and LOI were measured following established standard protocols. kf was determined using a Royal Eijkelkamp permeability device following ÖNORM L 1065 (2006). BD (ÖNORM EN ISO 11272, 2017) and Wk.max (ÖNORM EN 1062-3, 2008) were determined by oven drying at 60

°C, following standardized procedures based on the ÖNORM protocols (BFW, n.d.). Drying at temperatures of 60 °C and above yields more reliable results, particularly for weakly decomposed peat soils (Dettmann et al., 2021). Soil pH (ÖNORM L 1083, 2006) and EC (ÖNORM L 1099, 2015) were measured using calibrated devices, while LOI was determined following ÖNORM L 1080 (2021). Precision balances with a resolution of 0.001 g were used for all gravimetric measurements, and Milli-Q purified water was used for sample saturation and preparation to avoid contamination.

Fresh field samples were weighed and subsequently saturated with water for the determination of BD and $W_{k,max}$. Fully saturated samples were measured using the constant head method in the Royal Eijkelkamp device to calculate k_f (Figure 7). In total, all 50 collected samples were analysed for all parameters.



Figure 7: Royal Eijkelkamp device for permeability measurements (own picture, 2025)

After completion of these measurements, samples were dried at 60 °C for at least 72 h. The dried samples were then sieved to obtain fine material required for pH, EC, and LOI analyses. Measurements of pH and EC were conducted prior to LOI determination, which was performed by combusting samples at 450 °C for 3 h in a muffle furnace.

BD was calculated using the dry mass of the sample m_{dry} and the volume V_{cyl} of the sampling cylinder (Blume et al., 2009).

$$BD = \frac{m_{dry}}{V_{cyl}}$$

Equation 1: Bulk density equation (Blume et al., 2009)

Based on Geoecology laboratory briefings (2023) Wk.max was calculated using the dry mass m_{dry} and the moist mass m_{moi} of the cylindric soil sample after 24 h of saturation and a drainage period of 30 minutes.

$$Wk. \max [\text{Vol. \%}] = \frac{(m_{moi} - m_{dry})}{m_{dry}}$$

Equation 2: Maximum water holding capacity (Geoecology, University of Vienna, 2023)

kf was calculated from permeability measurements using a modified form of Darcy's equation, incorporating volume flow (q), cross-sectional area (A), and the hydraulic gradient ($i = h/l$) (Hölting and Coldewey, 2013).

$$kf = \frac{q}{A} \times \frac{1}{i}$$

Equation 3: Darcy equation (Hölting and Coldewey, 2013)

q = volume flow [ml/s]

A = cross section area [cm²]

kf = hydraulic conductivity

i = hydraulic gradient

Also, in the Geoecology briefing (2023) LOI was calculated based on mass differences before and after combustion at 450 °C.

$$W_{LOI} = \frac{m_{tot} - m_{ig}}{m_{tot} - m_{cru}} \times 100$$

Equation 4: Loss of ignition equation (Geoecology, University of Vienna, 2023)

$W_{LOI} [\%]$ = loss of ignition of the dry mass of a sample $m_{ig} [g]$ = mass of crucible with ignited sample

$m_{tot} [g]$ = mass of crucible with dried sample $m_{cru} [g]$ = mass of empty crucible

2.3.4. Data Processing and Analysis

Map Visualisation

All data shown in Table 3 were transformed into raster files and reclassified. For improved visual accessibility, a colour vision–deficient colour scheme was applied. Restricted locations were defined within the model settings, excluding river areas and built-up land. The datasets were then loaded into the ArcGIS Pro Suitability Modeler, renamed, and recoloured. Suitability weights were assigned according to the percentages listed in Table 8 (Chapter 4.3). The model was not explored using queries.

The transformation column in the Suitability Modeler was used to assign suitability values when reclassification had not been conducted beforehand. The most frequently applied transformation was *unique categories*, which simplified the assignment of suitability values on a scale from 1 to 5. For criteria with value ranges, a *range of classes* transformation was applied to create homogeneous suitability classes, while continuous functions were used for continuous variables. Because the Suitability Modeler requires predefined classes, reclassification was generally performed prior to importing layers. The transformation column only allows the assignment of suitability values, not the definition of class boundaries. Therefore, all class structures had to be defined in advance, after which suitability values could be assigned or adjusted.

After transforming all layers, weighting was applied to emphasize the relative influence of each criterion. In total, nine layers were included in the model, with the sum of all weights equalling 100%. Weighting schemes were evaluated using the evaluation panel.

Field data integration was conducted using GPS-georeferenced sampling points from the field campaign, linked to laboratory results and in situ measurements. The analysis integrates GIS and field data using four thematic criteria: hydrology, soil and vegetation, climate, and LULC.

Data Processing and Statistical Evaluation

Following data acquisition and model development, statistical evaluation and validation were conducted. As the thesis investigates how a combined GIS- and field and laboratory-based approach can be used to assess the ERP, consistency between spatial model outputs and empirical data was evaluated. Laboratory results were

validated prior to integration. Validation included descriptive statistics and correlation analyses to address the stated hypotheses.

Laboratory data were assessed for missing values, plausibility, and consistency. Analyses included boxplots and outlier detection, correlation matrices and heatmaps, principal component analysis (PCA), and cluster analysis for both sampled depths. Validation rules ensured comparability across variables, independent of sampling location, depth, or time. This approach enhances reproducibility and transparency and reflects careful handling of soil samples and derived data.

Normality was evaluated using the Shapiro–Wilk test. When normal distribution was confirmed, Welch’s two-sample *t*-test was applied to compare depths. For non-normally distributed variables, the Mann–Whitney *U*-test was used. As one representative value per depth (mean of up to three subsamples) was used, samples were treated as independent. Due to the limited sample size, statistical interpretations were made cautiously. Hypotheses H1 to H3 were tested in RStudio, primarily using Pearson correlation analysis.

Software and Literature Research

Data calculation and aggregation were performed in Microsoft Excel, while statistical analysis, validation, and visualization were conducted in RStudio. Microsoft Copilot provided coding support. GIS analyses and mapping were conducted using ArcGIS Pro. The literature review was conducted using platforms including u:search, Google Scholar, Connected Papers, Semantic Scholar, and CatalogPlus. Keywords included peatlands, rewetting, rewetting potential, GIS, suitability analysis, site selection, ecological rewetting potential, MCDA, wetland restoration, hydrological processes, ecosystem services, drained peatlands, and climate change mitigation. Boolean operators (AND/OR) were applied. Most sources published after 2018 were considered, with selected older studies included where relevant. This thesis was written independently, with a digital writing aid used solely for language revision.

2.3.5. Limitations

The limitations of this study arise from both data availability and methodological constraints. During the thesis process, access to high-quality and freely available data was challenging, despite the use of several online platforms such as data.gv.at, the Geosphere Data Hub, BEV, eHYD, eBOD, and ZAMG. Data obtained from these sources vary in spatial and temporal resolution, which affects their comparability. Precipitation and ET were calculated using R software, while WT levels were measured in the field using Elli Track loggers installed at all sites. In particular, ET values derived from Geosphere Hub data may introduce uncertainties. In addition, soil data from eBOD are not always fully congruent with site-specific field conditions. Furthermore, soil properties from eBOD are based on generalized data and only represent dominant conditions. The local heterogeneity of eBOD may smooth out small scale peat features in the peatlands.

Regarding fieldwork, most soil samples were already available in the laboratory, while peat thickness and degree of decomposition were measured during a single field day using the von Post classification method. A coring device exceeding one meter in length would have improved peat thickness measurements; instead, a Pürkhauer was used. All data acquisition was conducted in one day by a single person, which limited the number of instruments that could be transported and used in the field. Available equipment was therefore restricted to a Pürkhauer, hammer, hand spade, measuring tape, and the von Post reference table (Figure B1). The von Post method itself introduces a degree of subjectivity in assessing peat decomposition.

Further limitations arose from the sampling equipment. The cylinders used in the field differed from those typically used in laboratory analyses and were more susceptible to damage during hammering. This occasionally resulted in imperfect sealing during permeability measurements, leading to data loss. The selection of transects and sampling points may also have influenced validation results, as they represent only specific areas of the peatlands.

Overall, field data like degree of decomposition and peat thickness were collected during the summer campaign, which does not account for seasonal variations in WT levels or peat decomposition. Measurement uncertainties related to field instruments and laboratory devices cannot be fully excluded. During the second field campaign,

WT levels were relatively low, which may have influenced the classification of peat decomposition.

The GIS-based suitability model serves an illustrative purpose and is based on simplified assumptions. Not all parameters influencing peatland rewetting under real conditions were included. Criterion weighting was derived from literature and expert judgement, introducing an element of subjectivity. Field validation would have been more robust with higher sampling density and additional field campaigns. Moreover, the chosen transects reflect localized conditions but were used to draw broader conclusions about peatland status. Additional soil chemical analyses could have further refined the study results.

Overall, while the combined GIS and field and laboratory-based approach provides valuable insights, a comprehensive assessment of the ERP would require additional field data, repeated measurements over different seasons, and the integration of legal and socio-economic constraints.

3. Results

This chapter presents the results of the validation using field and laboratory data and the GIS-based suitability mapping for peatlands in Styria.

3.1 Results and Validation of Laboratory and Field Measurements

The values of the soil parameters, measured in the laboratory, illustrated as boxplots show depth-related changes in their value distribution (Figure 8). Measurements involving organic C (C_{org}) were treated with caution due to uncertainties in the calculations and are therefore not further interpreted.

The first boxplot, representing EC at a depth of 10-20 cm, shows values mainly ranging between approximately 127 and 170 $\mu\text{S}/\text{cm}$, with one outlier at 73 $\mu\text{S}/\text{cm}$. The median is around 160 $\mu\text{S}/\text{cm}$. In contrast, the second depth interval (20–30 cm) exhibits generally lower EC values. The highest values at this depth correspond roughly to the lowest values of the upper depth layer. Most values are distributed between 100 and 136 $\mu\text{S}/\text{cm}$, with a clearly lower median of about 100 $\mu\text{S}/\text{cm}$. No outliers are present, but the whiskers span a broader range, extending from approximately 63 to 174 $\mu\text{S}/\text{cm}$.

The second boxplot displays the distribution of LOI. In contrast to EC, the pattern is reversed, with higher values occurring at the deeper sampling depth. At 10–20 cm, LOI values are generally lower, with a median of about 50%. The interquartile range spans from roughly 40 to 58%, while the whiskers extend from 16 to 61%. At 20–30 cm depth, the median increases to approximately 62%, and the interquartile range broadens from about 23 to 75%. The whiskers cover values between 12 and 79%.

The final boxplot pair represents pH values. Here, a pattern similar to EC is observed, with higher values in the upper depth layer compared to the deeper layer. At 10–20 cm, the median pH is around 7,2, with an interquartile range from approximately 5,6 to 7,3 and whiskers extending from 5,3 to 7,5. In the 20–30 cm depth layer, pH values range from about 5,3 to 6,65, with a lower median of approximately 6,57 and whiskers reaching from 5,1 to 6,9.

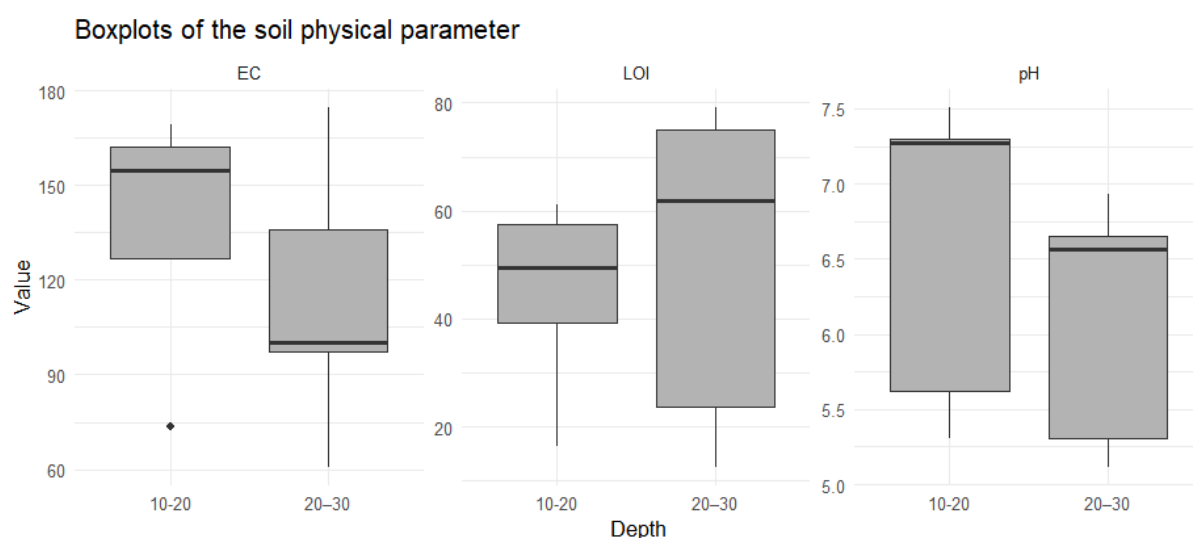


Figure 8: Boxplots of the measured soil physical parameters EC, LOI and pH. The values show the laboratory measurements of this thesis. Units of the parameters are EC [$\mu\text{S}/\text{cm}$], LOI [%]. The boxplots were created from mean results of all 5 sites of the AMooRe project, arranged regarding depth [cm]. They illustrate the variability of soil parameter values across sampling depths. Shown by the median, the interquartile range, whiskers that represent the range as well as outliers (own representation, 2025).

The table below (Table 4) presents all parameters measured and calculated in the laboratory. The boxplot descriptions shown in Figure 8 are based on the values listed in this table. The first part of the table includes the sampling locations and coordinates, followed by soil physical properties and, lastly, hydrological parameters of the peatlands derived from multiple measurements.

Overall, higher values of pH, EC, kf and BD are noticeable at both sites within the Irdning peatland. In contrast, LOI shows higher values at the second site, particularly at the deeper sampling depth. For Wk.max, both Irdning sites exhibit higher values in the second depth interval.

