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Declining extent of fen peat deposits over the past 50 years in Ogre Municipality, central Latvia

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ABSTRACT

Latvia's peatlands play an important role in achieving the country's climate goals and preserving natural diversity. Approximately 10% of Latvia's territory is covered by peatlands, more precisely defined as peat deposits. However, outdated inventories of these peatlands hinder the development of sustainable policies for managing natural recourses. This lack of data also complicates efforts to predict the extent of fens and assess their potential contribution to climate change mitigation, such as through rewetting activities. In this study, we assessed the extent of fens in one of Latvia's largest municipalities – Ogre. After a feasibility study using GIS tools, fen peat deposits were randomly selected and surveyed in the field to determine the type, thickness, and characteristics of the peat. Among the 20 sites surveyed, only five corresponded to fen peat deposits (with a peat layer of at least 30 cm), and only one of these qualified as a fen also in terms of vegetation and moisture regime. Existing fen peat deposits are subject to intensive erosion, mineralization, and decomposition, leading to greenhouse gas emissions. The results indicate that there are significantly fewer fen peat deposits than previously assumed, and a detailed analysis of their extent, involving field inspection and verification at the national level, is needed.

Introduction

Peat and peat soils contain up to 30% of the world's soil carbon stock, making them one of the most important carbon sinks (Jauhiainen et al. 2019). Latvia, like many other European Union countries, has announced its commitment to achieve climate neutrality by 2050 (Cabinet of Ministers 2020). Due to its geography and geological history, Latvia has a significant number of peatlands, which can be part of the solution to the country's climate and biodiversity objectives. An integral part of the European Green Deal is the development of carbon sequestration solutions to capture carbon dioxide from the atmosphere and store it in peatlands (Tanneberger et al. 2021). Peatlands act as natural carbon sinks by storing organic sediment, or peat, formed from plant residues without being fully decomposed in the anaerobic environment of water. Therefore, peatlands are considered as a crucial nature-based climate solution in greenhouse gas (GHG) emission reduction, particularly in the near term, i.e., 2030–2050 (Griscom et al. 2017; Strack et al. 2022).

The initiation of fens in Latvia dates back ca 11 000 years (Kalnina et al. 2015; Stivrins et al. 2025). Over the past 300 years, European peatlands have undergone substantial and widespread drying (Swindles et al. 2019). A slowdown in peat formation and carbon accumulation can also be expected in Latvia under warmer and drier climate scenarios (Felsche et al. 2024; Stivrins et al. 2025).

According to the State Audit Office of the Republic of Latvia (2023), the lack of data hinders the development of sustainable policies for managing natural resources. This lack of data also complicates efforts to predict the extent of peatlands and their potential contribution to climate change mitigation, as only about 60% of peat deposits are identified, based on peat stock data obtained between 1962 and 1980.

Over the last century, intensive drainage of peatlands has exposed existing peat to mineralization, making them sources of emissions rather than sinks of GHGs (IPCC 2019). Latvia ranks fifth among European countries in terms of GHG emissions from drained areas, with over half of the country's total emissions assumed to come from organic soils (Martin and Couwenberg 2021). When assessing soils, it is important to consider that they have a higher rate of decomposition of organic compounds due to their lower moisture and higher oxygen content (Sierra et al. 2017). New inventories of existing peatlands as well as the identification of drained areas can contribute to sustainable policies, as restoring their moisture regime can be one of the tools to mitigate climate change (Alm et al. 1999; Aalde et al. 2003; European Environmental Bureau 2021; Nature Conservation Agency 2022).

In Latvia, the terms *bog*, *fen*, *peatland*, and *peat soil* are often used as synonyms, but there are fundamental differences between them. For example, peat soil is defined as soil with a peat layer of at least 40 cm in the undrained state (Ministry of Agriculture 2023). Meanwhile, a peatland is considered as a peat deposit if it covers an area of at least 2 ha and has a commercially exploitable peat thickness of 0.9 m in a natural peatland or 0.7 m in a drained peatland, with an average peat layer thickness of >1 m (LVĢMC 2023). According to official information, such as the legislation and databases of the Latvian Environment, Geology and Meteorology Centre (LVĢMC), the term *peatland* generally refers to peat deposits, which cover 10% of Latvia's territory. Almost half of these areas are estimated to be fens (LVĢMC 2023).

