Mid-Term Progress Report

Water Joint Programming Initiative
2018 Joint Call

Closing the water cycle gap - Sustainable management of water resources

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Water management for sustainable use and protection of peatlands

WATERPEAT

PROJECT TITLE AND ACRONYM

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Project Website:
Project code: WaterWorks2017-WATERPEAT

Duration of project: 36 MONTHS
Start date: 1.4.2019

End date: 31.3.2022

Period covered by this report: 1.4.2019-31.10.2020

1. Publishable Summary

The main objectives of WATERPEAT project are to develop peatland water management for different land use options and environmental protection goals. In the project University of Oulu (UOulu) have focused on peatland catchment delineation, peat soil subsidence and peat soil and subsoil hydrological properties studies and resulted new data base and several manuscripts. Additionally, analysis have been done from water balance and water quality from sites situated in Finland, Norway and Indonesia. UOulu have started comprehensive systematic review related to peatland restoration and mitigation methods, optimizing mitigation options with modelling tools and newly developed coagulants. A first version of the review is ready focusing on peat properties. Results from the project can be directly used to guide practical water and water quality management in different peatland uses by authorities, land use managers, land users and other stakeholders. In Ireland, NUIG is expected to develop a hydrological model using data derived from a peatland catchment in order to predict nitrogen and phosphorus retention and release under different climatic scenarios and management schemes. Through the research of resultant chemical behaviour, laboratory work and soil column analysis will centre on the various treatments reflected in modern peatland management to study the chemical variables that change spatially. To date, preliminary site characterization via remote sensing and geophysical ground survey has been conducted; along with preparations for the soil core sampling procedure and laboratory instrumentation. In Norway, NIBIO has initiated a study on a peatland in southern Norway to study hydrology, subsidence and land use. Monitoring wells have been established at one site and a reference site. Also, work on remote sensing has been initiated to look into subsidence. NIBIO also lead part of the remote sensing work carried out in Indonesia with UOULU.

2. Work Performed and the Results achieved during the reporting period

a) Scientific and technological progress

In general, the project is progressing well. Some delays have occurred in installations of sampling and monitoring systems due to Covid-19, but the deviations are minor. The partner meeting for autumn 2022 was cancelled and the meeting will be organized on-line instead.

Below the work is reported for different partners.

Partner NUIG

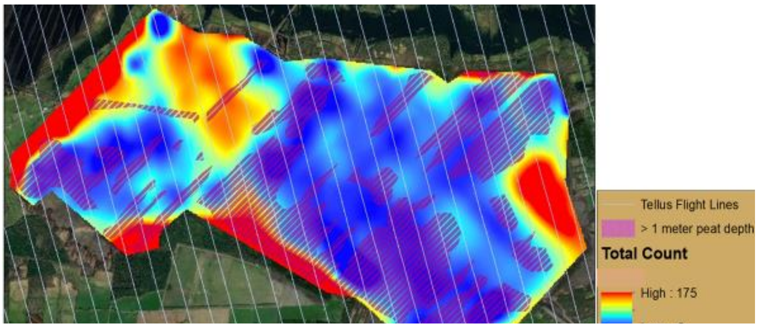

Figure 1: 2-D color ramp of interpolated radiometric signal for Garryduff using flight lines.

With reference to the milestones established by the EPA (pre Covid-19 adjusted), WATERPEAT has maintained and upheld the work outlined in the original project timetable, i.e., a literature review was completed prior to month fourteen of the project. Although a systematic approach to site characterization has continued to evolve since the start of WATERPEAT, the methodology has continued to remain as a three-fold undertaking. Field work planning and remote sensing tasks began during the wet season of the previous academic year and, therefore, proved to be difficult to accomplish under saturated field conditions. Initial radiometric data processing was the first task to be carried out while laboratory units were simultaneously undergoing preparation; ground based geophysical work had to be accomplished under drier conditions. The Tellus airborne survey, performed by Geological Survey Ireland (GSI), collects pre-processed electromagnetic and radiometric data that can be integrated by inversion methods that associate electrical resistivity and radioactivity with induced magnetic fields beneath a ground surface and gamma ray attenuation, respectively. The Bord na Mona cutaway bog, Garryduff, has been characterized using a radiometric dataset, offered by Geological Survey of Ireland (GSI), and an approach enlisting a branch of mathematics that uses retrospective methods to problem solving. In combination with ground-truthing, inverse problem solving uses remotely sensed results to determine ground-based effects, and inversions can be used when missing information in field data must be inferred. However, the frequent problems that may occur with quantitative remote sensing develop from the inversion technique itself and through using poor data acquisition methods for interpolation. One such issue that is typical for all quantitative remote sensing inversion problems happens when a solution is returned that may not be continuous with the variation of observed signals. Figure 1 shows the radiometric characterization of Garryduff overlain by Tellus survey lines and approximations for peat depth (shaded in purple).

To counter problems that may exist due to the spacing between survey flight lines and the frequency of point-to-point data collection, a three-fold methodology includes electrical resistivity tomography (ERT), an electromagnetic induction (EMI) survey, and remotely sensed radiometric data for complex modelling.

Without additional data, radiometric analysis via remote sensing cannot differentiate between soil moisture and texture thickness. The signal detection is merely a function of gamma ray emission as it emerges from bed material and through non-attenuating soil profiles. The data can be confirmed with additional ground truthing and survey. Electrical resistivity is a physical property, determined by measuring electromagnetic induction, and it describes a material's inability to carry electrical charge. Peat soils tend to be resistive; that is, peat soil resists conductance and carried electrical charges. In geophysical monitoring, conductors and sensors produce voltage and are able to detect the ionic content of a three-dimension ground area; in the case of WATERPEAT, the electrical conditions of the peatland subsurface. When ions and effective electrical conductors exist within a medium and are forced into a changing magnetic field, measurable secondary eddy currents are produced within the ions that occupy a given area. These can be chemical species, e.g., cations and anions capable of transferring electrical charge. The eddy currents that are produced within the ions create their own measurable magnetic field, which then interacts with the field created by a measuring device. This interaction generates a force that can be used to estimate chemical effects and movement. With an array of geophysical estimations, sampling locations for soil coring can be intelligently selected. Figure 2 shows the established ERT and EMI surveys that were carried out on September 24th and 25th.