A similar depth-related pattern is observed in the Wörschach peatland, which includes three sampling sites. At site three, LOI and Wk.max again display higher values in the second depth interval. At site four, higher BD values occur at the deeper depth, while all other parameters show higher values in the upper depth interval. At site five, EC, LOI and Wk.max are higher in the second depth interval.

Across all sites and depth comparisons, a consistent pattern emerges, with LOI and Wk.max generally showing higher values at 20-30 cm depth, whereas most other parameters tend to be higher in the 10-20 cm layer. Differences from this pattern are observed at site four for BD and at site five for EC.

Table 4: All measured laboratory values, arranged by site, coordinates and depth. The samples are divided according to the two peatlands. The units of the individual columns are pH, EC [$\mu\text{S}/\text{cm}$], LOI [%], kf [cm/s], BD [g/cm^3] and Wk.max [%]. The table shows physical and hydraulic soil conditions of the peat samples (own table, 2025).

Peatland	Site	Depth	pH	EC	LOI	kF	BD	Wk. Max
Irdning	1	10-20	5,30383	73,64281	16,4323	0,024	0,805	75,125
		20-30	5,302973	60,6466	12,49796	0,003	0,761	79,359
	2	10-20	5,62	126,84	61,21242	0,114333	0,436	104,8906
		20-30	5,11404	100,3855	79,17669	0,003083	0,342	162,8327
Wörschach	3	10-20	7,27	162	57,60888	0,01425	0,458	103,0043
		20-30	6,568438	97,25495	74,99737	0,009	0,451	103,7374
	4	10-20	7,51	169,1	49,36989	0,010167	0,358	165,097
		20-30	6,934117	135,9845	23,70824	0,002083	0,566	103,1513
	5	10-20	7,3	154,86	39,18369	0,015667	0,493	112,7906
		20-30	6,652034	174,706	61,77638	0,001833	0,338	177,8623

To ensure the usability and reliability of the values presented in Table 4, all measurements were validated prior to further analysis. The measured parameters exhibit varying levels of significance between sites and sampling depths.

Given the small sample size ($n = 50$) and taking only the mean value of each site and depth, a resulting sample size of $n=10$ per parameter is given. Several statistical tests were applied to assess data validity and comparability between sampling depths. Normality was evaluated using the Shapiro-Wilk test, acknowledging its strictness for small datasets. Depending on the distribution and variance structure, either Welch's

two-sample t-test (robust to unequal variances) or the non-parametric Mann–Whitney U-test was applied to compare differences between depths.

The Welch t-test indicated statistically significant differences between depths for pH, EC and LOI. BD and Wk.max showed minimally non-significant differences ($p = 0,0651$ and $p = 0,0658$, respectively). kf did not meet normality assumptions and was therefore analysed using the Mann-Whitney U-test, revealing a highly significant difference between depths ($p = 1,54 \times 10^{-5}$; Table 5).

Overall, the validation results indicate distinct depth-related differences for several soil physical parameters. In contrast, most hydrological parameters show limited variability and low significance levels. kf represents an exception, as it exhibited strong variability and required non-parametric testing due to non-normal distribution.

Table 5: The laboratory parameters were validated and evaluated for the p-value in order to verify the measurements. All 6 measured parameters were evaluated with the t-test except for the kf value. The Mann-Whitney U-test was considered due to better assessability (own table, 2026).

Parameters	Test	p-value
pH	t-test	0,1164
EC	t-test	0,4255
LOI	t-test	0,4385
BD	t-test	0,00651
kf	Mann-Whitney-U test	1,54E-05
Wk.max	t-test	0,0658

In addition to the laboratory measurements, further parameters were used to support the assessment of hydrological conditions at the study sites. WT data from in-field installed Elli Track sensors (Chapter 2.3.1) were incorporated for this purpose. The WT data were downloaded for the same time period as the GeoSphere datasets for evapotranspiration and precipitation to ensure temporal consistency and comparability. Separate WT hydrographs were generated for both AMooRe study sites to account for site-specific hydrological differences.

At the Irdning site, WT levels exhibited similar temporal fluctuation patterns due to the close proximity of the measurement locations. However, Irdning 1 consistently showed lower WT levels than Irdning 2, with fluctuations ranging from -91,7 cm to -40 cm, whereas Irdning 2 ranged between -59,7 cm and -22 cm. A pronounced water minimum was observed at Irdning 1 in early June. The highest WT level, above the surface, occurred mid-December, reaching values of -40 cm and -22 cm for Irdning 1 and Irdning 2, respectively. The mean WT levels were -72,5 cm for Irdning 1 and -45,7 cm for Irdning 2 (Figure 9; Table A2).

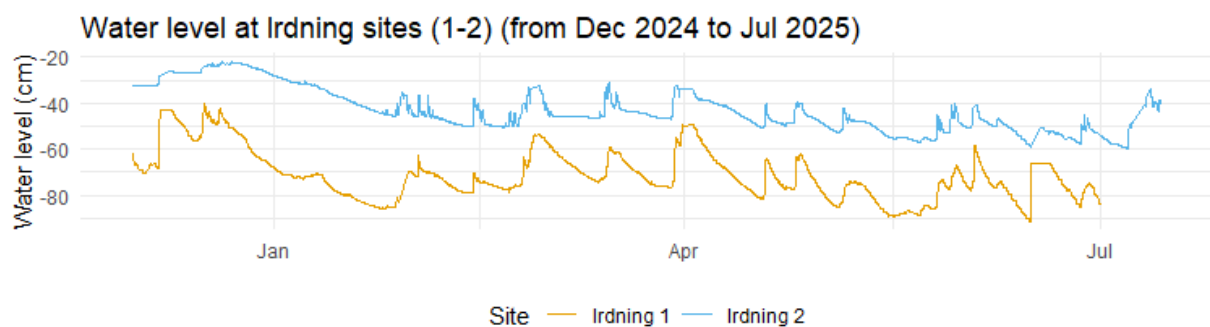


Figure 9: WT [cm] at the Irdning peatland from December 2024 to July 2025. The descriptions of Irdning 1 and 2 are equivalent to AMooRe 1-2. Site Irdning 1 is the 1st AMooRe station. The unit of the water level, used here as WT, is cm. The x-axis is the period of time during the measurements (own representation, 2025).

At the Wörschach site, the WT at all three measurement locations shows generally similar temporal patterns, with some site-specific differences. Wörschach 1 exhibits the lowest WT levels, ranging from -43,7 cm to -9,46 cm. Wörschach 3 has a very high WT, with values ranging from approximately -22,0 cm to +0,49 cm, while Wörschach 2 shows intermediate values between -34,4 cm and -7,46 cm. The mean values of the WT levels in Wörschach are ranging from -28, 3 cm at Wörschach 1, -20,0 cm at Wörschach 2 to -9,57 in Wörschach 3.

Compared to the Irdning site, WT levels in Wörschach are generally higher, the y-axis scale is also shorter than for Figure 9. They are closer to the surface and show lower fluctuation amplitudes. The highest WT fluctuations occurred in April, while the lowest WT levels were recorded in January and June (Figure 10; Table A3).

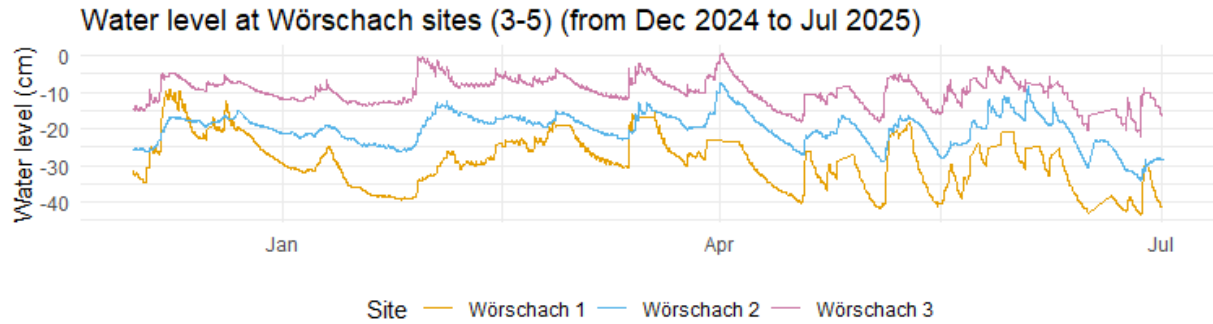


Figure 10: WT [cm] at the Wörschach peatland from December 2024 to July 2025. The descriptions Wörschach 1, 2 and 3 are equivalent to AMooRe 3, 4 and 5. Site Wörschach 1 is the 3rd AMooRe station, Wörschach 3 is the 5th AMooRe station. The unit of the water level, used here as WT, is cm. The x-axis is the period of time during the measurements (own representation, 2025).

The hydrological background of the two peatlands is presented in the following figure. Both precipitation and ET were considered to represent the water budget of the peatlands. Data from both climate stations were evaluated for the period since their installation, covering approximately eight months. Due to the close proximity and similar climatic conditions of the Irdning and Wörschach sites, only the results for Wörschach are shown, covering the period from December 2024 to July 2025.

Precipitation values [kg/m^2] were highest in December 2024, with approximately 22 kg/m^2 , and decreased until February 2025, reaching around 15 kg/m^2 . Towards the summer months, precipitation first declined further and then showed fluctuating but increasing values, with the highest measured precipitation occurring in mid-June at approximately 41 kg/m^2 . ET increased steadily from December 2024 to July 2025, with peak values of around 6 kg/m^2 in mid-June. The mean ET at Wörschach was approximately $2,27 \text{ kg/m}^2$, which is very similar to the mean value at Irdning ($2,25 \text{ kg/m}^2$).

Mean precipitation values were also comparable between the two sites, with $2,02 \text{ kg/m}^2$ at Wörschach and $1,89 \text{ kg/m}^2$ at Irdning. Overall, Wörschach shows slightly higher precipitation and evapotranspiration values than Irdning. Apart from these minor differences, no distinct trends or patterns are evident (Figure 11).

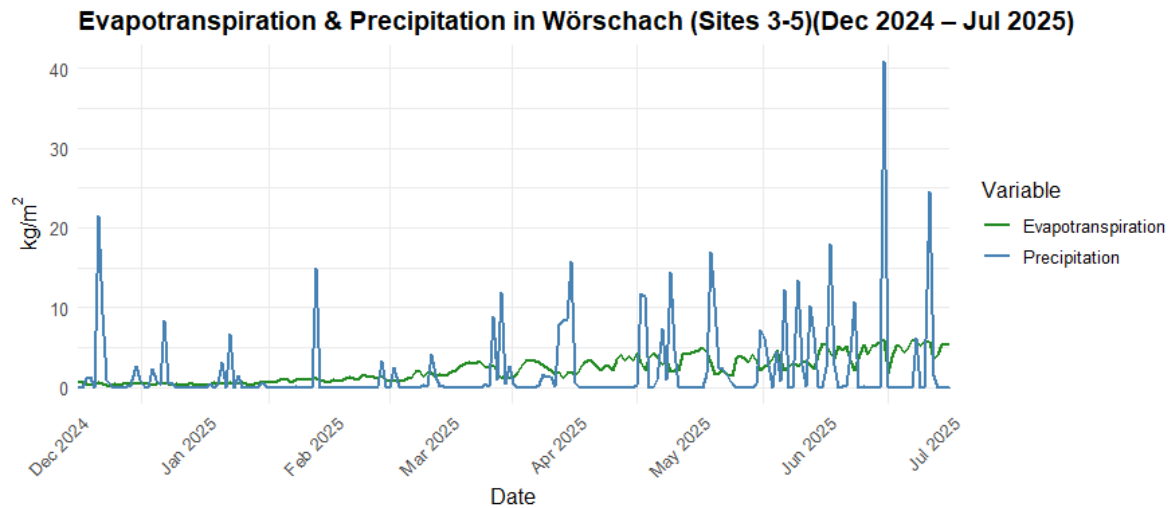


Figure 11: Precipitation and ET data from GeoSphere data hub for the months December 2024 to July 2025, covering the AMooRe Locations (3-5) in the Wörschach peatland. Due to the similarity, this illustration is used to represent both locations (peatland). The unit of both, ET and precipitation, is kg/m^2 . The x-axis shows the period of time considered (own illustration, 2025).

The hydrological and soil physical influences on the peatlands were recorded and linked to field measurements focusing on the actual peat conditions. The transects shown in Table 6 were created in advance and transferred to the field using the ArcGIS Field Maps application. At each sampling location, peat thickness and the degree of decomposition were determined. The degree of decomposition was recorded at all locations except for the fifth location in the second transect at Irdning, where mineral soil was encountered and no peat thickness could be measured. At all other locations, peat thickness was successfully measured and at least one peat horizon was classified according to the von Post degree of decomposition scale.

In Wörschach, five locations showed two or more peat horizons with different degrees of decomposition, while the remaining five locations within the transect showed only one measurable horizon. The mean degree of decomposition was H3, with a mean peat thickness of 0,7 m. The highest recorded degree of decomposition was H6, and peat thickness ranged from 0,3 to 1,0 m.

In Irdning, all locations within the transect exhibited at least two peat horizons with measured degrees of decomposition. The mean peat thickness was 0,8 m; the mean degree of decomposition was H4. The highest recorded degree of decomposition was H6, with peat thickness ranging from 0,7 to 1,0 m.

Table 6: Measurements and observations from field work, including peat depth, degree of decomposition and transect. The table shows the division according to the peatland, the transect, coordinates, location within the transect, degree of decomposition (methodology of von Post) in values from H1 to H10 and the peat thickness [cm] and [m] (own table, 2025).