A fen is a specific type of mire that is fed by groundwater or surface water and is usually rich in minerals, making it more alkaline. Fens form under wet conditions, where depressions become wet either due to groundwater recharge or increased rainfall, leading to fen peat accumulation in depressions dominated by low-permeability sediments (e.g., moraine sandy loam/till). Commonly, fens support a more diverse plant community, with grasses, sedges, and various plants adapted to the mineral-rich conditions. Fen peat is often predominantly formed by vascular plant roots and rhizomes growing into the existing peat body; i.e., primarily below-ground biomass is of importance (Michaelis et al. 2020). Regarding the term *peatland*, Joosten and Clarke (2002) define it as an area, with or without vegetation, that has a naturally accumulated peat layer at the surface and a minimum peat depth of 30 cm. In Latvia, as in many other countries, peat depth is a key criterion for defining an area as a peatland (Lourenco et al. 2022; Nusbaums and Rieksts 1997; International Peatland Society 2024). Uncertainty about the terminology can lead to the incorrect attribution of data, especially when peatlands are referred to as functioning ecosystems or areas with peat but without corresponding peat-specific vegetation (e.g., LVĢMC 2023).

The aim of this study is to assess the extent and changes of fen peat deposits in Ogre Municipality over the past 50 years. We focus on a particular region, rather than the whole territory of Latvia, as our aim is to test whether there are any discrepancies at all in comparison to the official data.

Materials and methods

Study area

Ogre Municipality (1838 km^2) is located in central Latvia (Fig. 1) and belongs to the Vidzeme planning region. In 1928, when Ogre acquired the status of a city, it had fewer than