Figure 2: ERT survey line (left) and EMI survey instrument and reach (right)

It is known that peatlands undergo seasonal water storage fluxes. Along with these fluctuations there are connections to solute transport within the deep layers of a peatland landscape. The ERT and EMI surveys, shown in figure 2, were placed along a region over the landscape that represents the most variation within the 2-D radiometric map described in figure 1. Since the radiometric characterization cannot by itself distinguish between a peatland's physical properties, the other two metrics (ERT and EMI) can more reliably detect the thickness of a peat layer at a given location and link the radiometric attenuation to a reduced ion content that is typical of raised bog soil and resistive layers. Essentially, the ERT line and EMI survey were used to validate the radiometric data given an expectation that a gradient in the resistivity would emerge when moving between locations across the bog. Reductions in electrical conductivity would imply low solute concentration within soil and greater conductance would suggest critical areas that are greater in ionic content and in need of remediation. WATERPEAT will then use these results to quantify the water chemistry differences that are proximity to the geophysical variations in the land.

Geophysical measurements are to be combined with direct measurements of water chemistry and by this method, evolution in the peatland's water chemistry will be detectable. Annual and climatic conductivity variations are also confounding considerations that may influence electrical resistivity measurements and this can induce an unwanted deterministic bias. Due to this nature, it could be beneficial for WATERPEAT to employ a temporal geophysical survey strategy across the same extensions of the Garryduff cutaway; a strategy that attempts to replicate seasonal variation in time.

To collect soil cores, a methodology was borrowed from the NUI, Galway School of Geography and Archaeology. Figure 3 shows the coring apparatus, fixed atop a wooden makeshift platform.

On July 16th, a set of ten preliminary samples were collected from the Garryduff cutaway site. In Figure 3, a steel cylinder, infilled with water and a device for maintaining constant pressure, is positioned above the coring location. The coring device uses a mechanism that creates a pressurized area above the sampling location. As the coring apparatus is plunged into the earth, the device controlling the pressure within the steel cylinder contacts the ground; changing the dimension of the pressurized area within the steel cylinder and causing water to expel. This action induces a suction within the steel cylinder container as it enters the earth, pulling the sample up as a topical force is applied downward. The device was selected due to its ability to retrieve intact soil cores of approximately one meter in length. As the cores are unearthed, great care is taken to maintain their structure and they are then placed into PVC piping with an internal diameter that is equal to the diameter of the soil samples. The PVC piping is also maintained for the laboratory column design – as seen in Figure 4 (left).

Figure 3: Setting the Usinger (Piston) Corer

Figure 4: Beginning (left) and end (right) instrumentation of soil samples in NUIG laboratory.

For soil column analysis within the laboratory, a rigid structure had to be built around the soil samples. Figure 4 illustrates the start and end product for the WATERPEAT soil water sampling structure. While keeping the soil secured within a PVC half pipe, a layer of liquid waterproof sealant is spread across the surface area of the soil and allowed to dry for a twenty-four hour period. Following the drying period, a layer of sturdy gauze is wrapped around the sealed soil to further secure the design and a second coating of the sealant is applied, over the gauze and cover the entire soil column. After the structure has been sealed completely, barring the top and bottom ends, the column can then be held vertically without becoming compromised. The top and bottom surfaces of the soil are left exposed in order to permit vertical flow and control over the hydraulic head within the instrumented sample. Finally, several sample ports are inserted up the side of the columns length.

Partner UOULU

Peat hydraulic and physical properties database

Objectives:

1. To test applicability of the van Genuchten soil water retention curve model (mostly applied to other soil types) for peat soils subjected to different land management regimes and quantify the corresponding van Genuchten model parameters.
2. To parametrize the hydraulic and physical properties of peat soils under different land use management regimes, which are not properly documented in the literature.

Materials and Methods: Peat properties data used for this study were collected from an ongoing and past research projects at the Water, Energy and Environmental Engineering Research Unit, University of Oulu, Finland. The peat properties database included (in total 3073 samples from 59 study sites) data on saturated hydraulic conductivity (Ksat, n = 2077), unsaturated hydraulic conductivity (K, n = 22), bulk density (BD, n = 439), porosity (n = 444), specific yield (Sy, n = 284), and soil water retention curve (SWRC, n = 284) for different peat layers, determined in field and/or laboratory studies.

The van Genuchten-Mualem soil water retention curve model and several other machine learning algorithms (e.g., K-nearest neighbours, principal component analysis, Random forest) were used to study the hydraulic and physical properties of peat soils as a function of three distinct peat layers (top, middle and bottom layers) for each land use of different management regimes.

Results: The outcome of this research is currently under review at Water Resources Research journal with title "Hydraulic and physical properties of managed and intact peatlands: Application of the van Genuchten-Mualem models to peat soils

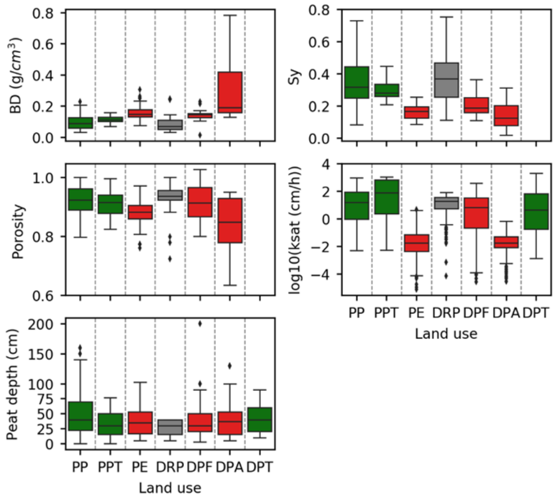

Figure 1. Mean bulk density, porosity, specific yield and saturated hydraulic conductivity (log scale) for each peatland land use management

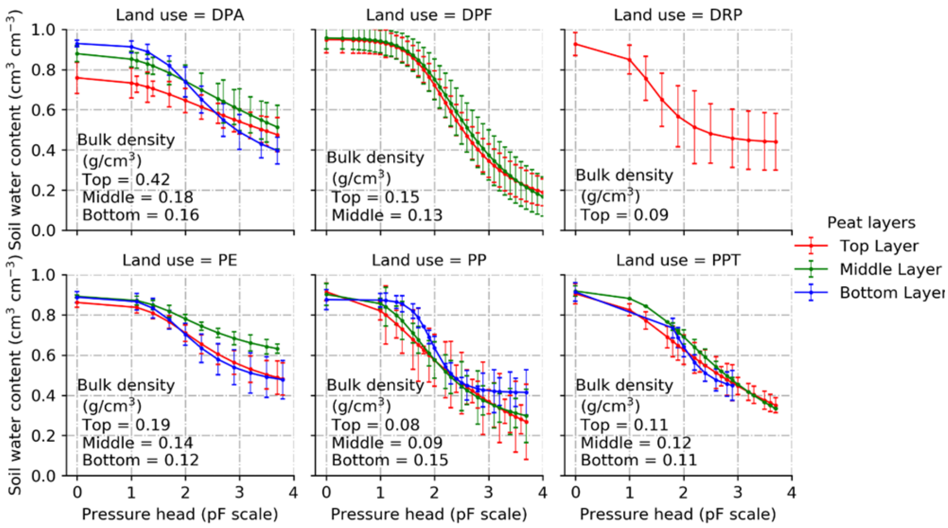

Figure 2. Fitted soil water retention curve for each land use across different layers and their corresponding bulk density values, error bars show the standard deviation.

