Radboud University
Department of Ecology
Heyendaalseweg 135
6525AJ Nijmegen
the Netherlands

Radboud Universiteit
SINCE 1923

Subject: PhD Thesis Pouya Ghezel Ayagh

31st August 2026

Dear examination committee

It has been a great pleasure and interest for me to evaluate the thesis "Assessing selected environmental properties of peatlands on a large spatial scale using the remote sensing tools and datasets" by Pouya Ghezel Ayagh conducted at the Warsaw University of Life Sciences under supervision by Professor Mateusz Grygoruk, head of the SGGW Centre for Climate Research.

Overall, the thesis is an original, well-structured and society-relevant contribution to water management, climate adaption and peatland science. It successfully links remote sensing, field validation and carbon-emission assessment across a representative European lowland setting. While inherent methodological uncertainties remain, e.g. around indirect carbon estimates, the work provides strong foundations for future climate monitoring and management applications.

Originality

The thesis provides an original and extensive assessment of hydrological controls, soil subsidence and climate mitigation potential in organic-rich lowland soils, with a strong focus on fen peatlands. Its originality lies in linking peat surface movement with water-level and soil-moisture dynamics across a gradient of land management, from relatively natural peatlands to drained agricultural systems. The three research chapters build a coherent argument: the first establishes remote sensing of soil subsidence, the second interprets vertical displacement in relation to carbon accumulation and degradation, and the third translates these observations into estimates of carbon emissions. The selected study area is large, environmentally diverse and representative of many European lowland peatland landscapes, which strengthens the wider relevance of the findings.

Innovation

The work is innovative in its use of public Sentinel-1 InSAR data to assess peat soil subsidence at a scale that cannot be achieved through field measurements alone. The thesis combines remote sensing, field validation, existing process relationships and statistical analysis in a way that is technically ambitious and policy relevant. The comparison among sites such as Biebrza, Wizna and Rospuda is particularly valuable because it captures differences in drainage intensity, management and peatland condition. The third chapter is especially innovative in moving from observed subsidence towards carbon-emission estimates. This progression is innovative because it connects observation, interpretation and application. The combination of field measurements, existing process relationships, spatial analysis and gradient-based comparison provides a strong methodological framework. At the same time, some methodological assumptions require caution. Subsidence is not a direct measurement of carbon loss; it may also reflect shrinkage, compaction, vegetation effects and elastic responses to water-table change.

Radboud University
Department of Ecology
Heyendaalseweg 135
6525AJ Nijmegen
the Netherlands

Relevance

The thesis is highly relevant for climate policy, peatland restoration, water management and land-use planning. It provides evidence that drained and intensively managed peatlands are associated with greater subsidence and potentially higher carbon losses, while better-preserved systems show lower but still measurable vulnerability. This is important for policy makers, water authorities, farmer organisations and restoration practitioners because peatlands are key hotspots for both climate mitigation and water retention. The work is also timely, as it addresses peatland dynamics after recent drought years and under increasing pressure on regional water resources. By focusing on a representative European lowland catchment, the thesis generates insights that are relevant beyond the immediate study area. Its strongest policy contribution is the development of scalable tools that can help identify degradation hotspots and support prioritisation of rewetting or conservation measures. The potential addition of remote sensing vegetation proxy data may have opened up an integration into biogeochemical plant-soil-carbon modelling frameworks. Yet vegetation is inherently challenging to study from space.

Scope of scientific achievements

The scientific achievement is substantial. The thesis provides technical foundations for remote-sensing-supported greenhouse-gas science and peatland monitoring. Chapter 1 demonstrates that InSAR can detect peatland vertical displacement with meaningful field validation. Chapter 2 expands this towards ecological interpretation across contrasting peatland systems. Chapter 3 develops a practical framework for estimating CO_2-related emissions. However, the scope also has limits. The current framework is strongest for CO_2 linked to oxidation-related subsidence. The approach seems adoptable to other biogeochemical domains. However, for the time being it does not yet fully account for CH_4, N_2O, dissolved carbon export, erosion, or short-term hydrological pulses. Future work should therefore integrate flood duration, water-table dynamics, eddy-covariance or chamber measurements, and more advanced biogeochemical models. This would improve attribution and support more complete climate-policy applications but would have required a much larger project, human ressources and time.