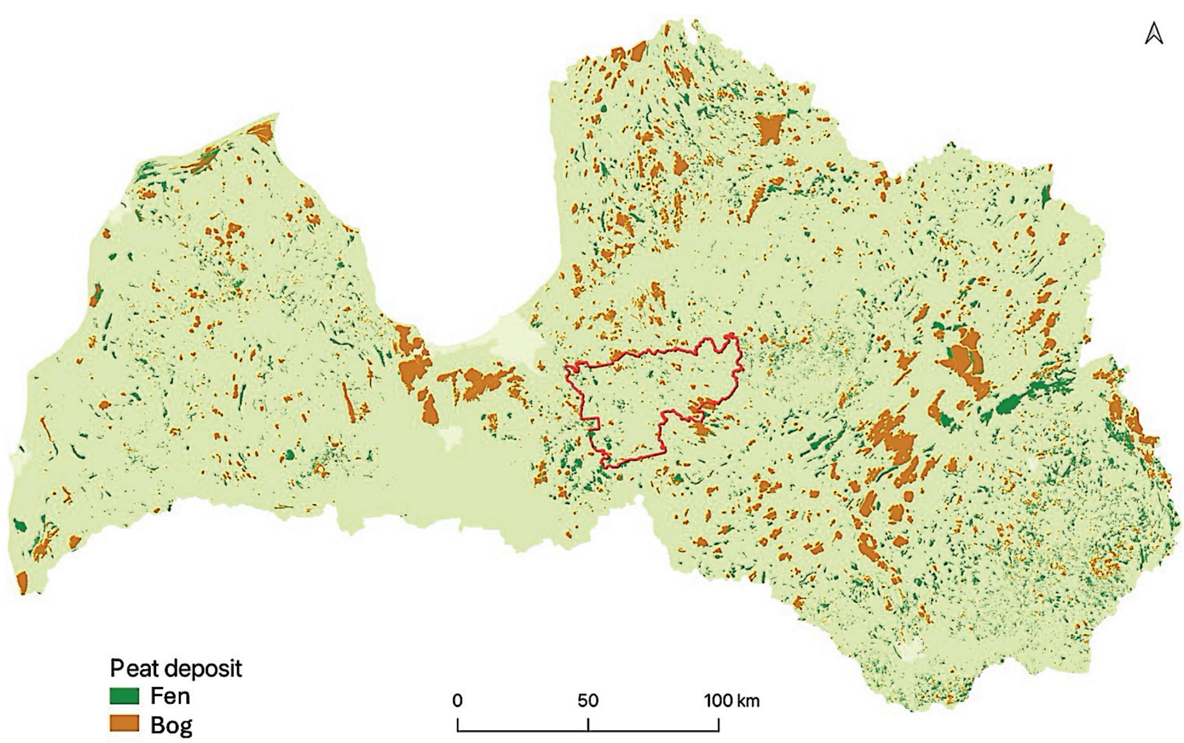

Fig. 1. Distribution of peat deposits in Latvia: bogs in brown-orange, fens in green, and Ogre Municipality outlined in red. Created using data collected and digitized within the framework of the European Regional Development Fund project "Innovations in Peat Research and Development of New Products Containing Peat" (project No. 2DP/2.1.1.1.0/10/APIA/VIAA/037; LVĢMC 2023).

2000 inhabitants, but the population grew significantly in the middle of the last century, encouraged by the proximity of Riga and the construction of a knitwear factory by the USSR. The factory brought in 5000 migrant workers and led to the construction of a large number of high-rise apartment buildings to provide residences, resulting in changes in land use (Ministry of Environmental Protection and Regional Development 2020). Of the total area, 56% is covered by forests, 41% by agricultural land (Ogre Municipality 2022), and peatlands in the municipality account for 1867 ha or 1.1% (State Land Service 2023). The area has marked differences in altitude and is therefore characterized by undulating terrain with depressions where peat can accumulate.

Data collection

Data on the location of fens were obtained from the Peat Fund maps (1962–1980), with improvements made by the Latvian Environment, Geology and Meteorology Centre (LVĢMC 2023) in 2020. The work uses the Ogre Municipality layer, which corresponds to the administrative-territorial division from the reform of July 1, 2021. In the current study, we use the official term for peatland (LVĢMC 2023) – *fen peat deposit*, indicating at least 30 cm of peat over an area of at least 2 ha (Nusbaums and Rieksts 1997; LVĢMC 2023). This term is used in the representation of peatland distribution at the national level and also in the national GHG reports (Jauhiainen et al. 2019).

Data analyses

To compare and assess possible changes in the distribution of fens, a remote sensing method was used to visually determine whether each fen peatland deposit resembled the open landscape characteristic of fens. Remote sensing and spatial analysis were carried out using the open-source software QGIS (version 3.36.2) and ArcMap (version 10.8.2). To successfully locate fens from the Peat Fund data, and using a coordinate system compatible with the current study (LKS92 / Latvia TM), the following maps were used: (1) 6th cycle orthophoto (2016–2018); (2) topographic map M 1:10000 from 1984 (University of Latvia 2024); (3) LVĢMC data on peat deposit points and polygons (LVĢMC 2023); (4) peat soils from the historical soils database (University of Latvia 2024); (5) OZOLS database (Nature Conservation Agency 2024); and (6) Latvian peat soil distribution (Ministry of Agriculture 2023). As there might be discrepancies in the geolocation of fens across various databases, it was subjectively assumed that a maximum possible offset of up to 500 m, measured from the center of the designated site to the edge of the peat deposit, would be acceptable for the location of the fens. In addition, if the size of a peat deposit was less than 2 ha (due to urban buildings, quarries, ponds, etc.), it did not meet the characteristics of a fen peat deposit and was marked as non-existent. If the orthophoto map showed an organic-rich agricultural field, it was assumed that the natural fen no longer existed but was still accounted for as a fen peat deposit. Spatial analysis tools were used to calculate the total area, in km^2, occupied by fen peat deposits in Ogre Municipality.

To determine whether the peat layer was at least 30 cm thick, a total of 20 fen sites were randomly selected for field inspection, where soundings were performed with a peat corer (50 cm long, 7 cm wide). It was assumed that if the site was a peat deposit, there would be a peat layer of at least 30 cm, regardless of where within the LVĢMC's range of specific fen peat deposits the probing occurred. In deposits where the peat thickness was 30 cm or more, peat sediments were sampled for further analyses at the Quaternary Laboratory of the University of Latvia. The loss-on-ignition method was used to determine the percentage of organic matter in the collected sediments. Every cm (1 cm^3 sample volume) of each sediment sequence was analyzed following Heiri et al. (2001). Changes in organic matter distribution through the peat cores were then characterized and used in further interpretations.