Peatlands	Transects	Locations	Degree of Decomposition	Peat Thickness
Wörschach	1	1	H4	>1m
		2	30-20cm: H3; 20-0cm: H2	>1m
		3	H3	30cm
		4	H1	>1m
		5	30-10cm: mineral soil; 10-5cm: H2;	50cm
		9	80-60cm: H3; 60-30cm: H5; 30-0cm: H6	>1m
		10	H6	>1m
	2	6	70-50cm: H2; 50-30 cm: H1; 30-0 cm: H1	70cm
Irdning	1	7	H1	>1m
		8	30-15cm: mineral soil; 15-0cm: H6	30cm
		1	70-50cm: H3; 50-20cm: H3; 20-0cm: H3	>1m
		2	70-20cm: H3; 20-0cm: H5	>1m
	2	3	80-30cm: H3; 30-0cm: H4	80cm
		4	70-50cm: H3; 50-20cm: H4; 20-0cm: H5	70cm
		5	mineral soil	-
		6	60-30cm: H6; 30-0cm: H4	70cm

Correlations within the individual depth intervals are shown in Figure 12. For the first depth interval (10-20 cm), the strongest positive correlation is observed between EC and pH ($r = 0,92$). High positive correlations are also evident between Wk.max and EC ($r = 0,76$), Wk.max and pH ($r = 0,71$), and between C_{org} and EC ($r = 0,71$).

Strong negative correlations occur mainly with BD. The highest negative correlation is observed between BD and EC ($r = -0,91$). Further negative correlations are found between BD and LOI ($r = -0,88$), BD and C_{org} ($r = -0,88$), and between BD and Wk.max ($r = -0,79$). BD also shows a negative correlation with pH ($r = -0,68$). The weakest negative correlation in this depth interval is observed between BD and kf ($r = -0,13$). All remaining parameter combinations in the first depth category show no significant correlations.

For the second depth interval (20-30 cm), the strongest positive correlation is again observed between EC and pH ($r = 0,69$). High positive correlations are also present between Wk.max and EC ($r = 0,68$), Wk.max and LOI ($r = 0,67$), and Wk.max and C_{org} ($r = 0,67$). The strongest negative correlations in this depth interval are observed between BD and LOI ($r = -0,89$), and between BD and C_{org} ($r = -0,89$). A moderate

negative correlation is also evident between BD and EC ($r = -0,63$). No correlation is observed between Wk.max and pH, while only very weak negative correlations are present between pH and LOI ($r = -0,03$) and between kf and BD ($r = -0,07$). Correlations involving C_{org} were treated with caution due to uncertainties in the calculations and are therefore not further interpreted (Figure 12).

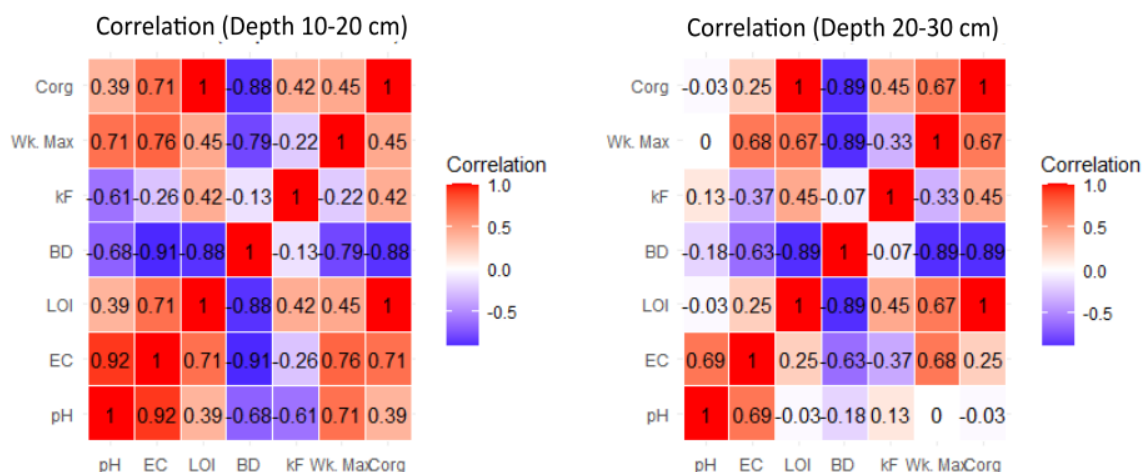


Figure 12: Correlation heat map of the laboratory parameters, blue values show a negative correlation up to -1.00. Red shows a positive correlation up to +1.00. The brighter colours show higher correlation, both negative and positive. White and very light colours show only low to no correlation (own representation, 2025).

To further examine parameter behaviour across depths, the distributions of the individual variables by depth interval are described below in relation to Figure 12. Changes are presented parameter by parameter, highlighting notable patterns and anomalies in the data. Mean values were calculated for each depth and sampling location to ensure independence of samples, with one mean value per depth and peat core used for the analysis.

The first row of Figure 13 shows the parameters BD, C_{org} and EC. BD exhibits a narrower value range in the first depth interval (10-20 cm) compared to 20-30 cm. Although values overlap between depths, a high outlier is present in the 10-20 cm level, while average values are similar between depths. C_{org} also shows lower values and a smaller range in the first depth interval, with a higher average value observed in the second depth. In contrast, EC displays higher values and a higher average value in the first depth interval than in the second depth, showing a reversed depth-related distribution compared to most other parameters.

The second and third row of Figure 13 include the boxplots of k_f , LOI, pH and Wk.max. The k_f values are generally low and decrease towards zero in the second depth interval, making them not directly comparable to values from the first depth. LOI shows a similar depth-related pattern to C_{org} and Wk.max, with lower values and a smaller range in the first depth interval compared to the second depth. While the average value of Wk.max is similar between depths, the LOI boxplot exhibits a higher average value in the second depth interval. The pH values show a pattern similar to EC, with higher values in the first depth interval and comparable value ranges and average values between depths.

Outliers are present in four of the seven boxplots. All boxplots except k_f display whiskers. The statistical validation (Table 4) showed no significant differences for BD and Wk.max, which is also reflected in the overlapping distributions visible in Figure 13.

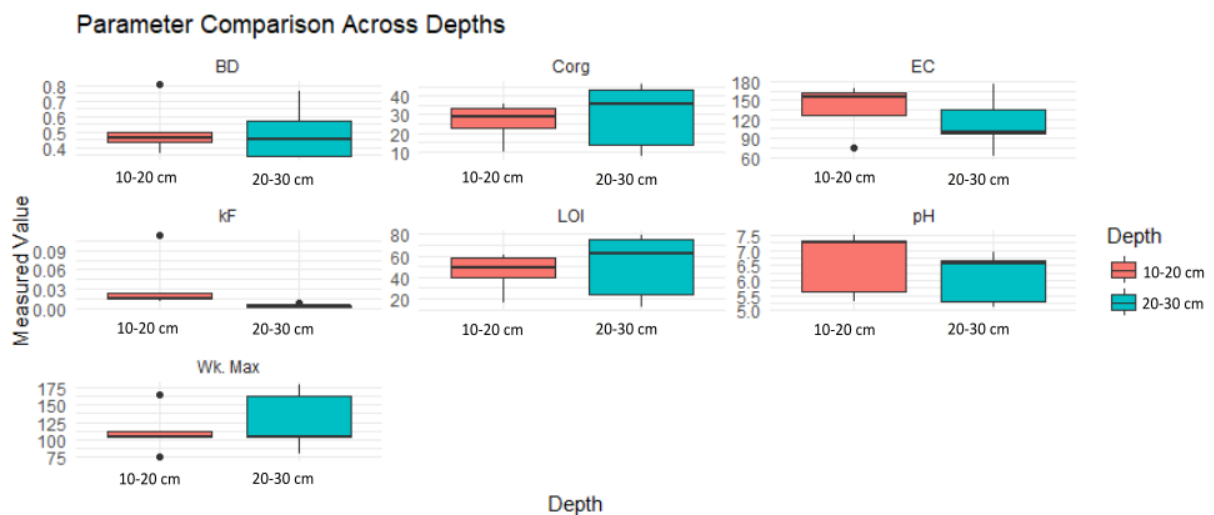


Figure 13: Lab parameter comparison across sampling depths. The red boxplots show the first depth interval (10-20 cm), and the blue boxplot shows the second depth interval (20-30 cm). The figure shows above each boxplot pair the parameter and on the y-axis the values. The boxplots are representing the median, interquartile range, whiskers and outliers (own representation, 2025).

After evaluating the laboratory results of the hydrological parameters k_f , BD and Wk.max, the most pronounced difference between depths was observed for k_f (Figure 14). The k_f measurements were conducted using the Royal Eijkelkamp permeameter (see Chapter 2.3.3), applying the same procedure for both depth intervals.

Statistical validation revealed a significant difference in k_f values between the two depth intervals. Higher values were observed in the first depth interval (10–20 cm) compared to the second depth interval (20–30 cm). The first depth interval shows a greater dispersion of values, including two outliers. In contrast, the second depth interval exhibits very low variability, with one outlier present. The boxplot for the second depth interval is nearly flat, indicating minimal value spread and a lower median compared to the first depth interval.

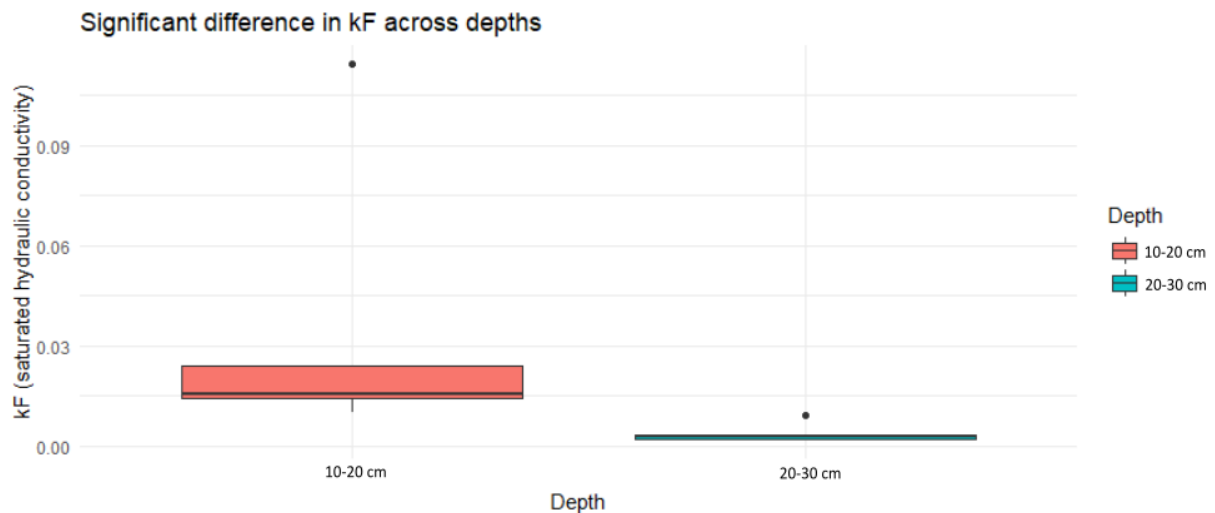


Figure 14: Comparison of the k_f value across two depths. The x-axis is depicting the two depth intervals; the y-axis shows the evaluated parameter. k_f has the unit [cm/s] (own representation, 2025).

3.2 Developed Suitability Map

After stating the results of the laboratory and field results, the final suitability map and additional data is presented. The following graph is based on the data presented in Table 4 and 6. The locations were selected according to the suitability value and measured peat depth; the coordinates are derived directly from the field measurements. All available field measurements were incorporated. The graph illustrates the relationship between the suitability value and the peat thickness (Figure 15) including the evaluated peatlands.

The Irdning peatland is represented by a point accumulation in the lower left corner of the graph, around the X-coordinate 14.11°E. Peat thicknesses of 0-20 cm, 40-80 cm, 80-100 cm and >100 cm were recorded, resulting in a total of six field points in the analysis. The associated suitability values are consistently low, ranging from 3,75 to 3,95. The peat thickness distribution is rather irregular; field points located closer to

the selected project sites 1 and 2 show higher peat thicknesses, although they remain within the same suitability value category.

The point accumulation in the upper right corner of the graph corresponds to the Wörschach peatland. Here, peat thickness values range from 20-40 cm and 40-80 cm, with most points exceeding 100 cm. The suitability values are high to very high, ranging from 4,35 to 4,55. The lowest suitability values at this site fall within the medium class (3,95-4,35). Overall, higher peat thicknesses and higher suitability values were measured in Wörschach compared to Irdning.

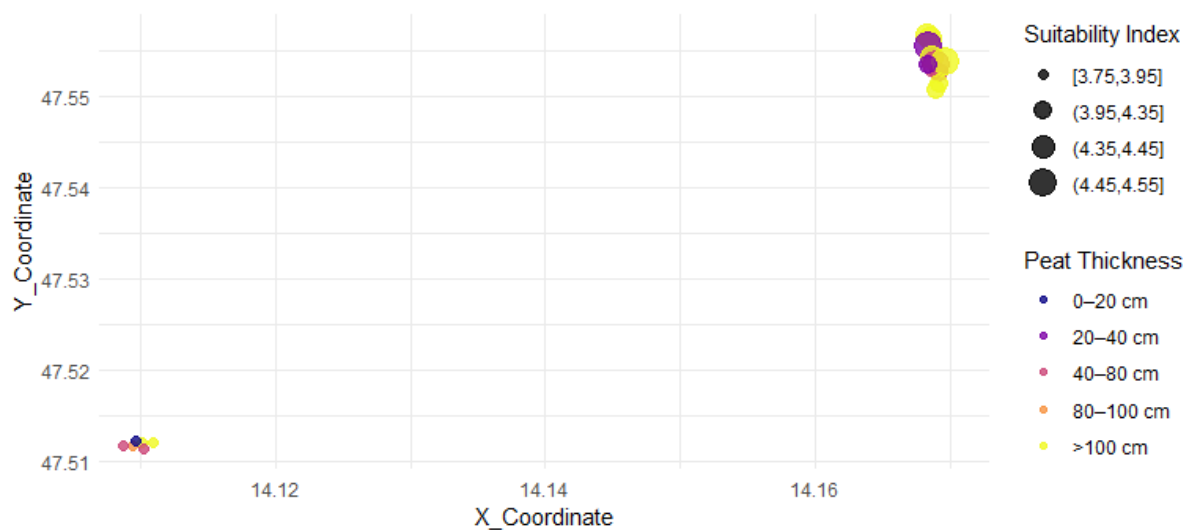


Figure 15: Analysis of suitable locations according to peat thickness and the suitability value of the Suitability model. The colour of the circles show the peat thickness classes [cm] from 0-20, 20-40, 40-80, 80-100, >100. The size of the circles show the value of the suitability value, ranging from small (3,75-3,95), medium (3,95-4,35), high (4,35-4,45) to very high (4,45-4,55). The x-axis shows the easting and the y-axis the northing, the coordinates of both sites and field maps are included in the figure (own illustration, 2025).