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Land subsidence analysis in organic and drained agricultural site.

The study aims at performing subsidence comparisons by determining the vertical differences of organic land surface at drained riparian floodplains. The national lidar data is compared to archived historical drainage maps including topography information back from several decades. The subsidence models are used to determine the changes in annual high-water cover, which has not been studied before in Nordic conditions. According to our unpublished results, subsidence of 202–349 mm within the last 24–51 years was found with the mean rates of 5.15–9.47 mm y^{-1} at riparian peatland sites in Finland (Figure 3). The rate strongly correlated with the total depth of the organic soil layers (Figure 4). The annually flooded area was increased by 101–194% during the last 24–51 years (Figure 5). By generalizing the results, we found an annual flood spread of 45% at the cultivated fields of the catchment and predicted further spread of 14% during the following twenty years, if the subsidence rate stays constant in time (Figure 6). The study shows that the risk of floods increases, so new management strategies such as rewetting, restoring and paludiculture should be considered for arable peatlands in the future.

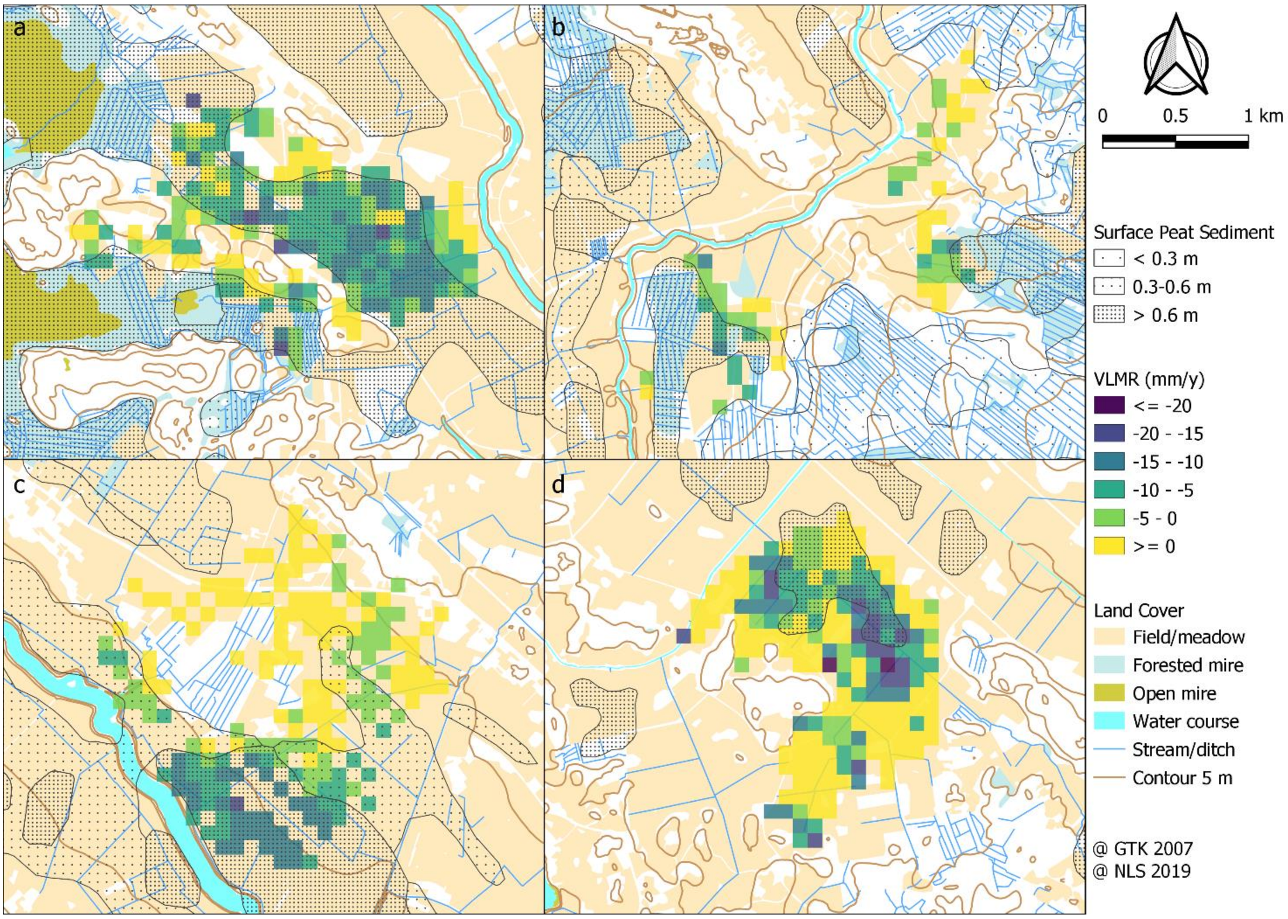

Figure 3. Vertical Land Motion Rate (VLMR) ΔZ/Δt for a) Kaivosoja, b) Junnonoja, c) Huokumaanoja and d) Herralanpuro sites in Finland. Negative values of VLMR represent subsidence.