Results

In the fieldwork carried out in the 20 surveyed bogs, a peat layer thickness of 30 cm, as well as the required size for a peat deposit of 2 ha, was found in three peat deposits: Jaunzušu, Ķervāni, and Būdas-Vistuļu peatlands (Fig. 2). Of these, only the Būdas-Vistuļu peatland exhibited a moisture regime and vegetation that corresponded to those of a fen. The other sampled sites were drained fens used for agriculture (agricultural fields).

The Kalna-Tuču samples contained a small admixture of organic matter. The results of the loss-on-ignition analysis showed that the organic matter content of sediment at 32 cm depth was only 41%, after which the organic content decreased upward to 5–10%, with a slight increase to 20% at 3 cm depth. Hence, the Kalna-Tuču site (Fig. 3) revealed insufficient organic matter content (mineral content >50%) to meet the criteria for a fen peat deposit. The rest of the sites had a sufficient amount of organic matter content to be classified as fen peat deposits. A common pattern was observed in the organic matter distribution at the Ķervāni, Būdas-Vistuļu, and Jaunzušu sites, with a decrease toward the top.

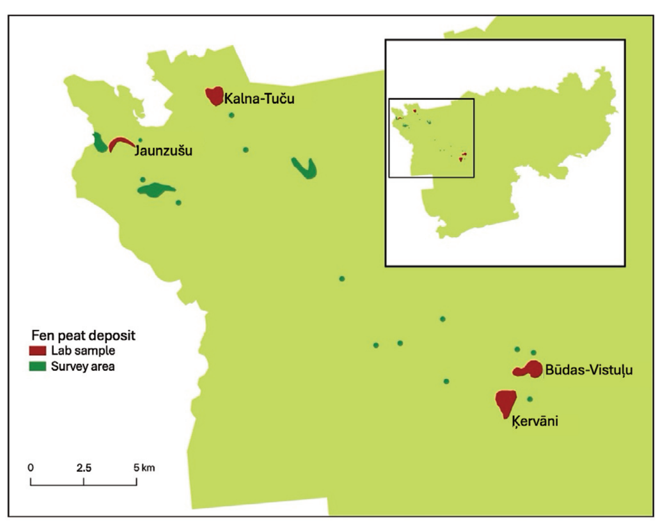

Fig. 2. Fen areas surveyed in the northwestern part of Ogre Municipality during the fieldwork (green) and the four fen peat deposits sampled for further laboratory analyses (dark red-brown).

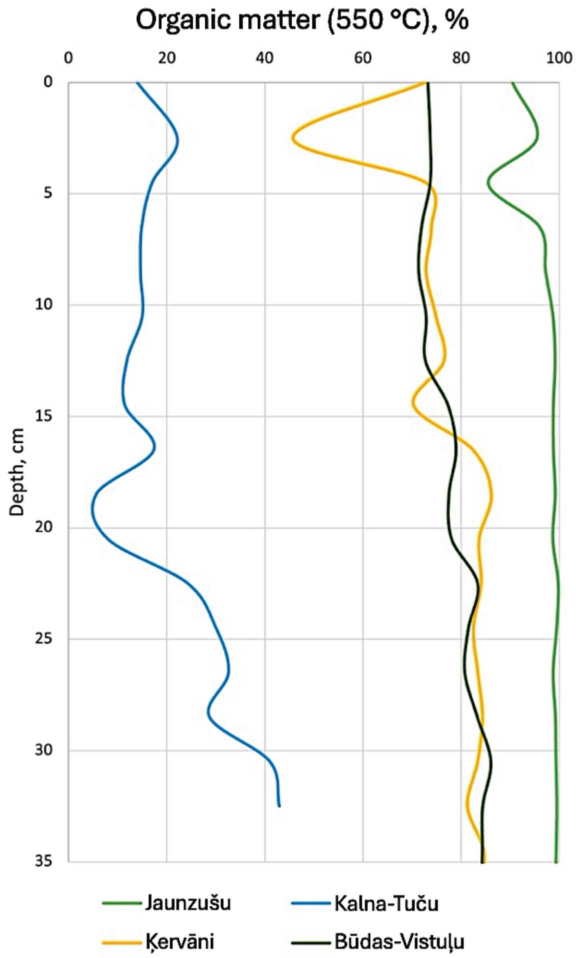

Fig. 3. Results of the loss-on-ignition analysis from four fen peatland samples. The x-axis represents the organic matter content in the sediments.