In addition to the peat thickness, LOI was an important parameter measured in both peatlands. The highest LOI values at both depth intervals were recorded at the second site in the Irdning peatland. Overall, in general higher LOI values were measured in the Wörschach peatland.

In Irdning, the lowest LOI value is approximately 12,50%, while the highest value reaches 79,12%, both measured at the second depth interval. The mean LOI value in is 31,59%. No clear pattern is visible, as sites 1 and 2 show different value distributions and higher LOI values occur at different depth intervals, making a direct comparison between depths not significant.

In Wörschach, the lowest measured LOI value is 23,71% and the highest is approximately 75,00%. The mean LOI value is 48,00%.

At two out of three sites, higher LOI values are observed in the second depth interval, indicating a consistent depth-related pattern that allows for comparison between depth intervals (Table 7).

Table 7: Laboratory results of the parameter LOI [%]. The LOI results are given, the measured depth interval as well as the coordinates, site and peatland of the values (own table, 2025).

Peatland	Site	X	Y	Depth	LOI
Irdning	1	14,11096	47,51237	0-20	16,4323
	1	14,11096	47,51237	20-30	12,49796
	2	14,11102	47,5119	0-20	61,21242
	2	14,11102	47,5119	20-30	79,17669
Wörschach	3	14,16894	47,54992	0-20	57,60888
	3	14,16894	47,54992	20-30	74,99737
	4	14,16802	47,55697	0-20	49,36989
	4	14,16802	47,55697	20-30	23,70824
	5	14,16952	47,55739	0-20	39,18369
	5	14,16952	47,55739	20-30	61,77638

Suitability Map

The suitability map created according to chapter 2.3.1 is shown in Figure 16. It illustrates the spatial suitability of the study area for the ERP and thus represents the potential rewetting suitability of peatlands in the Enns valley. Suitability values range from 1,29 to 4,55 and are classified into five classes following the reclassification process mentioned in Chapter 2.2. Very high suitability values range from 4,00 to 4,55, high from 3,00 to 4,00, medium from 2,00 to 3,00, and low from 1,29 to 2,00. In general, areas with a higher peat presence show higher suitability values.

The acquired field data are displayed as stars and circles, indicating the locations of the different sites, the circles the locations of the field measurements. The large raster cells result from the grid resolution of the eBOD dataset, while the finer raster in the background reflects the higher resolution of the DKM22 and DTM layers. The layers with the strongest influence on the suitability model are soil class and humus type, followed by soil water regime, permeability, soil depth, and pH. The weighting of all criteria used in the final suitability map is provided in the Table 8 (Chapter 4.3). The mean suitability value of the model is 2,8, with a standard deviation of 0,79 (Figure 16).

Built-up and industrial areas were assigned low suitability values, visible as red to brown areas on the map.

Lower suitability is also associated with steeper slopes and greater distances from water bodies. In contrast, areas close to water bodies or wetlands show high suitability values. These high suitability areas, displayed in blue, largely overlap with peatland locations and occur predominantly within the valley in a diagonal pattern across the study area.

A comparison with land use data shows that many suitable areas overlap with grassland and agricultural land, indicating medium to high rewetting potential. Additionally, many high suitability areas coincide with Natura 2000 sites, which have protection status and therefore also an increased restoration potential.

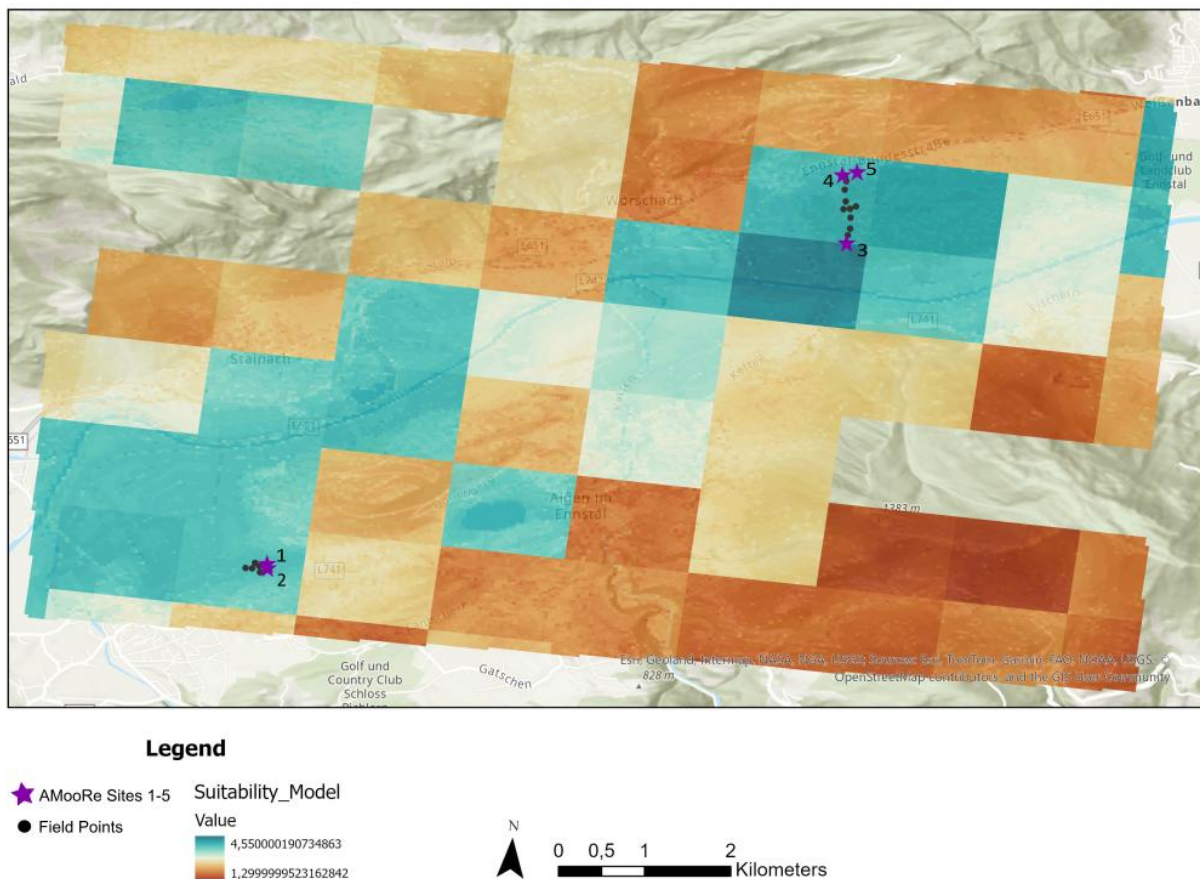


Figure 16: Suitability Model, showing the suitability values of the study area. The blue areas show more suitable areas while the red/brownish areas show less suitable areas. The values range from very suitable (4,55) to not suitable (1,29). The AMooRe sites and field points are also mentioned in the legend (own representation, 2025).

The distribution of suitability values is shown in Figure 17. The frequency distribution follows an approximately normal pattern, with a mean value of 2,81 and a standard deviation of 0,79. Values range from approximately 1,4 to 3,6 along the x-axis. A slight

right skew is visible, indicating a higher proportion of values below the mean and thus a larger extent of areas with lower suitability within the study area. Most values fall within the medium suitability class.

Within the model validation, the compact distribution and absence of extreme outliers indicate internal consistency of the suitability assessment and support the robustness of the ERP results. The near-normal distribution of values allows for further statistical analysis, as the underlying assumptions are sufficiently met.

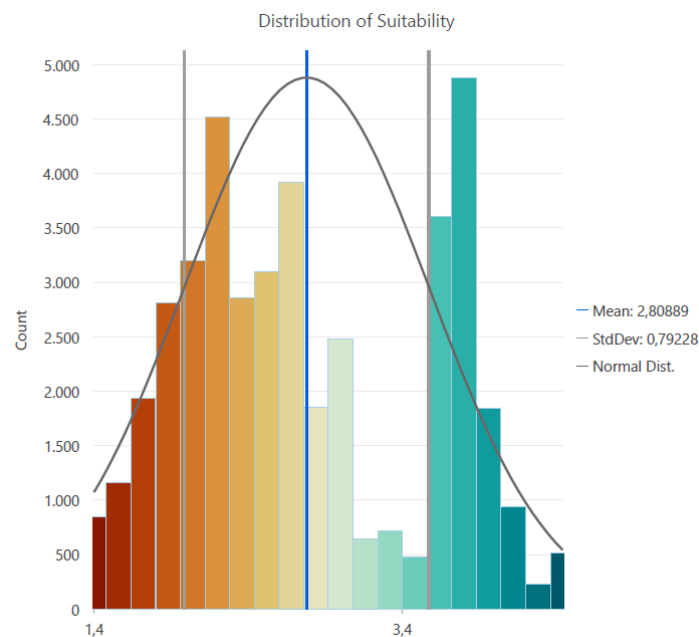


Figure 17: Distribution of the suitability values within the created model. The colours show the same colour spectrum as on the map, and the layout reflects the model (own representation, 2025).

Locate Map

To identify the most suitable areas for ecological rewetting, a locate map was created using the Suitability Modeler. Within the total study area of 6,77km², regions with the highest suitability values were identified. The average value suitability value was used as the evaluation criterion to delineate suitable areas. The resulting map (Figure 18) illustrates the spatial distribution of suitability values and highlights hotspot areas with the highest ERP.

Two circular regions were selected as outcome locations. Selecting one single location was considered too restrictive, while three locations resulted in areas that were not practically manageable. The selection was therefore based on feasibility and spatial coherence. As no specific requirements regarding minimum area size or distances

between peatlands were defined, the suitability value was the primary selection criterion, with distance units set to kilometres.

The two selected regions, highlighted in pink and grey, represent areas with high to very high suitability values. The pink area covers the Wörschach peatland, where very high suitability values were identified, while the grey area corresponds to the Irdning peatland, which also shows consistently high suitability values. High suitability is associated with areas of high peat occurrence, proximity to water bodies, low slope gradients, peat-favouring soil types, suitable pH values, and high water holding capacity. Land use in these areas is predominantly grassland, wetland, or agricultural land with appropriate conditions. The spatial proximity between high-value raster cells and field measurement points provides an indication of the model's plausibility. Overall, the locate map enables the identification of priority areas within the study area and supports further planning and implementation of ecological rewetting measures.

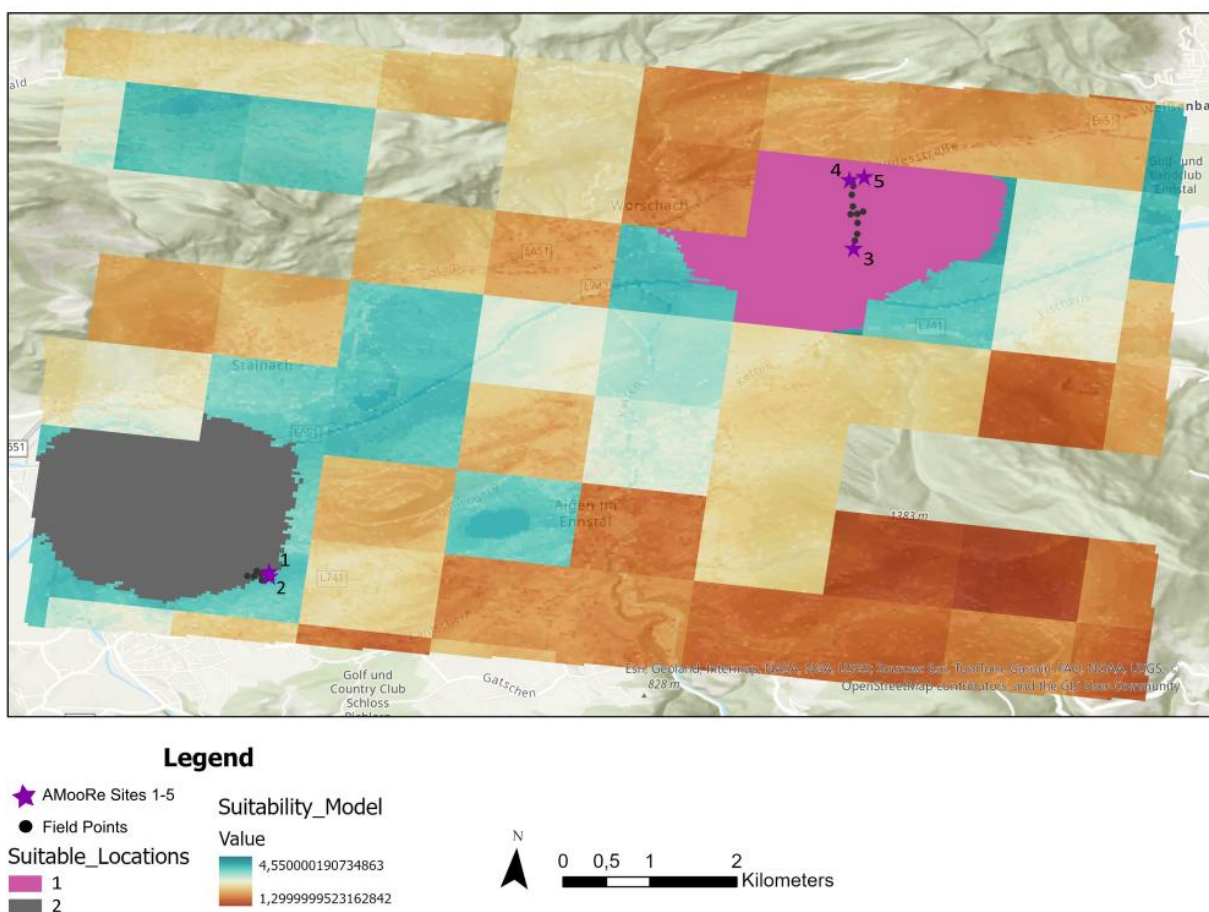


Figure 18: Figure 19: Locate Map and potential rewetting areas in the study area. The grey and pink coloured spots within the map show the suitable locations for an ecological rewetting within the study area, based on the locate map function in the suitability modeler (own representation, 2025).