Scientific independence

The thesis demonstrates a high level of scientific independence. It brings together publicly available and verifiable remote sensing datasets, field observations, carbon-release subsidence models and statistical interpretation into a coherent research programme. The work appears to have been conducted with a relatively small team, yet achieves a large analytical scope. The thesis is well framed, technically ambitious and generally well discussed. Its main limitation is not lack of effort or originality, but the inherent difficulty of inferring complex peatland carbon processes from surface displacement. Overall, it represents an independent, innovative and policy-relevant contribution to remote sensing-based peatland assessment.

Radboud University
Department of Ecology
Heyendaalseweg 135
6525AJ Nijmegen
the Netherlands

Chapter 1– Remote sensing of peat soil subsidence

This chapter asks whether Sentinel-1 InSAR data, processed through an accessible cloud-based workflow, can provide a reliable catchment-scale indicator of peat soil vertical displacement. The study focuses on the Biebrza Valley in Poland and applies ASF OnDemand InSAR products, a Small Baseline Set approach, and a seasonal–annual image selection procedure to reduce errors from vegetation, snow, moisture and atmospheric conditions. The remote sensing estimates were checked against field measurements from piezometer-based subsidence monitoring, with 337 records from 11 locations, and supported by detailed soil and peatland mapping.

The main result is a mean annual peatland subsidence rate of about 1.44 cm/year. Negative vertical displacement occurred across most of the organic soils, while positive displacement, interpreted as peat accumulation, was limited. The study estimated a large peat volume loss over 2015–2022, with an average annual dry matter peat loss of about 46 tonnes per hectare. Validation was reasonably strong, with R^2 around 0.69–0.70 and RMSE of 0.23 cm.

The discussion is convincing in showing the practical value of InSAR for detecting spatial patterns that would be impossible to capture with sparse field measurements alone. It also usefully links subsidence to drainage, regional water-resource instability and climate-driven evapotranspiration. However, the causal interpretation is less secure than the measurement result. Subsidence can reflect oxidation, shrinkage, compaction, hydrological fluctuation or a combination of these. The field validation is valuable but geographically limited, and the method still depends on careful image selection and local knowledge. The chapter provides the technical foundation of the thesis: a scalable remote sensing indicator for peatland condition at catchment scale.

Chapter 2 Carbon accumulation through peat vertical displacement

This chapter extends the first study by asking whether peat vertical displacement can be used as a proxy for net carbon accumulation, and how climate, land use, peat type and vegetation influence that relationship. The study compares three north-eastern Polish peatlands: Wizna, a drained system; Biebrza, a mixed natural and drained system; and Rospuda, a largely non-drained system. It uses InSAR-derived vertical displacement, with April imagery selected to minimise seasonal vegetation and groundwater-level effects, and analyses displacement patterns against climate and land-use variables.

The results show negative average vertical displacement in all three systems, from about −0.9 cm/year in Rospuda to −1.5 cm/year in Wizna. Drained agricultural areas had substantially higher subsidence rates than better-preserved peatlands, with drainage reported to accelerate degradation by up to 66.7%. The chapter also reports positive correlations between air temperature and vertical displacement, interpreted as possible increased gross ecosystem productivity, and negative or complex relationships with precipitation, reflecting peatlands' hydrological and temporal complexity.

Radboud University
Department of Ecology
Heyendaalseweg 135
6525AJ Nijmegen
the Netherlands

The discussion is important because it moves the thesis from detecting surface movement to interpreting peatland carbon dynamics. It recognises that even relatively intact systems may be vulnerable under regional climate change and declining water stability. However, the central proxy assumption remains a methodological weakness. Vertical displacement is not a direct carbon-flux measurement. Without paired chamber, eddy-covariance, peat-core or water-table observations, it is difficult to separate carbon accumulation, oxidation, shrinkage and elastic surface motion. The discussion would be stronger if supported by process-based hydrological or carbon modelling to test time lags and alternative mechanisms. This chapter contributes the conceptual bridge between remote sensing indicators and peatland carbon functioning.