In the Būdas-Vistuļu samples, the decrease in organic matter gradually decreased from 23 cm depth, where the organic fraction was 81%. The minimum value of 75% was attributable to the topmost 1 cm. In the Ķervāni samples, the relative organic content decreased from a depth of 16 cm (83%) and reached its minimum at a depth of 3 cm (44%). Only the Jaunzušu fen peat deposit had an organic matter content >82%. Similarly to the other sites, a decrease toward the surface was also observed here (Fig. 3).

According to the remote land use survey, there have been significant changes in the distribution of fens since 1962–1980, with 153 out of 218 fen peat deposits remaining, covering a total area of 43.3 km^2, which represents a 13.3% reduction in fen peat area. The most significant changes in the distribution of fen peat deposits have been observed in the vicinity of cities. For instance, some fen peat deposits have been removed to accommodate house blocks (Fig. 4). While these fen peat deposits were listed in the official Peat Fund Register for both 1962–1980 and the updated version from 2020, no trace of them remains in the field.

Alongside urbanization, mining activities in Ogre Municipality have led to the disappearance of certain fen peat deposits. For example, sand, gravel, or dolomite mining involves removing the topmost surface soil and organic-rich sediments to create quarry pits (Fig. 5). While fen peat deposits are not always entirely lost, the mining processes often result in prolonged and additional drainage in the surrounding areas.

Land use changes have led to a significant decrease in the extent of fen peat deposits in Ogre Municipality (Fig. 6). In 1962–1980, a total of 49.9 km^2 of fen peat deposits were

Fig. 4. Example of a lost fen peat deposit in Ogre city, where house blocks have been constructed on a previous fen peat deposit site.