4. Discussion

4.1 Reference to Research Question and Hypotheses

This study aims to clarify how suitability for ecological rewetting can be quantified and assessed. Key factors influencing rewetting potential include hydrological conditions, such as WT level, precipitation, ET, and overall water availability, land use within peatlands (natural, managed, or agricultural), peat characteristics (including peat thickness, degree of decomposition, and maximum water storage), and topography (particularly slope). In addition, proximity to infrastructure, including roads and settlements, plays a significant role in determining the feasibility and potential impacts of rewetting measures.

In this chapter, the methodology and results are discussed and compared with relevant literature in order to identify explanations and contextual examples for the observed findings. A summary of the key results provides an introduction and guidance for the discussion.

The results of the ERP, investigated through different analytical approaches in both peatlands, focus on spatial patterns. These patterns become evident through the combined application of a GIS-based suitability model and field-laboratory measurements. Overall, the analyses indicate that the assessed ERP mainly relies on peat depth, hydrological conditions, and soil physical properties.

Laboratory and field measurements revealed depth-related differences across the investigated parameters and showed consistent relationships between groundwater dynamics, peat and soil physical properties, and the resulting suitability values.

The suitability model identified highly suitable areas primarily in low-lying, peat-dominated zones that are close to watercourses, overlap with wetlands, and correlate with land use types such as grassland and agricultural land. In these areas, WT tables are high and close to the surface, particularly in the Wörschach peatland. Lower suitability values are associated with stronger anthropogenic land-use influence, steeper slopes, and greater distances from water availability.

Based on the research question of how a combined GIS-based suitability model and field-laboratory measurements can be used to map and evaluate the ERP of peatlands in Austria, the results presented in Chapter 3 show a general agreement between the GIS-based model outputs and the field-laboratory results. The integration of spatial

analyses with empirical measurements provides a reliable and robust framework for consistently identifying areas with high ecological rewetting potential.

The hypotheses addressed in this study and discussed in the following chapters are:

(1) Hydrological and soil-related criteria have a stronger influence on ERP than climate and land use/land cover criteria,

(2) Hydrological parameters, particularly WT dynamics and k_f , significantly influence the ERP of peatlands,

and (3) Field and laboratory measurements correspond spatially with GIS-identified high-suitability areas.

4.2 Hydrological and Soil Physical Properties

The laboratory results presented in Chapter 3.1 revealed significant differences between the two sampled peat intervals (10-20 cm and 20-30 cm) for several soil parameters. pH, LOI, k_f , and EC showed statistically significant depth-related changes, whereas BD and $W_{k,max}$ did not differ significantly between depths. Overall, the upper depth interval (10-20 cm) exhibited higher pH, EC, and k_f values, while the deeper interval (20-30 cm) showed higher LOI and $W_{k,max}$ values. This pattern indicates increasing OM content and water retention with depth, as reflected by LOI and $W_{k,max}$, respectively.

An increase in BD with peat depth has been described by Clymo (1992) and is also apparent in the results of this thesis. Although the depth-related difference was not statistically significant, the tendency of increasing BD with depth is consistent with the literature and has been widely reported. Holden et al. (2001) linked increasing BD to decreasing hydraulic conductivity. In the present study, a slight increase in BD and a decrease in k_f with depth were observed; however, the correlation between BD and k_f was weak. Correlation heat maps (Figure 12) show a small negative correlation in the upper depth and an even weaker relationship in the lower depth. Thus, while the general inverse relationship between BD and k_f can be supported, a clear depth-driven effect cannot be fully confirmed based on the available data.

Contrasting findings regarding BD-depth relationships have been reported in the literature. Milner et al. (2020) observed increasing BD with depth, whereas Frogbrook et al. (2009) and Parry and Charman (2013) reported decreasing BD with depth. The results of this thesis reflect this variability, as the deeper layer shows a broader range of BD values, including both higher and lower values compared to the upper depth (Figure 13). This variability highlights the site-specific nature of BD depth relationships in peat soils and suggests that multiple processes operate simultaneously within a single depth interval. Literature-derived BD ranges (0,02-0,254 g/cm³; Quinton et al., 2000) support the values measured in this study. Higher dry BD values are positively correlated with decreasing C content and increasing management intensity (Chapman et al., 2017), while BD, hydraulic conductivity, and humification remain closely interdependent despite spatial variability (Mustamo et al., 2016).

Depth-related changes in hydraulic conductivity have also been reported by Baird et al. (2008), who observed increasing permeability with depth in some peat profiles. In contrast, the laboratory results of this study show decreasing *k_f* values with increasing depth. Given the small sample size (*n* = 5 per depth), this discrepancy highlights the need for a larger dataset to allow more robust conclusions. Lower *k_f* values are typically associated with degraded peatlands, and *k_f* does not necessarily change proportionally with BD (Liu and Lennartz., 2019), which is consistent with the findings of this thesis. The measured *k_f* values fall within literature-reported ranges ($0,7 \times 10^{-5}$ to $1,3 \times 10^{-2}$ m/s; Rezanezhad et al., 2010) but are relatively low, suggesting that the peatlands cannot be classified as pristine or only slightly degraded.

Hydraulic conductivity is also strongly influenced by the degree of decomposition. Increasing decomposition leads to pore collapse and thus reduced *k_f* values (Päivänen, 1973). In this study, the degree of decomposition does not show a consistent depth-related trend but varies by site. Nevertheless, the observed decrease in *k_f* with depth is compatible with generally higher decomposition in deeper peat layers. According to Quinton et al. (2000), permeability can vary up to three times more than the degree of decomposition over the same depth interval, which may explain the variability observed in the results.

Peat soils typically exhibit very high porosity (>80%) and organic C contents exceeding 20 mass% (Dettmann et al., 2014). The peat soils investigated in this study show OM contents above this threshold, which explains the relatively low BD values. High OM dominance, combined with the low density of organic material, results in reduced BD even in more decomposed peat layers (Driessen, 1977). While Quinton et al. (2000) reported decreasing BD with depth for mineral soils, this relationship requires adaptation for peat soils, where decomposition often increases BD and reduces pore space, thereby decreasing k_f .

Higher OM content enhances soil water retention, which is reflected in the LOI and Wk.max results. Both parameters increase with depth, and correlation heat maps show positive correlations in both depth intervals. Increased water saturation restricts oxygen diffusion and slows decomposition processes (Clymo et al., 1998). At the same time, higher water storage capacity is associated with greater pore space and lower BD (Liu et al., 2020). In this study, Wk.max shows a strong negative correlation with BD, which becomes more pronounced with depth. Differences in LOI and OM content between the two peatlands may additionally be influenced by microtopographic variability (Ahmad et al., 2025).

The comparatively low LOI values measured in this study further indicate peatland degradation. Klingenfuß et al. (2014) reported soil OM contents of approximately 95% in near-natural Sphagnum peat and around 85% in vascular peat in northeastern Germany. In contrast, the mean LOI value in this study is 40,6%, suggesting thinner peat layers, mineral admixture, and drainage induced OM loss. Higher ash content likely reflects groundwater influence, erosion, or sediment deposition (Klingenfuß et al., 2014). Therefore, the investigated peatlands are better classified as degraded rather than intact peat deposits.

Average WT levels below -10 cm reduce peat growth and increase decomposition (Swindles et al., 2025). Furthermore, lower WTs can reduce the ET. The literature emphasises that the measured ET in peatlands is at least 1.5 times higher than precipitation. Nevertheless, ET cannot be measured completely due to several influences. In addition, ET is influenced by the level of WT (Håkan and Jeglum, 2013). In this case, however, the measured ET is much lower than precipitation. This could be because the data was not taken on site, for example by an eddy covariance device. The data comes from GeoSphere and applies to both areas, which also shows no

differences. To support the above statement, more and more accurate local data would be needed, which was not considered here due to time constraints. WT levels observed in this study are generally deeper than this threshold, except for Wörschach 3, which is consistent with increased decomposition and reduced OM content. Sphagnum-dominated peatlands show a negative relationship between decomposition and k_f , accompanied by increasing BD, reduced porosity, and higher water retention (McCarter et al., 2020; 2021).

Similar patterns are observed in this study, with decreasing k_f and increasing BD and $W_{k,max}$ with depth. Water retention in deeper peat layers may positively influence flood attenuation and subsurface flow dynamics. The flow velocity is decreasing with increasing peat depth, which is also related to the measured water retention and increased BD. This results in a lower possibility for water movement because the high BD gives low pore space, which describes a more decomposed peat. This peat condition also results in a reduced water flow. Both peatlands have proportionally fen and bog area, therefore influence of both, groundwater and precipitation, steep areas or slopes are no influence on the water flow. Groundwater is also a dynamic parameter, increasing the WT heights during droughts and supporting groundwater downward movement in wet periods. (Håkan and Jeglum, 2013). High k_f values in the upper peat layer are particularly relevant for rewetting measures, as they facilitate groundwater level rise. Contradictory behaviour in parameter values such as BD and k_f occurs primarily in the acrotelm, as this is where the most active hydrological regulation takes place. Lower k_f values in the catotelm may limit rewetting efficiency.

The influence of WT dynamics and k_f patterns highlights their significant role in peatland functioning. A stable and elevated WT level reduces decomposition and can promote peat accumulation. In addition, WTs close to the surface result in peak flows after a rainfall event (Holden, 2006). Long term degradation is altering peat properties and the ability for buffering of extreme events. Hydraulic conductivity determines water redistribution and storage processes within the peat body, thereby influencing rewetting success and being a key factor. Seasonality is also noticeable within the peatland hydrology: water storage of peatland is often combined with a reduced storage capacity in spring, because of a low ET, snowmelt and a non-active vegetation (Holden, 2006). In general, water movement is a controlling factor in peatlands and

can only be assessed based on local data (Holden, 2006). These observations directly relate to Hypothesis 2 and allow it to be partially confirmed.

pH and EC values further support peatland classification. Reported pH ranges for rich fens vary between 5 and 8 (Rydin et al., 2013; Solovey et al., 2021), which corresponds well with the pH range observed in this study (5,1–7,5). Mean EC values are lower but still fall within the broad range reported for rich fens. While this supports classification as rich fens, the wide EC range reduces the precision of this distinction.

Correlation patterns between OM, BD, pH, and EC differ from those reported for constructed fens (Nwaishi et al., 2015). While the strong negative correlation between OM and BD is consistent, contrasting relationships were observed for pH and EC. These differences are likely related to less intensive drainage, natural groundwater influence, and site-specific vegetation effects in the Enns Valley peatlands. Constructed fens typically exhibit much lower WT levels, which enhance mineralisation and increase pH and EC (Nwaishi et al., 2015).

Management practices and drainage further affect peat soil properties. Wittnebel et al. (2021) and Liu et al. (2020) reported increasing BD following drainage, whereas Howson et al. (2023) and Worrall et al. (2024) observed decreasing BD with depth across different peatlands and land use types. As no historical BD datasets or recent drainage measurements are available for the study sites, these effects cannot be directly validated. However, the broad BD ranges observed suggest that both trends may occur locally. Increasing the sample size would be necessary to better resolve these relationships. Overall, the dominance of hydrological and soil-related parameters and their influence on ERP supports Hypothesis 1.

4.3 Assessment of the GIS-Model and Spatial Patterns

The GIS model presented in Chapter 3.2 shows the results of the applied suitability model. A weighted overlay of nine spatial layers (slope, distance to water, pH, soil water, humus type, land use, soil type, permeability, and soil thickness) resulted in a hotspot mapping of potential ecological rewetting areas within the study area in the Enns Valley. This chapter analyses spatial patterns, model validation, and practical implications.

The resulting suitability map formed the basis for identifying and prioritising areas with high ERP. Field measurements and observations contributed to refining the model, improving its accuracy, and strengthening specific criterion combinations. The spatially explicit results provide a transparent, reproducible, and flexible tool for assessing the ERP at the investigated peatland sites.

The model aimed to identify areas suitable for rewetting. According to Quast (2001), preferred sites are low-lying areas connected to watercourses, ensuring water availability and facilitating restoration. Land use also plays a key role, as agricultural areas are sensitive to water abstraction, influencing rewetting feasibility.

Within the modelling workflow, layers were assigned different weights according to their influence on ERP. The highest weight was attributed to humus type, reflecting peat availability. Overall, the evaluation of ERP was primarily based on soil and hydrological parameters.

Most soil characteristic layers were derived from the eBOD platform, based on a generalised digital soil map with a 1km raster resolution. Parameterisation was performed for each raster cell based on the dominant soil type and its upper horizon. Although the data are generalised, digitalised and published in 2016, eBOD provides nationwide coverage, representing a major advantage. Additional layers were based on Austrian-wide datasets for land use, hydrology, and digital terrain models.

The selection of layers follows Qu et al. (2018), who distinguished between natural and anthropogenic factors. In this study, natural factors dominate the evaluation of ERP, including topography, hydrology, and soil conditions (Wang et al., 2011). Anthropogenic influence is represented by land use, which reflects management intensity and peatland condition (Hatvany, 2009). Layer prioritisation resulted in the identification of potential rewetting areas (Table 8). All those criteria were influential and striking regarding the ERP, mainly derived from literature.

The soil characteristics derived from eBOD are accounting for 85% of the suitability model and therefore the ERP. These criteria are representative of peat-forming properties and therefore also influence the possibility of rewetting. If the soil conditions were not present, the suitability model would not include these areas in its calculations. Further, the proximity to water and topography is also within the most influential natural factors for the ERP (White and Fennessy, 2005).