Hydrology of cultivated peatlands

Totally 3 cultivated peatland sites in Finland and Norway (OULU and NIBIO) are intensively monitored for hydrological processes and used to analyze hydrological processes and controls of these systems (Figure 12). On-going activities

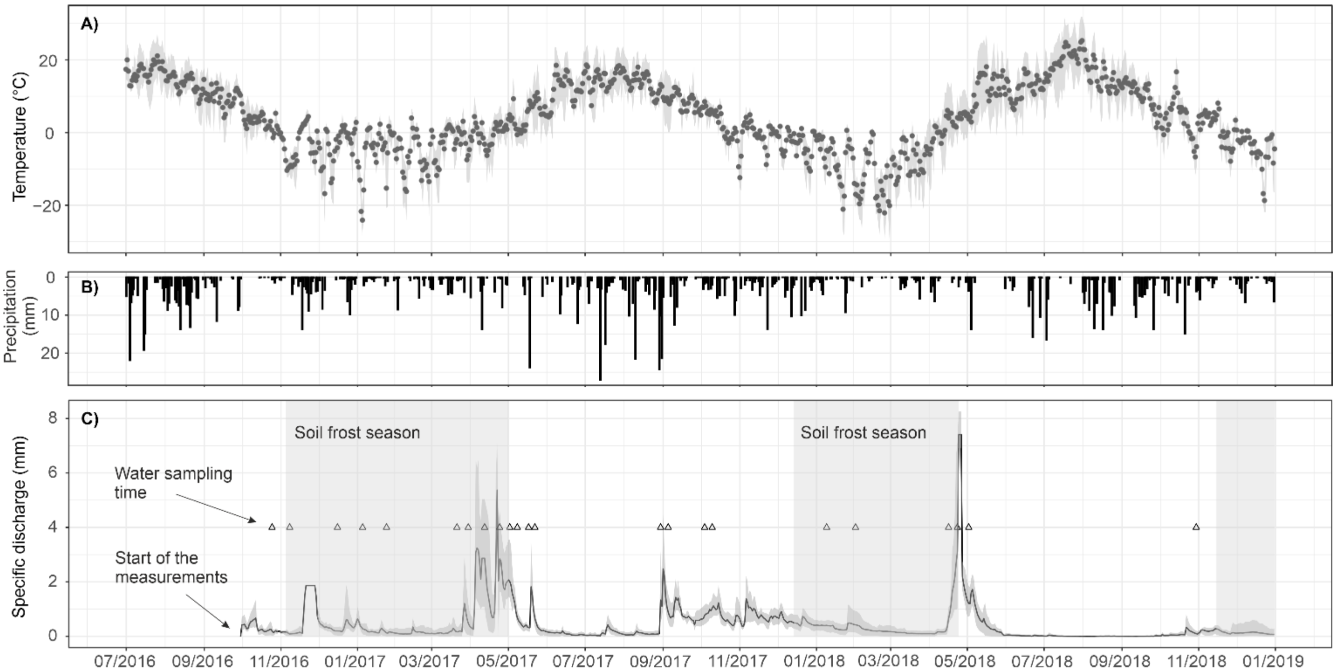

Figure 12. Hydrological response of Ruukki study site.

A systematic review of previously published research work on peatland restoration and used methods for different purposes

Objectives: A review of mitigation measures on peatland management options and use of peatlands as buffer zones to retain water and reduce negative environmental impacts is being conducted. The review focuses on mitigation measures on peat-dominated catchment and the use of peatlands, e.g., as buffer zones, to reduce negative environmental impacts from the following perspective:

- Leaching (total phosphorus, total nitrogen and dissolved organic carbon)
- Hydrology (retain water using water table and runoff as proxy)
- Green House Gases emissions (CH4, N20 and CO2)

Materials, methods and progress: A systematic review is being conducted using several published works, in total 303 published articles have been selected from different databases (Google Scholar, ScienceDirect, ISI Web of Science, ResearchGate, Springer, Scopus, Wiley Online Library, Georef and Geobase) and gone through an initial review process. From this 303 initially added and further reviewed articles, a total of 186 have fulfilled the initial screening, and second stage review process and are almost ready for further analysis. Currently, further cleaning of the data entries is being carried out to prepare the database for analysis. The articles that passed the second review process (188 unique articles) included study sites from different countries (Figure 13), mainly in Europe and North America due to the prevalence of peat soils in these regions.

Results: Data cleaning, statistical analysis and writing of the article are in progress.

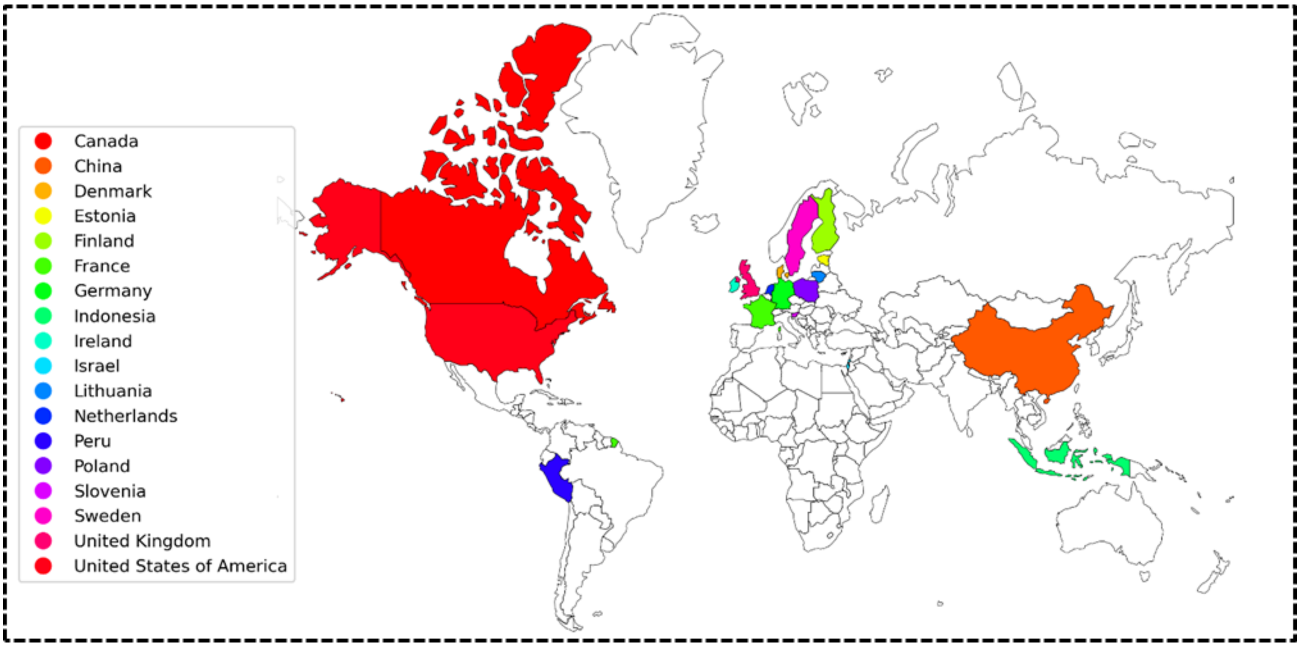

Figure 13. Global distribution of study sites (coloured) included in the 186 articles included in this systematic review, most of the study sites are in North America and Europe, where peat-dominated catchments are typically common.