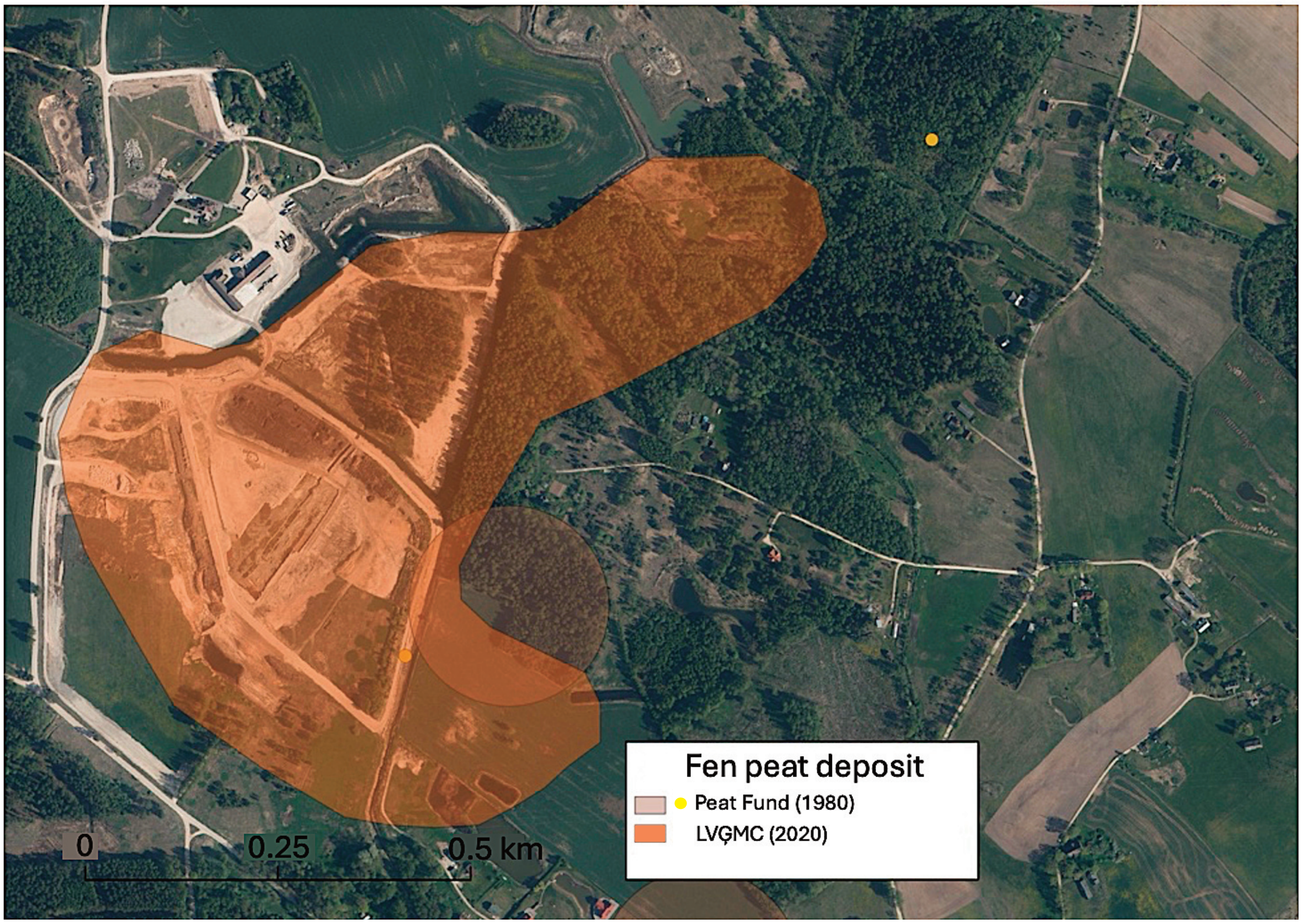

Fig. 5. Example of a fen peat deposit lost due to mining activities.