Table 8: Final Weighting of the layers mentioned above. The weight is summing up to 100%, which is the unit for all mentioned parameters. The criteria and the application were discussed in the methodology (Chapter 2.2 and 2.3.1), this is the final breakdown of the criteria (own table, 2025).

Criteria	Weight [%]
Soil type	20
Soilwater	10
Permeability	10
Distance to water	5
Slope	5
Humus type	25
Soil Thickness	10
Land use	5
pH	10

The anthropogenic criterion, LULC, is the only one used in this context out of availability reasons and the focus on the ERP. Land use reflects the human impact to date and can therefore determine the possibilities for rewetting. The rewetting of a degraded peatland is more rentable than rewetting of agricultural land used for many years (Wang et al., 2015). Historical usage had no direct influence on the suitability model but is nevertheless used in the discussion for this purpose.

The suitability map showed areas that are suitable for ecological rewetting, as well as areas that are mainly unsuitable for this purpose. During the weighting process, a few natural factors were given a higher rating, but it was then determined in the analysis or model that the data would not be adopted or evaluated. The suitability modeler has a dynamic visualisation, so changes in the weighting and the suitability map were displayed simultaneously. This made it easier to weight the layers, as the influence was visible and data that was not adopted could be given a lower rating or be excluded. Significant changes or influences that would have distorted the model, e.g. the display of proximity to bodies of water, could therefore be directly influenced. Similar processes were observed in Qu et al. (2018). A change in the weights would alter the calculated hotspots. However, this would also reveal the stability and consistency of the suitability areas.

The suitability map identified both suitable and unsuitable areas for rewetting. High suitability classes (4-5) cover approximately 30% of the study area, corresponding to roughly 10-15km² of potential hotspot areas. Lower suitability classes (1-2) account for about 48% of the area. This distribution aligns with estimates that around 90% of peatlands have been affected by drainage or agriculture (AGES, 2025).

Areas with high suitability overlap with locations of field sampling and laboratory measurements, supporting Hypothesis 3. The correspondence between empirical data and GIS-derived suitability demonstrates the robustness of the combined methodological approach.

The iterative process, from field sampling to GIS modelling and revalidation, represents a hybrid approach for ERP assessment. Regarding Hypothesis 1, hotspots are primarily characterised by soil and hydrological conditions, such as high LOI and suitable kf values, supporting the hypothesis. However, climate and land-use factors were less strongly integrated into the empirical analysis and should be addressed more explicitly in future studies.

Overall, both peatlands fall into high suitability classes, supporting the general assumptions of this study. Site-specific differences within these areas are discussed in the following chapter.

4.4 Site-Specific Differences

After answering and evaluating the hypotheses, the overall question arises as to how the combined model and field–laboratory approach can be used to assess the ERP of peatlands in Austria. This question has largely been addressed through the evaluation of the individual hypotheses. While the suitability model provides an overall assessment, clear differences between the peatlands remain evident and are therefore discussed in this chapter.

Table 9 summarises the most relevant characteristics of the investigated peatlands and the main focus of this thesis. Despite both sites being located within the Enns Valley, belonging to the same climatic region, and having been analysed using the same methodological framework, distinct site-specific differences were identified between Irdning and Wörschach. These differences are most pronounced in field observations, laboratory results, hydrological measurements, and the outcomes of the GIS-based

suitability model. This underlines the importance of local site conditions for assessing the ERP.

The peatlands differ in terms of peat thickness and degree of decomposition. Irdning has a smaller spatial extent than Wörschach and shows, on average, slightly greater peat thickness but also a higher degree of decomposition. Both peatlands exhibit multiple peat horizons, which provide buffering capacity against hydrological WT fluctuations (Rezanezhad et al., 2016). This buffering supports long-term water storage and stabilises groundwater conditions, contributing to the high suitability values determined by the ERP model. In contrast, Wörschach shows greater variability in peat thickness, including shallow peat layers of around 30 cm. These shallow deposits may limit vertical water storage and reduce water retention capacity, making the peatland more sensitive to hydrological changes and potentially lowering its ERP.

Differences in pH and EC further highlight site-specific conditions. Wörschach shows higher mean EC values and a more neutral pH compared to Irdning. This geochemical environment is typical for rich peatlands but also indicates stronger interaction with mineral substrates, likely due to thinner peat layers. Irdning, in contrast, exhibits lower EC values and slightly acidic pH conditions. These conditions favour peat stability and reduce mineral-driven decomposition processes, which contributes to the higher suitability values observed in the GIS model (MSU, n.d.).

According to eBOD, both sites are located in fen peatlands or transitional mires. Classification as fens is therefore more appropriate than classification as bogs. In terms of pH value, both are correctly classified, as bogs have a pH value of 4.5–5.5, and the pH values of both peatlands are at the limit or above (WI, 2025).

Laboratory analyses revealed systematic differences in soil physical properties between the two peatlands. Wörschach showed higher LOI and Wk.max values, indicating better OM preservation and higher water storage capacity. These properties are characteristic of less degraded peatlands and are consistent with the shallow groundwater conditions observed in the field (Liu et al., 2022).

In Irdning, lower LOI values and reduced Wk.max indicate enhanced decomposition and compaction, likely resulting from historical drainage and stronger mineral influence. BD values also show greater variability in Irdning, reflecting spatial heterogeneity in peat condition and degradation status (Liu et al., 2022). These differences directly affect the ERP, as peatland areas with higher OM content and greater water retention capacity generally respond more positively to rewetting measures.

WT dynamics represent a key factor controlling peatland functioning and the ERP. In Wörschach, WT levels were generally higher and exhibited greater temporal fluctuations, indicating more dynamic hydrological conditions. Within the WT fluctuations a seasonal pattern is visible. In contrast, Irdning showed a deeper but more stable WT level, particularly during the summer months. Such lower WT levels promote aerobic decomposition processes and are commonly associated with peat degradation (Regan et al., 2019). These contrasting WT behaviours help explain differences in ERP between the two peatlands. The shallow but fluctuating WT conditions in Wörschach support peat preservation and high water retention but may also enhance periodic oxidation of OM. In Irdning, the deeper WT levels increase the susceptibility of the peat body to progressive decomposition and limit the effectiveness of rewetting measures unless active hydrological interventions are implemented (Craft, 2016). At the same time, WT conditions in Irdning are comparatively stable.

Both peatlands are protected under Natura 2000 and the Birds Directive. Despite this protection status and therefore also higher ERP, they remain under ecological pressure from intensive land use, grassland removal, fertilisation, and modifications of adjacent water bodies (EEA, 2024). Anthropogenic interventions have been documented since at least 1840 (Gemeinde Wörschach, n.d), particularly peat extraction and drainage. Wörschach, however, exhibits higher spatial coherence in both field measurements and model results. Large parts of the peatland overlap with wetlands and Natura 2000 protected areas, indicating lower land-use intensity and higher conservation value. This spatial coherence increases the reliability of the suitability model and supports the high ERP values identified for Wörschach.

Land use and anthropogenic pressure differ markedly between the two sites. Irdning is more strongly affected by agricultural use and infrastructure development, leading to fragmented peat deposits and higher spatial variability in peat properties. This is reflected in the ERP model by lower and more heterogeneous suitability values. However, management practices in the area are already being improved, including the removal of sand and gravel, enhancement of water availability, and reduction of cultivation intensity (EEA, 2024).

These management strategies can be combined with ERP based rewetting approaches. Wörschach contains areas with a high ERP, where only minor adjustments may be required to achieve substantial restoration benefits. The measured peat thickness, high OM content, and WT level, offering potential for further elevation, create favourable conditions for successful rewetting.

In contrast, Irdning requires more targeted interventions due to existing drainage and degradation processes. The lower WT level, reduced OM content, and ongoing anthropogenic impacts necessitate WT level regulation and mitigation of drainage effects. Nevertheless, Irdning still falls within areas of potential ecological rewetting, and restoration measures remain feasible, although outcomes are expected to be more limited and strongly site dependent.

Overall, these differences in ERP assessment highlight the need for site-specific validation and evaluation of key parameters such as hydrology, geomorphology, and land use. The combined GIS-based and field–laboratory approach applied in this study has proven effective in capturing these site-specific characteristics and provides a robust framework for prioritising peatlands for ecological rewetting in Austria. It should be noted, however, that the field data, and also the laboratory results, reflect the conditions at the time of measurement. Additionally, the field observations and measurements cannot be extrapolated to the entire site, as only a fraction of the peatlands was examined using this approach.

Table 9: Summary of both peatlands within the study site (adopted from Ahmad et al. (2025); data from: European Environment Agency (2024), own data (2025)).

Description	Irdning	Wörschach
Areal extent	267 ha	401,73 ha
Peat thickness (on average)	0,8 m	0,7 m
Degree of decomposition (on average)	H4	H3
Average pH	5,33	7,03
Average LOI	31,59%	48,00%
Average kf	0,013 cm/s	0,007 cm/s
Average BD	0,55 g/cm ³	0,44 g/cm ³
Average Wk.max	100,45%	124,09%
Average WT	-57,87 cm	-19,29 cm
Protection status	Natura2000 site, Birds Directive since 2006	Natura2000 site, Birds and Habitats Directives since 1995
Threats and Pressures	Intensification, grassland removal, modification of standing water bodies	Peat extraction, fertilisation, drying out
Anthropogenic impact	Drainage measures in 1925	Peat extraction since 1840
Management	Modifying of inland water courses, non-intensive mowing	Sand and gravel extraction

4.5 Implications of Management on Rewetting and the ERP

Following the discussion of the results, including laboratory and field measurements, the GIS-based suitability model, and site-specific differences, this chapter concludes by addressing the significance of these findings for peatland rewetting and the ERP.

Based on the results, it is possible to discuss how the ERP can be managed for individual peatlands depending on their location. The findings demonstrate depth-dependent differences in peat properties. The upper peat layer is characterised by lower decomposition, higher kf, and greater water storage capacity. In contrast, deeper layers show increased decomposition, higher BD, reduced pore space, and lower hydraulic conductivity. These vertical variations are critical for understanding the peatlands ERP and must be considered when designing restoration measures.

Overall, the results indicate a transition from the acrotelm to the catotelm. These layers are key hydrological components and represent one of the most important controlling factors in peatland functioning. The acrotelm is typically not fully water-saturated; its pore space acts as an aquifer and supports intensive aerobic and less intensive anaerobic microbial activity. In contrast, the catotelm exhibits lower hydraulic conductivity, higher decomposition, and reduced porosity (LBEG, 2021).

One of the most influential conditions for peatland functioning is the peatland WT. In near-natural bogs, the WT is generally stable and remains very close to the peat surface, as illustrated in Figure 19. Such conditions are essential for maintaining peat accumulation and ecosystem stability.

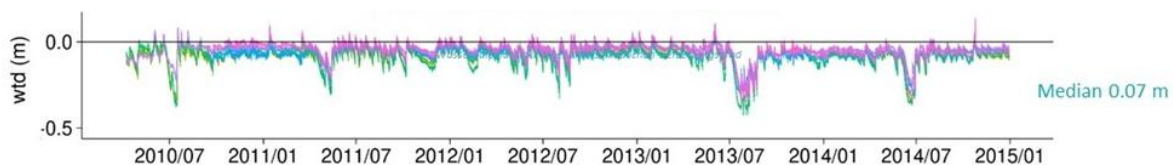


Figure 20: The WT of a near-natural bog in Germany. The WT is known for being stable and close to the surface, very shallow. The y-axis shows the unit of the WT [m], the x-axis shows the measured time period (Dettmann, Thünen-Institut, n.d.).

Resilience to climatic and hydrological fluctuations is considered an inherent property of intact peatland ecosystems (Regan et al., 2019). As these fluctuations are expected to intensify due to climate change, maintaining peatlands in an intact or restored state and strengthening their resilience is increasingly important.

Key parameters for monitoring peatland integrity are outlined in the FAO report for peatland mapping and monitoring (FAO, 2020). These parameters are particularly relevant for drained peatlands and are grouped into GHG emissions, sustainability, disaster risk reduction, and C stock. Relevant indicators that could also be applied in the Enns Valley include local climate conditions, socio-economic factors, peat depth, drained peatland area, LULC (change), and fire risk.

As the peatlands in this study are investigated within the MOIST and AMooRe LIFE projects, the practical implementation of further research and monitoring is feasible. GHG emissions are already being measured, allowing for future evaluation of C stocks, while specific rewetting measures are currently in the planning phase. However, fire

risk management has not yet been addressed and represents an opportunity to integrate risk mitigation with ESS enhancement.

Referring to the LIFE Peat Restore project, incorporating fire risk management into rewetting strategies could enhance multiple ESS, including biodiversity conservation, hazard reduction, water regulation and filtration, and climate regulation (LIFE, 2021). Intact peatlands provide substantial benefits not only within their boundaries but also to surrounding landscapes.

According to the International Peatland Society (IPS, n.d.), peatlands in the Enns Valley could provide the following ESS (Table 10):

Table 10: Ecosystem services provided by peatlands and examples for the Enns Valley (adapted from IPS, n.d.).

Provisioning services	Peat substrate and fresh water
Regulating services	Climate regulation on locale scale, water regulation in the watershed and local scale, erosion protection and regulation of soil conditions
Cultural services	Opportunities for education and research and a space for tourism and recreation
Supporting services	Accumulation of OM and peat formation, higher biodiversity and nutrient cycling

With regard to LULC development, as highlighted by the FAO (2020), drainage infrastructure such as canals and ditches should be closely monitored. The ERP model, based on field data and spatial peatland information, can support targeted subsidy allocation, focus monitoring efforts on identified hotspots, and serve as a spatial screening tool for planning purposes rather than a final decision-making map. This approach can assist local authorities and land managers in prioritising restoration activities.

Further restoration measures, such as trench and drainage sealing or dam construction, could improve water availability and stabilise the WT within peatlands (Peatland Strategy 2030+, BMLRT, 2022). Additionally, alternative land management approaches such as paludiculture could be considered as part of future planning strategies.

To further enhance the methodological significance of the ERP model, several extensions could be implemented. Given the significant role of hydrology in peatland restoration and ecosystem functioning, integrating dynamic hydrological modelling, such as MODFLOW simulations or machine learning approaches, could substantially increase the model's predictive power and applicability.