Controlled drainage in cultivated peatlands

Water table variations in Ruukki and Norwegian sites will be modelled using DRAINMOD which will allow for study of controlled drainage impacts on the sites water table.

DRAINMOD models of the Ruukki site and Norwegian sites have been set up and modelling process is on the calibration stage and on-going. Preliminary results of water table variation modelling of the sites are expected by the end of the year.

Effect of peatland restoration on water quality

The effects of drainage and subsequent restoration (raised water table conditions) on the hydrological dynamics of drained-restored peatland catchments will be thoroughly studied using analytical techniques, existing data sets (WT, Q and water quality) for 46 study sites collected since 2008 by Metsähallitus will be used. On-going progress.

Usability of coagulants for water treatment of peaty waters

The effectivity of newly developed (commercially available) coagulants and the possibility of coagulant recovery (produced sediments) and recycling will be investigated. A pilot-scale system, built to simulate all stages of chemical purification will be used for testing the most suitable coagulants in field conditions. Review of past as well as on-going projects in the chemical treatment method will also be conducted and results added to the report.

Subtask progress: Practical research activities have been concluded in 3 phases as described below. A writing of manuscript reporting on the results obtained in the 3 test phases is on-going. Review of past as well as on-going projects in the chemical treatment method will also be conducted and results added to the final report.

Figure 14. Jar test equipment

Phase 1 - A research plan was elaborated based on the jar test (Fig. 14) methodology to evaluate the effectiveness of different coagulants and blends of different products. Parameters used during the experiments were selected based on real conditions in peat extraction sites treatment facilities in Finland. When applicable, commercial quality products were acquired, and real peat extraction runoff water was used.

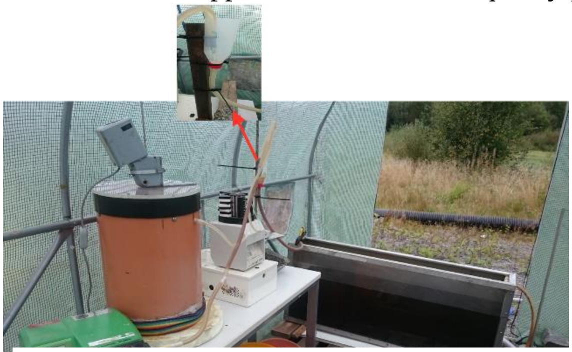

Figure 15. Pilot system

Phase 2 – In this phase, the performance of the best coagulant agent identified during laboratory-based tests in Phase 1 was compared to that of the coagulant normally used in Finnish peat extraction sites. Experiments were conducted using a continues flow pilot treatment system (Fig. 15). Commercial quality products and real peat extraction runoff water was used.

Phase 3 – The possibility of decreasing coagulant dosage and improving suspended solids removal via the recirculation of sediments collected from the sedimentation basin back to the runoff water arriving for treatment was investigated. This phase included preliminary laboratory experiments followed by pilot tests. Real peat extraction runoff water was used, and coagulant agents normally applied in Finnish extraction sites were applied.

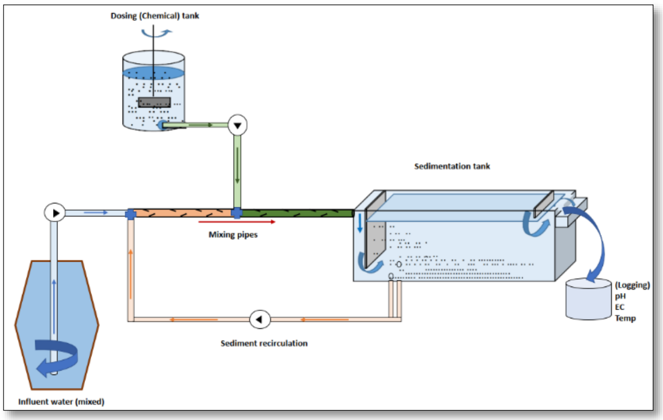

Figure 16. Schematic view of recirculation of

Task 2.4 Automatic drainage water control and regulation

Results from the DRAINMOD modelling will inform bases for automatic water level control and regulation. With experimental mock-up scenarios, efficient drainage water regulations will be tested with the model. On-planning phase, waiting for input from Task 2.3

Historical land use analysis and identification of ditches analysis using remote sensing methods.

The study aims to develop techniques for semi-automatically mapping the location of ditch networks in peat-dominated catchments by using aerial photos and LIDAR data, and to generate time series of drainage networks. We demonstrate our approach using data from the Simojoki river catchment (3160 km^2) in northern Finland. For two representative locations in cultivated peatland (downstream) and peatland forest (upstream) sites of the catchment, we found total ditch length density (km/km^2) estimated from aerial images and LIDAR data varied from 2% to 50% compared against the monitored ditch length available from National Land survey of Finland (NLSF) in 2018 (Figure 7). A different pattern of source variation in ditch network density was also seen for whole catchment estimates and for available drained peatland database from Natural Resources Institute Finland (LUKE) (Figure 8). No significant differences were found using the non-parametric Mann-Whitney U-test with 0.05 significance level based on the samples of pixel based identified ditches between (i) aerial images & NLSF vector files and (ii) LIDAR data & NLSF vector files. The proposed approaches provide open-access techniques to systematically map ditches in peat-dominated catchments through time that are needed to relate spatiotemporal drainage patterns to observed changes in many northern rivers.

Indonesian peatland hydrological data analysis (partners OULU and UGM)

The study aims to assess how rainfall and drainages control the spatial and temporal variability of drained tropical peatland in Padang island, west of Sumatera, Indonesia. We analyze water table depth (WTD) and rainfall record from monitoring stations across the island (Figure 9) and estimate the rain-to-rise ratio (Specific yield/Sy) for the corresponding depth, and then estimate the rate of WTD drop during rain interval period from master recession curve. The rain-to-rise ratio vary on depth (Figure 10) in which deeper layer is more sensitive to rainfall. Meanwhile, master recession curve (Figure 11) illustrates that recession rate near plantation drainage is much higher than recession rate further away from plantation, prompting deep WTD near drainages. The study improves our understanding of water table dynamic in tropical peatland. We aim to use this temporal variability of WTD to assess the response of surface vegetation to WTD dynamic for further study.