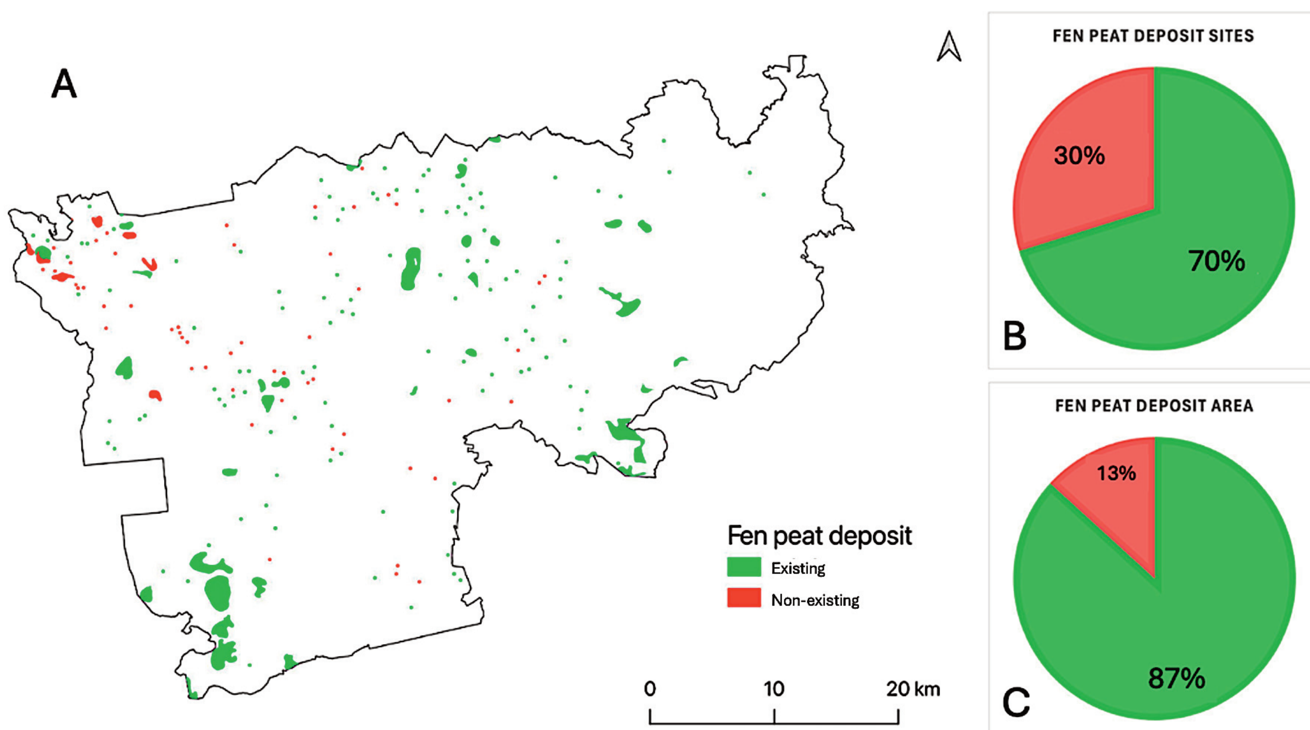

Fig. 6. Changes in the distribution of fen peat deposits in Ogre Municipality, comparing data from 1962–1980 and 2024: **A** – spatial distribution changes, **B** – changes in the number of sites, **C** – changes in total area.

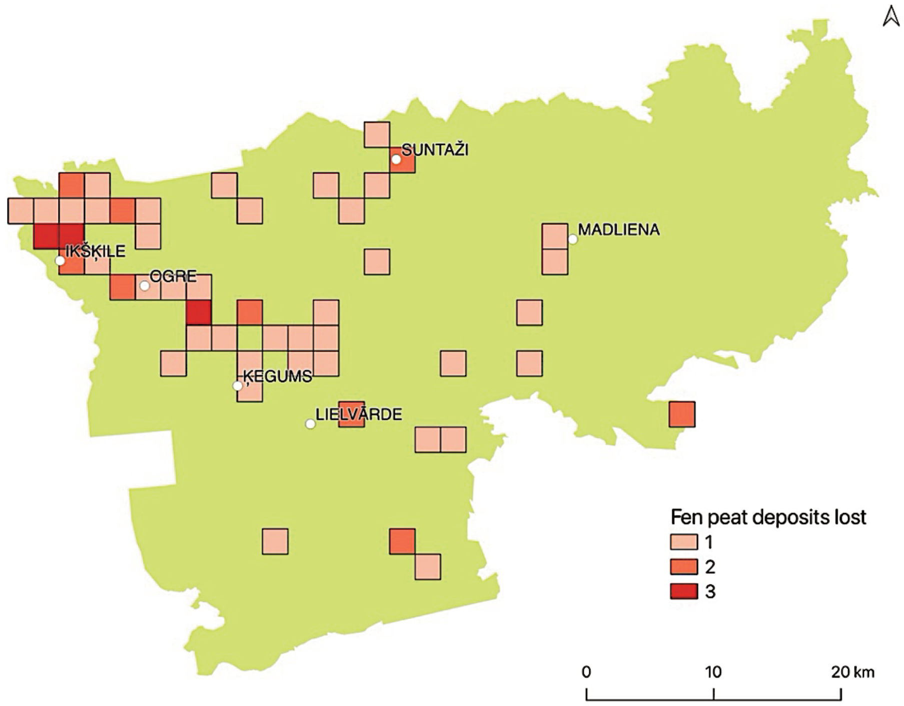

Fig. 7. Heat map illustrating the loss of fen peat deposits in Ogre Municipality. Each cell represents the number of lost fens within a 5 km radius: 1 – one lost fen, 2 – two lost fens, 3 – three lost fens. The map highlights spatial patterns of fen degradation in the region.

mapped in the municipality. However, after additional adjustments in 2020 (LVĢMC 2023), fen peat deposits accounted for 50.6 km^2. Although these numbers indicate a slight increase, it is likely that there has not been a scrutinized review of remote data or a detailed comparison with the present-day situation. Our remote analysis results show that 30% of fen peat deposit sites have been lost (Fig. 6). In terms of area, 13% of the fen peat deposits mapped in the 1962–1980 period have disappeared.

Higher loss of fen peat deposits was observed closer to cities and villages (Fig. 7), such as Ikšķile, Suntaži, Lielvārde, Ogre, and Ķegums. Some fen peat deposits also diminished in rural areas, aligning with the distribution of agricultural fields. Although visually distinctive changes are evident from the orthophoto maps, additional field verification is important. Therefore, the estimates of fen peat deposit conditions in this study should be considered as rough minimal estimates of the actual extent of the issue.