4.6 Limitations in the Assessment of the ERP

When interpreting the ERP, several limitations and sources of uncertainty must be considered, despite the overall consistency of the results.

The methodological workflow was designed based on data availability and the use of the suitability modeller within ArcGIS Pro. Following the literature review, the study by Koppensteiner et al. (2023) served as a methodological reference. Although their approach relied on different, non-public datasets and did not explicitly use the ArcGIS Pro Model Builder, the GIS framework was adopted and adapted for this study.

A key source of uncertainty is the relatively small number of measurement points per peatland. The fixed number of monitoring stations limited both WT measurements and sample collection. Station locations were predetermined by the project to ensure reproducibility and long-term assessability of the peatlands, thereby constraining flexibility in site selection.

Additionally, point-based field data were intersected with the raster grid of the suitability map. This upscaling process may introduce interpolation errors, which should be considered when evaluating ERP results. Statistical validation between field-derived parameters and modelled suitability values would further improve certainty in the results and enhance accuracy. Discrepancies may also arise between local site conditions and modelled suitability classes due to differences in data structure (differences between point data and raster layer) and spatial resolution. Moreover, WT measurements represent point-based observations influenced by seasonal conditions and restricted to a specific time period; therefore, long-term monitoring would be required for more robust assessments.

The suitability model relies on literature-based parameter weighting, which inherently introduces uncertainty and subjectivity. Although dynamic weighting allowed sensitivity to different parameter combinations to be assessed, it may also have resulted in alternative hotspot configurations. A principal component analysis (PCA) of the GIS input parameters could have reduced uncertainty (Qu et al., 2018); however, this approach was not feasible due to insufficient data volume.

Finally, model validation was limited to the peatlands investigated and the available field data within the study area. This constrained the assessment of model performance across a wider range of peatland types and management histories. Extending the application of the model to additional peatlands in Styria would substantially improve its validation and general applicability.

In addition to data-related uncertainties, the ERP is also subject to time constraints, topicality and ongoing processes. As a result, this model reflects a snapshot of the current reality in terms of locality factors, weather and hydrological conditions. The further course of the rewetting measures is not linked to extreme events that may arise as a result of climate change or to the conditions after rewetting. These criteria were not included in this model. The same applies to vegetation surveys and socio-economic factors that are considered in rewetting experiments. For reasons of time, these should be included in future model developments in order to represent reality more accurately. This will make the model more robust and enable further decision-making processes to contribute to the success of rewetting.

5. Conclusions

Concluding, the thesis assessed the ERP of selected peatlands in the Enns Valley by using an integrated approach that combines laboratory and field measurements with a GIS-based suitability model. The study addressed the research question of whether ERP can be evaluated through the combination of spatial GIS analysis and site-specific peat properties, and which factors are most influential in determining rewetting suitability.

The results demonstrate that the applied approach provides a robust and consistent framework for identifying areas with a high ERP. Hydrological and soil-related parameters, particularly WT dynamics, peat thickness, OM content, and k_f , proved to be the dominant controls on the ERP. This confirms the assumption that hydrology and soil properties have a stronger influence on the rewetting suitability than climate or land-use parameters, thereby supporting Hypothesis 1.

Laboratory and field analyses revealed depth-dependent differences in peat properties. The upper peat layers showed a higher k_f and $W_{k,max}$, while the deeper layers exhibited higher BD and a greater degree of decomposition. These results also highlight the importance of vertical peat structure for understanding peatland functioning and rewetting potential.

The spatial variability of ERP across the study area was effectively captured by the GIS-based model. Suitable peat and hydrological conditions correspond with areas of high to very high ERP, confirming Hypothesis 3. The model functions as a spatial evaluation and planning support tool, helping to prioritise monitoring efforts and underscores peatland management and restoration processes. However, its intension is not to be used as a decision-making tool. Further research could investigate the impact of anthropogenic and natural factors on the potential for rewetting, and the role of historical land use regarding rewetting.

Groundwater dynamics, WTs and hydraulic conductivity were shown to play a significant role in peatland processes and rewetting potential. Shallow and stable WTs raise peat preservation and enhance restoration possibility, whereas deeper or strongly fluctuating WT levels increase decomposition risks and limit rewetting success. These findings partially confirm Hypothesis 2 and emphasise the key role of hydrological control in peatland restoration.

The application of a GIS-based ERP framework combined with field data demonstrates a functional approach to peatland assessment. Thanks to the data basis and the simple transfer of field and laboratory methodology, this approach can be applied to other areas. For more meaningful outcomes and predictive power, a standardised procedure in the Alpine region including consistent validation, a long-term monitoring, hydrological models pre and post rewetting, additional field, especially peat thickness, and climate

data, emission data and a further development of an interdisciplinary approach should be integrated.

Overall, this study answers the research question by showing that a combined GIS-based and field laboratory approach is suitable for assessing the ERP of peatlands in Austria. The approach enables a spatially explicit, but also transferable, transparent and scientifically sound assessment that supports hydrologically oriented renaturation planning in the Enns Valley and comparable regions.

6. Outlook

The model is currently considered up to date and comparatively simple due to the selected parameters and the deliberate exclusion of socio-economic factors, which on the other hand play a key role during implementation. As follow-up measures, long-term WT monitoring could be conducted, additional depth intervals could be sampled for laboratory and field analyses, GHG emissions could be incorporated, and vegetation dynamics at the study sites could be investigated.

A key advantage of using publicly available datasets is the high transferability of the approach to other regions in Austria and potentially beyond. While the GIS framework is adaptable and scalable, site-specific field and laboratory investigations remain necessary to ensure reliable results.

Rewetting as a restoration strategy is essential for both climate change mitigation and adaptation and represents a long-term research task, particularly with respect to impacts at the catchment scale. Improved understanding of site-specific controls on peatland processes and landscape interactions can support more targeted, effective, and prioritised restoration measures. Furthermore, integrating ESS perspectives may help to close existing research gaps and turn scientific findings into practical climate protection strategies.

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8. Appendix

Appendix A Laboratory Measurements

Table A1: All laboratory results in one table (own table, 2025).

Peatland	Site	X	Y	Depth	pH	EC	LOI	kF	BD	Wk. Max
Irdning	1	14,11096	47,51237	10-20	5,30383	73,64282	16,4323	0,024	0,805	75,125
	1	14,11096	47,51237	20-30	5,302973	60,6466	12,49796	0,003	0,761	79,359
	2	14,11102	47,5119	10-20	5,62	126,84	61,21242	0,114333	0,436	104,8906
	2	14,11102	47,5119	20-30	5,11404	100,3855	79,17669	0,003083	0,342	162,8327
	3	14,16894	47,54992	10-20	7,27	162	57,60888	0,01425	0,458	103,0043
	3	14,16894	47,54992	20-30	6,568438	97,25495	74,99737	0,009	0,451	103,7374
Wörschach	4	14,16802	47,55697	10-20	7,51	169,1	49,36989	0,010167	0,358	165,097
	4	14,16802	47,55697	20-30	6,934117	135,9845	23,70824	0,002083	0,566	103,1513
	5	14,16952	47,55739	10-20	7,3	154,86	39,18369	0,015667	0,493	112,7906
	5	14,16952	47,55739	20-30	6,652034	174,706	61,77638	0,001833	0,338	177,8623

Table A2: WT fluctuations and measurements at the two AMooRe sites in Irdning. Data is from the Elli Track devices installed at the sites. Calculations made in R (own table, 2025).

Site	Min.	Max.	Mean	Median	SD	Quantile 25	Quantile 75	Amount
Irdning 1	-91,7	-40,1	-72,5	-74,2	9,54	-78,1	-67,5	8321
Irdning 2	-59,7	-22,0	-45,7	-46,7	8,03	-50,5	-42,8	8389

Table A3: WT fluctuations and measurements at the three AMooRe sites in Wörschach. Data is from the Elli Track devices installed at the sites. Calculations made in R (own table, 2025).

Site	Min.	Max.	Mean	Median	SD	Quantile 25	Quantile 75	Amount
Wörschach 1	-43,7	-9,46	-28,3	-29,3	7,86	-35,0	-22,2	85716
Wörschach 2	-34,4	-7,46	-20,0	-19,2	4,61	-22,8	-16,9	8724
Wörschach 3	-22,0	0,49	-9,57	-9,11	4,05	-12,2	-6,82	7912

Table A4: kf measurements and calculations (2025).

Proben	Tiefe	Pegel Zylinder	Pegel Becken	delta h	s/40ml	V	Q	A	I	kf (m/s)	kf (cm/s)
1a1	30	6,5	4,8	0,017	838,4	0,00004	4,77099E-08	0,00255	0,04	4,402E-05	4,40E-03
1a2	30	6,5	5,3	0,012	4909,2	0,00004	8,14797E-09	0,00255	0,04	1,065E-05	1,07E-03
1a3	30	5,9	4,8	0,011	1319,4	0,00004	3,03168E-08	0,00255	0,04	4,323E-05	4,32E-03
1b1	30	6,6	5,3	0,013	4877,2	0,00004	8,20143E-09	0,00255	0,04	9,896E-06	9,90E-04
1b2	30	5,7	4,9	0,008	992,1	0,00004	4,03185E-08	0,00255	0,04	7,906E-05	7,91E-03
1a1	10	6,5	5,3	0,012	2612,1	0,00004	1,53133E-08	0,00255	0,04	2,002E-05	2,00E-03
1a2	10	5,4	5,3	0,001	157,1	0,00004	2,54615E-07	0,00255	0,04	3,994E-03	3,99E-01
1a3	10	5,8	5,3	0,005	102,2	0,00004	3,91389E-07	0,00255	0,04	1,228E-03	1,23E-01
1b1	10	6,3	5,3	0,01	3001,2	0,00004	1,3328E-08	0,00255	0,04	2,091E-05	2,09E-03
1b2	10	5,5	4,9	0,006	281,2	0,00004	1,42248E-07	0,00255	0,04	3,719E-04	3,72E-02

Table A5: BD and Wk.max measurements and calculations (2025).

Probe	Zylinder (g)	Petrischale (g)	Hilfe (g)	gesamt (frisch)	Sample (frisch)	g (trocken)	Sample (trocken)	nass	Wassersättigung (g)	Wassergehalt (frisch/trocken)	Wk max (nass-trocken)/trocken	Bulk density	Volumen	Wk Max (Vol.%)
1a1 10	108,01	48,9	156,91	286,47	129,56	236,71	79,8	148,24	305,15	1,624	0,858	0,840	95	85,764
1a2 10	110,09	48,07	158,16	297,4	139,24	246,19	88,03	145,03	303,19	1,582	0,648	0,927	95	64,751
1a3 10	109,23	48,24	157,47	281,63	124,16	239,52	82,05	138,36	295,83	1,513	0,686	0,864	95	68,629
1b1 10	110,05	42	152,05	287,94	135,89	232,64	80,59	143,17	295,22	1,686	0,777	0,848	95	77,652
1b2 10	112,52	47,07	159,59	275,84	116,25	232,15	72,56	131,23	290,82	1,602	0,809	0,764	95	80,857
1a1 30	111,77	49,46	161,23	283,16	121,93	243,24	82,01	139,18	300,41	1,487	0,697	0,863	95	69,711
1a2 30	111,41	44,81	156,22	265,77	109,55	226,93	70,71	128,68	284,9	1,549	0,820	0,744	95	81,983
1a3 30	112,94	56,19	169,13	277,56	108,43	237,54	68,41	130,76	299,89	1,585	0,911	0,720	95	91,142
1b1 30	108,18	49,52	157,7	283,44	125,74	233,68	75,98	138,3	296	1,655	0,820	0,800	95	82,022
1b2 30	112,88	56,87	169,75	307,72	137,97	254,68	84,93	147,5	317,25	1,625	0,737	0,894	95	73,672

Table A6: Results of laboratory measurements (Nussbaumer, 2025).

Standort	Tiefe (cm)	Kf (cm/s)*	Kf (cm/h)*	Kf (cm/d)*	ohdichte (g/cm^3)	Vkmax (Vol.-%)
2	0-10	1,14E-01	13,72	329,33	0,436	104,9
3	0-10	1,43E-02	1,71	41,00	0,458	103,0
4	0-10	1,02E-02	1,22	29,36	0,358	165,1
5	0-10	1,57E-02	1,88	45,00	0,493	112,8
2	20-30	3,08E-03	0,37	8,89	0,342	162,8
3	20-30	9,00E-03	1,08	25,87	0,451	103,7
4	20-30	2,08E-03	0,25	5,88	0,566	103,2
5	20-30	1,83E-03	0,22	5,17	0,338	177,9

Table A7: All data of all measurements, calculations and observations (2025).