Chapter 3 Remote sensing-based assessment of carbon emissions

This chapter asks whether peatland carbon emissions can be estimated through a largely remote-sensing-based framework using subsidence rates. The proposed framework combines four parameters: subsidence rate, oxidation component, bulk density and soil organic carbon content. The carbon-emission equation converts oxidation-related peat loss into tonnes of CO_2-equivalent per hectare per year, although the paper clarifies that "CO_2-equivalent" here refers to mass conversion from carbon to CO_2, not full greenhouse-warming-potential equivalence.

The method uses the InSAR-derived subsidence product, equations from a global meta-analysis to estimate the oxidation component, and a northern peatland dataset for bulk density and soil organic carbon. The estimates were checked against field survey data. The mean oxidation component was about 34.5%, with higher values in agricultural areas. Estimated bulk density and soil organic carbon agreed reasonably with field data, and the resulting emission estimate for Biebrza was 7.49 ± 3.6 tonnes CO_2-eq/ha/year. This was much lower than the 14.49 tonnes CO_2-eq/ha/year obtained using a more conventional constant-parameter approach. (Nature)

The chapter is the most policy-oriented of the three. It translates remote sensing observations into an emissions metric relevant to climate reporting, restoration targeting and regional water management. Its main strength is that it makes uncertainty in peat properties and oxidation explicit, rather than relying only on default emission factors. Its main weakness is that the framework still depends on indirect parameters and empirical transferability. It excludes emissions not directly linked to oxidation-related subsidence, such as methane, nitrous oxide, lateral carbon export and erosion. The conclusion that the tool could be applied broadly is promising but somewhat stronger than the evidence currently supports; broader calibration across peat types, land uses and climate zones is still needed.

Radboud University
Department of Ecology
Heyendaalseweg 135
6525AJ Nijmegen
the Netherlands

Together, the three chapters form a coherent research trajectory. Chapter 1 develops and validates the remote sensing indicator. Chapter 2 tests its ecological interpretation as a proxy for carbon accumulation and degradation across contrasting peatland settings. Chapter 3 converts the indicator into a carbon-emissions framework that could support monitoring, reporting and verification.

The thesis makes a useful contribution by showing how remote sensing can move peatland assessment from isolated field plots towards catchment-scale and potentially continental-scale monitoring. This is highly relevant for climate policy and water management because governments need spatially consistent evidence to identify degradation hotspots, prioritise rewetting, assess restoration performance and improve greenhouse-gas inventories. Remote sensing offers broad coverage, repeat observations and access to wet or remote areas where field surveys are costly or unsafe.

However, the work also demonstrates why remote sensing cannot replace field measurements. It measures surface expression, not the full biogeochemical process. Field data remain essential for calibration, validation and interpretation of carbon fluxes, peat properties, vegetation change and water-table dynamics. Modelling is the missing link for policy application: process-based hydrological and carbon models could test future climate and water-management scenarios, quantify uncertainty, and separate the effects of drainage, evapotranspiration, vegetation change and peat oxidation.

The remaining gaps are therefore clear: replication in a pan-European approach assessing relevant low-land catchments; integration with direct CO_2, CH_4 and N_2O measurements; improved estimates of bulk density, soil carbon and oxidation components; stronger uncertainty propagation; and explicit coupling with hydrological and carbon-cycle models. The thesis achieves its overall objective at catchment scale and sets out a credible pathway towards continental-scale assessment with the continental policy application waiting for the next PhD candidate.

Radboud University
Department of Ecology
Heyendaalseweg 135
6525AJ Nijmegen
the Netherlands

Radboud Universiteit
SINCE 1923

Based on the analysis described above I evaluate the PhD thesis of Pouya Ghezel Ayagh "Assessing selected environmental properties of peatlands on a large spatial scale using the remote sensing tools and datasets" by conducted at the Warsaw University of Life Sciences.

In view of the high scientific quality of the dissertation, the originality and significance of the research undertaken, and the high level of scientific competence demonstrated by the Doctoral Candidate, I hereby recommend that the dissertation be distinguished and that the distinction of the doctoral dissertation be awarded in accordance with the applicable regulations of the Warsaw University of Life Sciences (SGGW).

Yours sincerely,

Dr. Christian Fritz

[Chair of Peatland Eco-Hydrology group]
Radboud University, the Netherlands

Signature:

Date: 31st August 2026