Discussion

Climate change-induced fluctuations in precipitation and air temperature play an important role in the formation and persistence of wetlands, affecting the overall plant life cycle and environmental conditions (Liepiņa 2017; Bambe et al. 2024). A recent study by Felsche et al. (2024) demonstrated a notable northward shift in the climatology of hot and dry summers anticipated in the Baltics under the current climate change trajectory. Higher summer temperatures, driven by increased solar insolation, may lead to greater evaporation and drier soil conditions during the growing season, which are unfavorable for peat formation and preservation. In a warmer and drier climate, peat formation can slow due to enhanced decomposition processes, similar to conditions during the warmest phase of the Holocene (8200–4200 years ago) in Latvia (Kalnina et al. 2015; Stivrins et al. 2025). Decomposition is generally fast under aerobic (oxygen rich) conditions, where most of the initial plant mass is mineralized (Malmer and Wallén 2004).

For peat accumulation and preservation, it is crucial to maintain water-saturated, anoxic, or oxygen-limited conditions (Drzymulska 2016). Our results from the loss-on-ignition analysis (Fig. 3) indicate possible overburden mineralization of the surface peat layers. This raises concerns that most of the sites may soon no longer qualify as fen peat deposits. The disappearance of these sites may not always mean that the peat deposit has entirely disappeared; rather, as the peat mineralizes and decomposes, the thickness of the peat layer decreases, thereby affecting the size of the deposit. Official data on peatlands state that the peatlands in Latvia cover 964 208 ha, of which fens account for 369 634 ha (38% of all peatlands). However, the current study tentatively suggests that these figures are likely overestimated. Although the Nature Counting project (Nature Conservation Agency 2022) has provided additional information on peatlands, it surveyed only peatland habitats of European Union importance within a 149 517 ha area, such as active raised bogs (habitat type No. 7110), alkaline fens (habitat type No. 7230), and Fennoscandian mineral-rich springs and spring fens (habitat type No. 7160). While this is a highly relevant and important update for the protection and biodiversity of peatlands, there is no institution monitoring the so-called ordinary fens and fen peat deposits outside of the habitats' protection framework.

Our results show that urban development in Ogre Municipality, alongside drainage for forest logging and agriculture, has contributed to the loss of fen peat deposits. The majority of the lost fen peat deposits (74%) are within a 5 km radius of cities. The number of lost sites identified in the fieldwork was 85%, compared to only 30% during the remote sensing survey. Due to limited visibility and lack of information on the actual thickness of the peat layer and on-site vegetation, we cannot confirm that the fen peat deposits, especially those in forests, still exist. These results suggest that the true number and distribution of fen peat deposits could be critically reduced (by 30–85%) compared to the official data. Extensive field mapping of fen peat deposits is needed, as not all can be identified remotely or through modelling. Van der Velde et al. (2021) even suggest that peatlands with a thin peat layer should be included in national inventories, considering the status of peatland health, reported emissions, and monitoring to ensure preservation. This will not be possible if inventories are based on outdated peatland extent. Indeed, as 1962–1980 was a period of intense drainage, which continued into the 1980s, these old data cannot be fully trusted. However, they give an indication where existing deposits are most likely located and where their presence should be checked. Fens, which account for 38% of all Latvian peatlands, are most probably overestimated. For comparison, 90% of Estonian fens have been drained for agriculture and forestry, with only 10% remaining (Paal and Leibak 2013). One option to halt the disappearance of fen peat deposits is rewetting. It has been suggested that sedge communities establishing after rewetting have the potential for renewed peat formation, regardless of the prevailing trophic level (Hinzke et al. 2021). This is, however, a highly debated topic in Latvia, and more science-based studies are highly relevant in this regard (e.g., Jurasinski et al. 2024).

Conclusions

Existing fen peat deposits are subject to intensive mineralization, which means that the existing peat layers are decomposing, resulting in GHG emissions and the eventual disappearance of these deposits. Urban development in Ogre Municipality, along with drainage for logging and agriculture, has contributed to the loss of fen habitats and fen peat deposits. The main conclusion of this study is that there are significantly fewer fen peat deposits than previously indicated, for example, by the LVĢMC's database. A more detailed analysis of their distribution is needed, with inspection and verification in the field at the national level.

Data availability statement

Research data associated with this study are available upon request from the corresponding author.

Acknowledgments

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