Partner NIBIO

After a review and discussion with deifferent groups at NIBIO on past studies in Norway linked to peatland forestry, an experimental site was selected in Southern Norway. After a field excursion in June 2020, the Norwegian team equipped a forested, temperate mire (Akersmyra, close to Tønsberg, Southern Norway). The site has long-term monitoring data on forest biomass and an adjacent pristine reference site (Gjennestadmyra) to examine long term effects on hydrology and impacts of hydrology on peatland forest biomass, peat properties and subsidence. Additionally, the team is developing novel methods (digital photogrammetry and use of lidar data) to enable cost-efficient measurements of subsidence (an indicator for peat loss) remotely over large geographical areas and for long time periods.

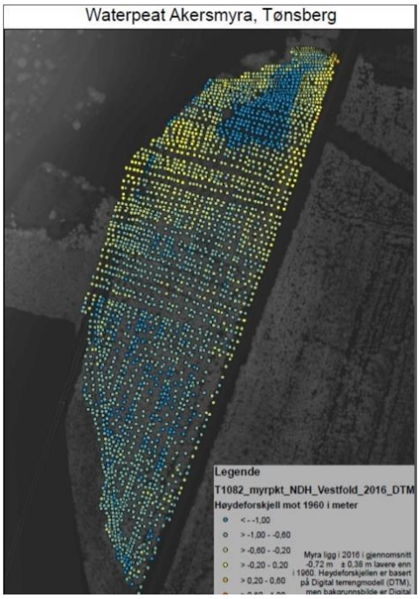

Figure 1. Soil loss as determined with areal photography and satellite images.

Hydrology analysis of 2 sites in southern and northern Norway was mentioned under OULU collaboration (this is done in collaboration with the NFR funded MYR project).

A work was stared with UOULU, NIBIO and UGM on Indonesian peatlands. Here remote sensing was used in different ways to study peat systems as in WP3 (figures below)

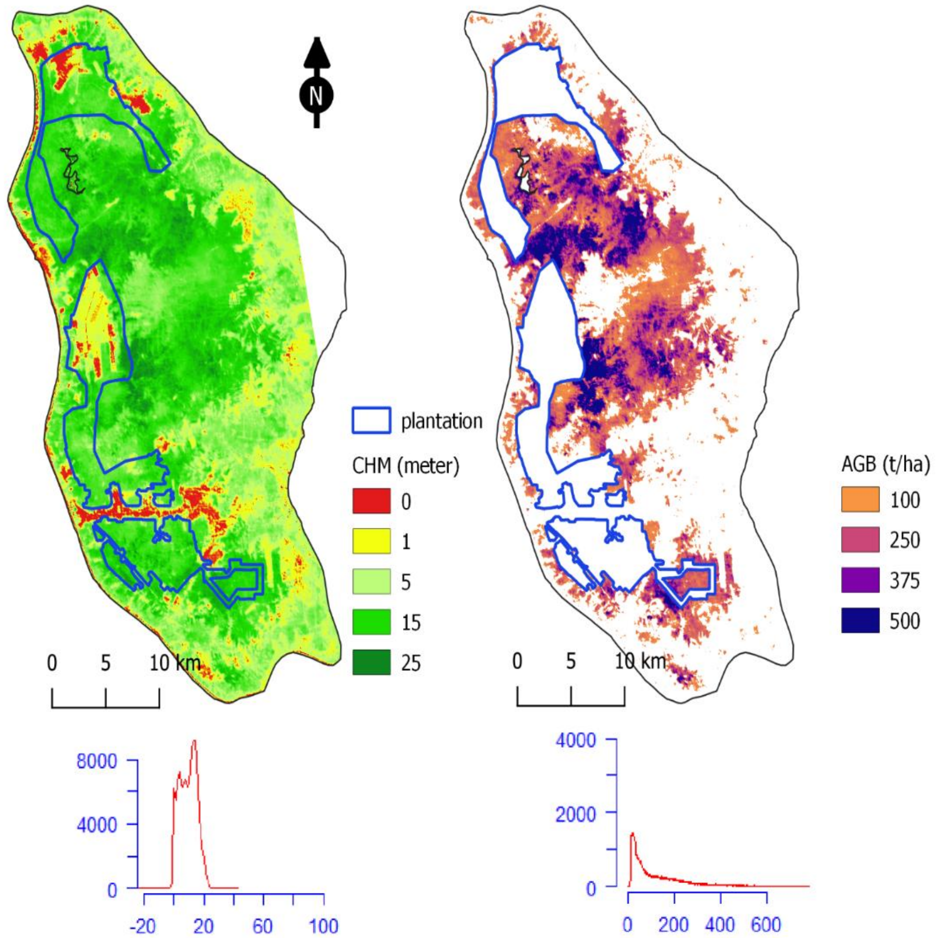

Figure 2. Remote sensing images of biomass changes in Pedang Island Indonesia.

Fire risk and compliance monitoring in tropical peatlands

The study aims to demonstrate the use satellite-based remote sensing for mapping and monitoring fire in tropical peatlands. We estimate the burnt area from fire event in 2015 at Central Kalimantan Indonesia using time series of Sentinel-1 dataset (Figure 27a and 27b) and then compare with burnt area delineated from time series of Landsat images by visual observation (Figure 1c and 1d) and hotspot distribution from MODIS satellite (Figure 27e, 27f, and 27g). Burnt area delineated manually from Landsat datasets (Figure 28a) resemble high similarity with burnt area estimated from Sentinel-1 (Figure 28b), where 74% (290,309 hectares) of burnt area are overlap one and another. This suggest the potential of Sentinel-1 to derive burnt area that is easily produced from change analyses in comparison to manual delineation using Landsat that is labor-intensive and burdensome.