Station-ID	Gebiet	X-Koordinate	Y-Koordinate	Formhöhe leit. cm ca	Horizont 1 DC cat	Horizont 2 DC cat	Horizont 3 Labor pH um	BD num	Wk num m	Stope cat	Humusart cat	pH Feldtest cat	Dat. Gewiss. ser m. cat	Indikator g. cat	Vegetation	Bodenwasser er cat	Bodemass er cat	Bodentyp	Durchlässigkeit leit. cat	Bodenmächtigkeit cat	Bodenmächtigkeit cat	Lage	Neuerschlag num	Wasserstand num	Stabilität num			
W1	Wiersbach	14,1833	47,5587	>100	H4	NA	NA	NA	NA	5	5	Torf	1	4	5	chwarzzerle Birke	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	mäßig	3	mittelgütig	Tabloden der Enns	2021205	NA	4,45		
W2	Wiersbach	14,1855	47,5584	>100	H2	H3	NA	NA	NA	4	5	Torf	1	4	4	chwarzzerle Birke	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	mäßig	3	mittelgütig	Tabloden der Enns	2021205	NA	4,45		
W3	Wiersbach	14,1833	47,5564	30-100	H3	NA	NA	NA	NA	4	5	Torf	1	5	5	chwarzzerle Birke	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	mäßig	3	mittelgütig	Tabloden der Enns	2021205	NA	4,5		
W4	Wiersbach	14,1836	47,5542	>100	H1	NA	NA	NA	NA	4	5	Torf	1	4	5	chwarzzerle Birke	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	mäßig	3	mittelgütig	Tabloden der Enns	2021205	NA	4,45		
W5	Wiersbach	14,182	47,5526	30-100	H2	NA	NA	NA	NA	4	5	Torf	1	4	4	chwarzzerle Birke	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	mäßig	3	mittelgütig	Tabloden der Enns	2021205	NA	4,3		
W6	Wiersbach	14,169	47,5535	30-100	H1	H2	NA	NA	NA	4	5	Torf	1	4	4	chwarzzerle Birke	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	mäßig	3	mittelgütig	Tabloden der Enns	2021205	NA	4,55		
W7	Wiersbach	14,187	47,5538	>100	H1	NA	NA	NA	NA	4	5	Torf	1	4	4	chwarzzerle Birke	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	mäßig	3	mittelgütig	Tabloden der Enns	2021205	NA	4,5		
W8	Wiersbach	14,184	47,5534	30-100	H6	NA	NA	NA	NA	5	5	Torf	1	4	4	chwarzzerle Birke	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	mäßig	3	mittelgütig	Tabloden der Enns	2021205	NA	4,35		
W9	Wiersbach	14,169	47,5507	>100	H6	H5	NA	NA	NA	5	5	Torf	1	5	3	chwarzzerle Birke	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	mäßig	3	mittelgütig	Tabloden der Enns	2021205	NA	4,35		
W10	Wiersbach	14,1892	47,5515	>100	H6	NA	NA	NA	NA	5	5	Torf	1	5	4	chwarzzerle Birke	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	mäßig	3	mittelgütig	Tabloden der Enns	2021205	NA	4,35		
I1	Irlding	14,111	47,5222	>100	H3	H3	NA	NA	NA	5	4	humus/Arm	3	5	3	Mähwede	3	uneinheitlichmäßig feucht / wechselseitlich	moor/Nied	mäßig	3	mittelgütig	im Tabloden/Senke	1,865915	NA	3,95		
I2	Irlding	14,101	47,521	>100	H5	H3	NA	NA	NA	5	4	humus/Arm	3	5	3	Mähwede	3	uneinheitlichmäßig feucht / wechselseitlich	moor/Nied	mäßig	3	mittelgütig	im Tabloden/Senke	1,865915	NA	3,9		
I3	Irlding	14,1094	47,517	30-100	H4	H3	NA	NA	NA	5	4	humus/Arm	3	5	3	Mähwede	3	uneinheitlichmäßig feucht / wechselseitlich	moor/Nied	mäßig	3	mittelgütig	im Tabloden/Senke	1,865915	NA	3,95		
I4	Irlding	14,1087	47,517	30-100	H5	H4	NA	NA	NA	5	4	humus/Arm	3	5	3	Mähwede	3	uneinheitlichmäßig feucht / wechselseitlich	moor/Nied	mäßig	3	mittelgütig	im Tabloden/Senke	1,865915	NA	3,95		
I5	Irlding	14,1087	47,523	<30	/	NA	NA	NA	NA	5	4	humus/Arm	3	5	3	Mähwede	3	uneinheitlichmäßig feucht / wechselseitlich	moor/Nied	mäßig	3	mittelgütig	im Tabloden/Senke	1,865915	NA	3,95		
I6	Irlding	14,1103	47,514	30-100	H4	H6	NA	NA	NA	5	4	humus/Arm	3	5	3	Mähwede	3	uneinheitlichmäßig feucht / wechselseitlich	moor/Nied	mäßig	3	mittelgütig	im Tabloden/Senke	1,865915	NA	3,75		
1a	Irlding	14,111	47,5124	NA	NA	NA	NA	5,30383	0,805	0,024	75,125	5	4	humus/Arm	3	5	3	Mähwede	3	uneinheitlichmäßig feucht / wechselseitlich	moor/Nied	mäßig	3	mittelgütig	im Tabloden/Senke	1,865915	-125,51	3,75
1b	Irlding	14,111	47,5124	NA	NA	NA	NA	5,302973	0,761	0,003	79,359	5	4	humus/Arm	3	5	3	Mähwede	3	uneinheitlichmäßig feucht / wechselseitlich	moor/Nied	mäßig	3	mittelgütig	im Tabloden/Senke	1,865915	0	0
2a	Irlding	14,111	47,519	NA	NA	NA	NA	5,62	0,436	0,114333	104,8906	5	4	humus/Arm	3	5	3	Mähwede	3	uneinheitlichmäßig feucht / wechselseitlich	moor/Nied	mäßig	3	mittelgütig	im Tabloden/Senke	1,865915	-105,89	3,95
2b	Irlding	14,111	47,519	NA	NA	NA	NA	5,11404	0,342	0,00383	162,8327	5	4	humus/Arm	3	5	3	Mähwede	3	uneinheitlichmäßig feucht / wechselseitlich	moor/Nied	mäßig	3	mittelgütig	im Tabloden/Senke	1,865915	0	0
3a	Wiersbach	14,1839	47,589	NA	NA	NA	NA	7,27	0,458	0,01425	103,0043	5	4	humus/Arm	5	5	3	Seggen	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	beschnei	5	teigförmig	Tabloden der Enns	2021205	-87,71	4,55
3b	Wiersbach	14,1889	47,589	NA	NA	NA	NA	6,58428	0,451	0,009	103,7374	5	4	humus/Arm	0	5	3	Seggen	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	beschnei	5	teigförmig	Tabloden der Enns	2021205	0	0
4a	Wiersbach	14,168	47,557	NA	NA	NA	NA	7,51	0,358	0,010367	165,087	5	5	Torf	1	4	3	chwarzzerle Birke	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	mäßig	3	mittelgütig	im Tabloden/Senke	2021205	-85,28	4,3
4b	Wiersbach	14,168	47,557	NA	NA	NA	NA	6,93417	0,566	0,002083	103,1513	5	5	Torf	0	4	3	chwarzzerle Birke	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	mäßig	3	mittelgütig	im Tabloden/Senke	2021205	0	0
5a	Wiersbach	14,165	47,5574	NA	NA	NA	NA	7,3	0,483	0,015867	112,7906	4	5	Torf	1	4	3	chwarzzerle Birke	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	mäßig	3	mittelgütig	im Tabloden/Senke	2021205	-80,55	4,4
5b	Wiersbach	14,1695	47,5574	NA	NA	NA	NA	6,652034	0,338	0,001833	177,8623	4	5	Torf	0	4	3	chwarzzerle Birke	4	gut versorgt / feucht / wechselseitlich mit Überwiegender fauchten Phase	moor/Nied	mäßig	3	mittelgütig	im Tabloden/Senke	2021205	0	0

Appendix B Field Measurements

Übersicht zur Bestimmung der Humifizierungsgrade für Torfe

nach POST (1924) und GROSSE-BRAUCKMANN et al. (1977) in SUCCOW (1988), zit. n. MEIER-UHLHERR, R., SCHULZ, C. & LUTHARDT, V. (2011): Steckbriefe Moorsubstrate.
HNE Eberswalde (Hrsg.), Berlin, modifiziert

Zur Bestimmung des Humifizierungsgrad feuchter, grubenfrischer Torfe wird neben der Betrachtung der Pflanzenstrukturen im Torf ein etwa hühnereigroßes Stück Torf in der Faust gepresst und dabei die Farbe des austretenden Wassers, die Menge des zwischen den Fingern hindurchtretenden Torfes und der Rückstand beim Quetschen beurteilt.

Humifizierungsgrad	Merkmale feuchter, grubenfrischer Torfe			Merkmale trockener Torfe	
	Pflanzenstrukturen im Torf	beim Quetschen zwischen den Fingern hindurchgehend:	Rückstand nach dem Quetschen	strukturierte Pflanzenreste im Torf	Farbe des Torfes
H1 äußerst gering	deutlich erkennbar	farbloses klares Wasser	nicht breiartig	einziger erkennbarer Bestandteil	weißlich bis gelb
H2 sehr gering		schwach gelbbraunes, fast klares Wasser			ziemlich hellbraun
H3 gering		braunes, deutlich trübes Wasser			dunkler braun
H4 mäßig		braunes, stark trübes Wasser			ziemlich dunkel bis schwarz
H5 mittel		stark trübes Wasser, daneben etwas Torfsubstanz	etwas breiartig	nahezu einziger erkennbarer Bestandteil	
H6 mittel - hoch	schwach undeutlich erkennbar	bis 1/3 der Torfsubstanz	stark breiartig	über 2/3 der Torfsubstanz	
H7 hoch	undeutlich erkennbar	etwa 1/2 der Torfsubstanz	Pflanzenstrukturen deutlicher als vorher	etwa 1/2 der Torfsubstanz	
H8 sehr hoch	sehr undeutlich	etwa 2/3 der Torfsubstanz	besonders aus widerstandsfähigen Resten (z. B. Fasern, Holz)	etwa 1/3 der Torfsubstanz	
H9 äußerst hoch	fast nicht mehr erkennbar	fast die gesamte Torfsubstanz		nur sehr wenig der Torfsubstanz	
H10 vollständig	nicht mehr erkennbar	die gesamte Torfsubstanz	kein Rückstand	keine pflanzlichen Strukturen	

Anmerkung:

Diese Übersicht gilt nur für primäre, im Zuge des Moorwachstums aufgewachsene Torfe, nicht für infolge von Entwässerung sekundär zersetzte Torfe (vererdet, vermulmt).

Figure B1: Scheme for identifying the degree of decomposition in the field. Adapted from von Post (1924)(HNE Eberswalde, 2011).



Figure B2: AMooRe site 1 in Irdning (own picture, 2025).



Figure B3: AMooRe site 4 in Wörschach (own picture, 2025).



Figure B4: AMooRe site 5 in Wörschach (own picture, 2025).



Figure B5: Peat thickness measurement with the Pürkhauer in Wörschach (own picture, 2025).



Figure B6: Peat degree of decomposition measurement according to von Post (1924) in Wörschach (own picture, 2025).

Appendix C GIS Suitability Modeling

Table C1: Classification of slope value layer in Suitability Map (own table, 2025).

Category	Value	Justification
< 2%	5	flat, level slope
2%-5%	3	low slope gradient, good potential for rewetting
>5%	1	high slope gradient, rather unsuitable

Table C2: Classification of distance to water layer in Suitability Map (own table, 2025).

Category	Value	Justification
0-50 m	5	Proximity to water bodies at its highest
50-100 m	4	Proximity to water bodies high
100-200 m	3	Moderate proximity to water bodies
>200m	1	far distance to bodies of water

Table C3: Classification of land use layer in Suitability Map (own table, 2025).

Category	Value	Justification
Wetlands, standing waters, water courses	5	Very high suitability for rewetting potential
Forest land, perennial cropland	4	High suitability for rewetting potential
Grassland, annual cropland	3	Moderate suitability for rewetting potential
Parks and gardens; others	2	Low suitability for rewetting potential
Building land – sealed and partly sealed;	1	Very low suitability for rewetting potential

Table C4: Classification of humus type layer in Suitability Map (eBOD, 2025).

Category	Value	Justification
Peat	5	Very high suitability for rewetting potential
Gleyic humus / anmoor mull	4	High suitability for rewetting potential
Mull + moder mull + gleyic mull (heterogeneous)	3	Moderate suitability for rewetting potential
Moder mull	2	Low suitability for rewetting potential
Mull	1	Very low suitability for rewetting potential

Table C5: Classification of soil permeability layer in Suitability Map (eBOD, 2025).

Category	Value	Justification
Very high	5	Sandy, well-structured, coarse sand, gravel
Moderate	3	Loam, silty sand
Very low	1	Highly compacted, clayey, fine-textured (clay, silt)

Table C6: Classification of soil thickness layer in Suitability Map (eBOD, 2025).

Category	Value	Justification
Very deep	5	High storage potential and capacity
Moderately deep	3	Limited root space, average soil
Very shallow	1	Low storage capacity, high drainage tendency

Table C7: Classification of soil water conditions in Suitability Map (eBOD, 2025).

Category	Value	Justification
Wet, moist to wet	5	Very wet, optimal conditions for rewetting Very wet conditions, almost saturated
Moist, well supplied, alternating moisture with a predominance of the moist phase	4	Wet, good water supply Soil well supplied with water, high water capacity Varying moisture, mostly moist
alternating moisture uneven moderately moist	3	Varying moisture, moderately suitable Uneven moisture conditions, moderately suitable Moderate moisture
moderately dry dry to moderately dry	2	Relatively dry, low water capacity Between dry and moderately dry
Dry	1	Dry, not suitable for rewetting

Table C8: Classification of soil type layer in Suitability Map (eBOD, 2025).

Category	Value	Justification
Anmoor, Transitional mire fen, bog	5	Organic, high water retention capacity, very well suited for peatland conservation, Highly organic, high water retention capacity, very suitable, Typical peat soil, high organic content, very good for rewetting, High organic layer, water-rich, best conditions for rewetting
Gley, Typical gley	4	Heavily water-saturated soils with good rewetting potential, Moist, groundwater-influenced soils, highly suitable for rewetting
Brown alluvial soil, Alluvial soil	3	Transitional area, slightly higher water storage capacity, Moderately water-saturated, potential rewetting area
Loose sediment brown soil, brown earth, brown loam,	2	Mineral, low water storage capacity, low rewetting potential Mineral to humic, dry, low potential for rewetting, Like brown earth, moderate water storage capacity
Pararendsina, rocky brown earth, Ranker	1	Calcareous, dry soils, poor rewetting potential Stony, very low water retention capacity, hardly suitable Flat, stony soils with low water storage capacity

Table C9: Classification of pH value layer in Suitability Map (eBOD, 2025).

Category	Value	Justification
3,5-4,5	5	Peat accumulation, low decomposition and good for Sphagnum growth
4,5-5,5	4	Neutral and optimal for most plants, good for transition mires
5,5-7,5	3	Moderately acidic, still acceptable for many plants, often found in agricultural soils
>7,5	2	Acidic soils, often found in rich fen peat soils, mineral soil influence
<3,5	1	Highly acidic (very unsuitable for most vegetation, degradation