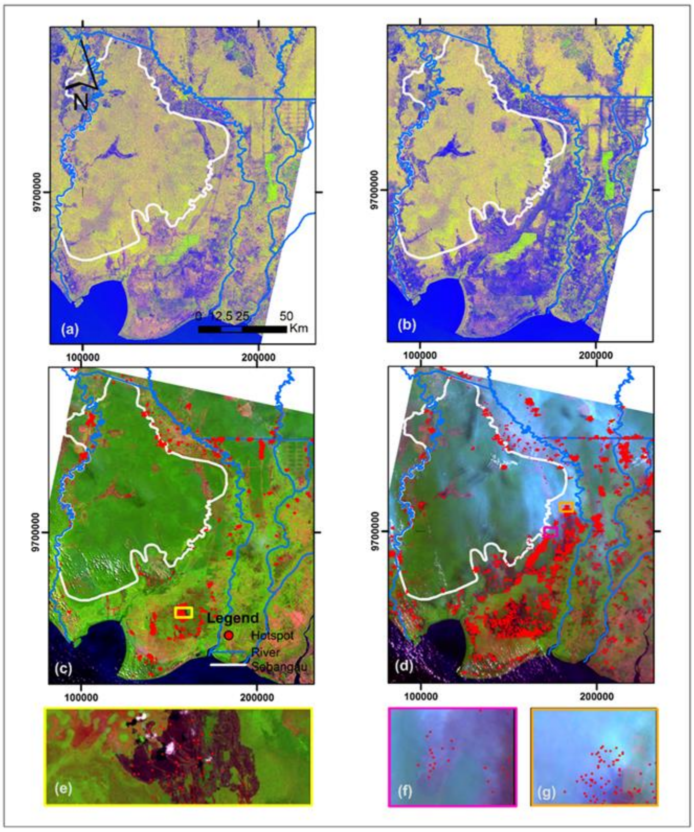

Figure 27. (a) Sentinel-1 acquired at August 13 and (b) at October 24 and (c) Landsat acquired at August 19 and (d) at September 20 overlaid with hotspot (e, f, g).

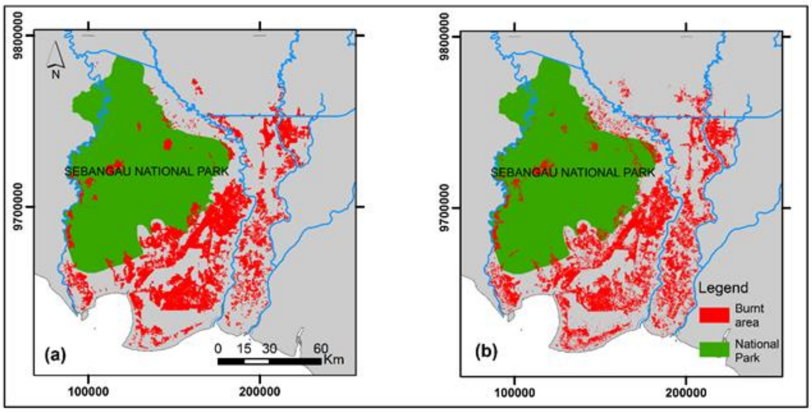

Figure 28. (a) Burn areas delineated from Landsat series and (b) from Sentinel-1 VH polarization.

a. Collaboration, coordination and mobility

All the partners work efficiently. The collaboration has consisted of staff visits, joint analysis of results, research planning and field site visits etc. This has been very effective and efficient.

From UOULU a PhD candidate visited NIBIO for 3 months. Also the coordinator from UOULU visited NIBIO and worked in project planning and design in Norway. The PhD at UOULU was originally from UGM and the first paper is written in collaboration with UGM in Indonesia. NUIG and UOULU participated at the joint seminar (virtual) in April 2020 (EGU 2020 conference).

We have had some collaboration with MYR funded by NFR and Finnish foundations such as Kone foundation (one PhD and post doc funded). Also we have worked with Luke in Finland.

b. Impact and knowledge output

WATERPEAT's primary impacts are ongoing, as the research ultimately aims to i) increase the scientific understanding on peatlands for efficient land and water resources management and to ii) deliver methods and decision support tools for land managers and appropriate stakeholders upon project completion. During the current reporting period, we have

- talked with stakeholders and informed about the project progress,
- highlighted knowledge gaps that surround peatland site characterization and to assemble the most up to date summary relating to global peatland and water resources protection, and land use, with respect to the varying policies at the international level,
- carried out hydrological analysis of past data and started collecting new data,
- worked with peatland restoration and water protection measures,
- looked into ways to monitor and observe peatlands processes with remote sensing technology.

The content of this deliverable is for policy making, private industry, and semi-state owned companies for their own consultation.

3. Table of Deliverables

Please indicate whether the planned deliverables are completed, delayed or readjusted. Explain any changes/difficulties encountered and solutions adopted. Please add/delete rows, as necessary in the table below.

Deliverable		Lead partner	Due	Changes
D1.1	Methods to cost-efficiently delineate peatland catchments and observe land use changes	NIBIO	24	
D1.2	Data and information on key water quantity and quality processes from experimental sites	UOULU	24	
D2.1	Literature review on restoration, water treatment methods and land management options	UOULU	14	A review made on peatland soil properties. D2.1 in preparation.
D2.2	Report on mitigation experiments (leaching control, drainage and runoff water treatments)	NUIG	28	

D3.1	Visually appealing (high quality) schematics on peatlands processes and mitigation options	UOULU	20	
D3.2	Report on modelling, analysis of extreme events and assessment of future climate impacts, including a set of model parameter ranges for soft calibration of hydrological models	UOULU	34	
D3.3	Options for efficient monitoring: a synthesis report on methods with applications to important management cases	NIBIO	36	
D4.1	Dissemination plan, communication matrix and stakeholder map	UOULU	1	Completed (updated every 6 months)
D4.2	Stakeholder opinion assessment with a simple multicriteria analysis	UOULU	18-22	
D4.3	Newsletter, www, twitter (M1-M36, when news appears)	UOULU	1-36	2 newsletters completed
D4.4	Policy briefs (M12-M36)	UOULU	12-36	Delayed
D4.5	Poster and high advocacy presentation	UOULU	6,24,36	Poster made, and ppt made (but not updated due to lack of conferences)
D4.6	On-line training course (M30, with a training event M34)	UOULU	30 (36)	
D4.7	Final legacy package on peatland water management	UOULU	36	

4. Budget review

Please include a budget breakdown here, i.e. how the funding has been used so far.

NUIG

Category	**Budget**	**Cumulative expenditure (to 20.10.20)**
Salaries	70,033	17,511
Travel and subsistence	24,000	2754
Consumables	20,000	6748
Overheads	34,210	(collected by NUIG at project finish)
Total	148,243	27 013

NIBIO (in NOK)

Category	Budget	Cumulative expenditure (to 20.10.20)
Salaries	3 460 300	800 000
Other costs	421 000	200 000
Total	3 884 000	1 000 000

OULU

Category	Budget total	Cumulative expenditure (until Nov 2020)
Salaries	238 754	95836
Travel and subsistence	18 224	1192
Consumables	46 932	1542
Overheads	193 391	77 739
Total	497 301	176 309

5. Consortium Meetings

Please list below the Consortium meetings which took place during the reporting period, by filling in the table below. Add/delete rows as necessary in the table below.

N°	Date	Location	Attending partners	Purpose/ main issues/main decisions?
1	8.5.2019	Skype	All	Getting started
2	20.8-21.8.2019	Oulu	All	Kick-off, stakeholder workshop
3	13.3.2020	Skype	All	Check progress and summer activities, prepare 2nd newsletter
4	Several meetings	Ås	UOULU and NIBIO	To plan joint activities and studies in Norway

6. Stakeholder/Industry Engagement

Meetings have been arranged in Finland and Ireland. The meeting in Norway was cancelled due to Covid. However, we have met some stakeholders (Fylkesmannen and a land owner).

In Ireland, the main industry/stakeholder involvement has been from the government-funded organisation responsible for the management of peatlands in Ireland, Bord na Mona. They have provided access to study sites, health and safety training, and input into study methodologies.

The project newsletter was sent to stakeholders.

7. List of Publications produced by the Project - Open Access

International	Peer-reviewed journals	1. Monteverde, S., Healy, M.G., O'Leary, D., Daly, E., Callery, O. Developing land use strategies within landscapes of changing priority, the case of peatland management. In review. Submitted to Ecological Indicators. (June, 2020). 2. Meseret Walle Menberu, Hannu Marttila, Anna-Kaisa Ronkanen, Ali Torabi Haghighi and Bjørn Kløve. Hydraulic and physical properties of managed and intact peatlands: Application of the van Genuchten-Mualem models to peat soils. Submitted to Water Resources Research. (May, 2020). 3. Ismail, Ali Torabi Haghighi, Hannu Marttila, Uun Kurniawan, Oka Karyanto, Bjørn Kløve. Water table variation on different land use units in a degraded tropical peatlands island of Indonesia. Submitted to Hydrology Research. (May, 2020).
	Communications (presentations, posters)	1. Monteverde, S., Healy, M.G., Callery, O. 2020. Developing land use strategies in landscapes with changing priority, the case of peatland management. Session HS10.6. EGU General Assembly 2020. https://doi.org/10.5194/egusphere-egu2020-22648 (online presentation). 2. Two newsletters, distributed via Twitter (@WaterPeat_NUIG) 3. O'Leary, D., Healy, M.G., Callery, O., Brown, C., Daly, E. 2020. Defining potential peatland management zones using unsupervised self-organising map clustering on airborne radiometric data. Session #B025-07. AGU Fall Meeting, 1 – 17, December. (Online.)
	www	https://www.researchgate.net/project/WaterPeat-Water-Management-for-the-Sustainable-Use-of-Peatlands
National	Finland	Water JPI days
	Norway	Fagdagene NIBIO, key note presentation

8. Knowledge output transfer

For each of the Knowledge Output arising from the project so far, please complete the following table.

Short Title *Please provide a short and concise title to describe the Knowledge Output*	Use of remote sensing data to characterise peatlands
Knowledge Output Description *Please only include generated Knowledge Outputs, not those that are expected. Note:*	Radiometric data have been used to show physical variations in peat profiles over peatland

Knowledge Outputs can be non-deliverables, milestones or 'grey knowledge'. Also, multiple Knowledge Outputs could exist within one deliverable, and should be separated. *Try to give a comprehensive description, making the Knowledge Output fully understandable to a non-expert.* *If relevant please provide detail of where the Knowledge Output differs from its equivalent, e.g. What are the key characteristics of the Knowledge Output? What research is it adding to and what is innovative about the Knowledge Output? (Max 500 characters).*	areas. The radiometric 'signals' may be used to identify areas from which representative soil cores may be collected (and subsequently experimented with in the laboratory). As these remotely observed data would normally be measured through exhaustive on-site data collection methodologies, the collection of remotely observed data and the verification of their accuracy in characterising a study site, means that in future laborious site characterisation work can be significantly speeded up.
Link to Knowledge Output *If you can provide a link to the Knowledge Output then please do so, e.g. digital object identifier (DOI), web address, download, research paper.* *If the Knowledge Output is not publicly available currently but will be in the future, please provide details. Also, if it is available but only upon request, please state this.* *If the Knowledge Output is not planned to be publicly available, please state "Not available for public".*	O'Leary, D., Healy, M.G., Callery, O., Brown, C., Daly, E. 2020. Defining potential peatland management zones using unsupervised self-organising map clustering on airborne radiometric data. Session #B025-07. AGU Fall Meeting, 1 – 17, December. (Online.)
Sectors & Subsectors *Choose as many options as required from the list. Pick those sectors that you think would benefit from the application of this Knowledge Output.*	• Others ○ Other General ○ Agriculture ○ Governance ○ Consumer Health & Welfare ○ Finance ○ Modelling & Prediction ○ Socio-Economics ○ Stakeholder Involvement
End User *Choose as many options as required* *Per identified End User, please identify possible applications of the Knowledge Output.*	o Education & Training o Environmental Managers & Monitoring o Industry o Policy Makers / Decision Makers o Scientific Community o Civil Society o Other
IPR	n/a

Please indicate whether IPR has been applied to this Knowledge Output (applied for a patent, copyright etc), or not. *Please insert "n/a" if no IPR has been applied.*	
Policy-Relevance If the Knowledge Output is relevant to the WFD or any other related Directives, please list and explain why	Not yet
Status *Please identify whether the Knowledge Output is finalised, is still being generated or whose status/future is unknown. Consider:* *• Is your knowledge conclusive enough that it provides sufficient evidence to make an impact on, or be applied by, an End User?* *• Is there a corroborating body of evidence, or are contradictory results, available?* *• Does your knowledge progress beyond the current state-of-the-art / evidence base?* *• Is more research or demonstration needed to validate the results?*	The output will be finalized and summarized later

9. Open Data

We will follow given guidelines.

10. Problems Encountered during Project Implementation

No major problems have been encountered. Some delays have occurred due to the pandemic.

11. Suggestions for improvement regarding project implementation?

No suggestions.