Interreg Care-Peat

Deliverable T1 4.1
Development of a user friendly DST-interface

Stéphanie PINSON, Sébastien GOGO and Laurent ANDRE

Name	Organisation
Stéphanie PINSON	BRGM – French Geological Survey
Sébastien GOGO	University of Rennes 1
Laurent ANDRE	BRGM – French Geological Survey

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Development of a user friendly DST-interface

Final Report

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Study carried out as part of
activities in the INTERREG NWE CARE-PEAT Project

S. Pinson, S. Gogo, L. André,
With the collaboration of all the partners of the CARE-PEAT Project

Checked by:	**Approved by:**
Name: C. Auterives	Name: A. Saada
Function : Hydrogeologist	Regional Director Centre Val de Loire
Date: 06-09-2021	Date: 22/09/2021
Signature:	Signature:

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Contact : qualite@brgm.fr

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Synopsis

The INTERREG NWE CARE-PEAT project focuses on the reduction of carbon emissions and the increase of C-storage in peatlands by testing innovative technologies and methods on 5 pilot sites located in the North West Europe (Belgium, France, Great-Britain, Ireland, Netherlands). The main objectives are to *(i)* demonstrate and quantify CO_2 emissions and C-storage and *(ii)* propose restoration scenarios and solutions for the reduction of CO_2 emissions from peatlands, using advanced management tools developed from pilot sites.

This report presents a Decision Support Tool able to map the carbon sink/source zones of the investigated sites using a GIS (Geographical Information System). This mapping will allow a rapid visualization of the site in order to identify, characterize and quantify the gas transfers according to the specificity of each site (vegetation, water table, precipitation/recharge).

This report presents the methodology to reach this objective of mapping the CO_2 emissions at the peatland scale. However, it presents also the different hydrological and hydrogeological indicators that can be proposed to the peatland owners and the managers. Indeed, the study of the gas emissions must not be the only criteria to evaluate and only a cross analysis of all these data can help the managers in selecting the best restoration works.

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Introduction

Since the last decades, peatlands are investigated to characterize them and to determine if they behave as a source or as a sink of carbon. Indeed, if they account for only 3-5% of total land area, many of these lands are degraded and emit rather than store carbon. Qiu et al. (2021) demonstrate that a drained and cultivated peatland emit notable amount of CO_2. Through a modelling approach, they estimate that northern peatlands converted to croplands emitted 72 Pg C over 850–2010, with 45% of this source having occurred before 1750. This source surpassed the carbon accumulation by high-latitude undisturbed peatlands (36 to 47 Pg C).

There is thus a practical and societal need to prevent further degradation and increase recovery of our remaining peatlands. However, many of these degraded peatlands belong by private owners or collectivities that rely on unsustainable use of peatland to live. Efficient peatland restoration to promote C sequestration require taking into account both environmental and economical considerations.

One issue in implying owners in this strategy of peatland restoration is the lack of tools to help them in managing their lands. Indeed, many models have been developed to calculate or estimate the behavior of such ecosystems (see Couwenberg et al., 2008; 2011; 2012). But, peatlands are complex ecosystems since their functioning is a mix of hydrological, biochemical and biological processes. In the INTERREG NWE CARE-PEAT project, a methodology was setup to take into account this complexity : it is based on a coupling between different measuring methods (on the ground, with drones and satellites) tested and related to each other and an integrated numerical model which can predict C-emissions and sequestration in different peatlands.

Based on the main outputs of the numerical model (developed in WP T1 Activity 3) and together with the results of the pilots and investments executed in the different areas and across different peatlands, a Decision Support Tool (DST) will be developed for peatland managers so they can choose the best options (methods and techniques that consider ground conditions and species combinations) to restore their peatland and to achieve maximum C-sequestration. Indeed, peatlands are not homogeneous ecosystems and this spatial heterogeneity implies different behaviors in a same peatland. The consequence is that the restoration must be adapted to the site. To do that, the owner must be able to know this initial state before starting its restoration strategy.

In the CARE-PEAT project, we develop a Decision Support Tool able to map the carbon sink/source zones of the investigated sites using a GIS (Geographical Information System). This mapping will allow a rapid visualization of the site in order to identify, characterize and quantify the gas transfers according to the specificity of each site (vegetation, water table, precipitation/recharge). This report presents the methodology to reach this objective of mapping the CO_2 emissions at the peatland scale. However, it presents also the different hydrological and hydrogeological indicators that can be proposed to the peatland owners and the managers. Indeed, the study of the gas emissions must not be the only criteria to evaluate and only a cross analysis of all these data can help the managers in selecting the best restoration works.

Chapter 1: Existing tools to estimate GHG fluxes from peatlands

Degraded peatlands are emitting carbon and greenhouse gases mainly because of their drainage and burning. The estimation of global emissions leads to amounts close to 5 % of all emissions caused by human activities (about 2 Billion tons of CO_2 per year). However, the real estimation of the carbon (CO_2 and CH_4) or other greenhouse gases (GHG) like N_2O is still a challenge.

One way to understand the behavior of the peatlands consists to estimate the gas fluxes by direct on-site measurements. Different techniques exist to measure this fluxes, like the ones used in the CARE-PEAT project: closed chambers allow for flux measurements on small areas, whereas the eddy covariance technique can be used to measure GHG fluxes over larger areas (Baldocchi et al., 1988; Lenschow, 1995).

The other way to estimate gas fluxes is the numerical approach. The main challenge consists to translate the main chemical, physical and (micro)biological processes occurring into peatlands into equations to represent the functioning of the ecosystem. Their combination and coupling lead to an estimation of the fluxes. However, the estimation of gas fluxes by the models needs input parameters. According to the different papers already published on this topic (Joosten et al., 2015), the most relevant parameters to estimate GHG emissions are:

- ***The water table***: Couwenberg et al. (2008) and Couwenberg and Fritz (2012) analyzed a wide range of data from across the world and they showed that mean annual water table is the best single variable explaining annual GHG fluxes from peatlands.
- ***The vegetation***: Joosten et al. (2015) consider that vegetation can be used as a proxy for GHG fluxes. Vegetation is used in a VCS (Verified Carbon Standard) methodology since it is a good indicator of water table depth, it is controlled by site-specific parameters (like soil acidity, nutrients, site history) and it is directly and indirectly responsible for the predominant part of the GHG emissions by regulating CO_2 exchanges (Emmer and Couwenberg, 2018).

The land use and the subsidence (loss of peat height because of shrinkage and oxidation) are also suitable proxies (see Van den Akker et al., 2008). Soil and air temperature and soil wetness are also relevant parameters as inputs for the numerical models (Roulet et al. 2007, Nilsson et al. 2008, Maljanen et al. 2010). These acquisitions need to be done regularly to take into account the night and day alternations and the seasonal variations (recharge conditions, vegetation, solar radiations…). All these measurements are most often done by specialist (hydrologist, geochemist, botanist…) and cannot be managed by private owners. Moreover, as estimated by Joosten & Couwenberg (2009), the costs for measurements of such parameters is averaging ca. €10,000 per hectare and year. In practice, direct measurements can only be used in selected areas in order to develop, calibrate and verify models with which GHG fluxes can then be estimated over much larger areas (Joosten et al., 2015).

1.1. GHG ESTIMATION FROM PROXY : THE WATER TABLE DEPTH

Different methods allow estimating the greenhouse gas emissions from peatlands. One solution consists to use the water table depth as a proxy. Different curves can be found in the literature: some of them plot the GHG (combining CO_2, CH_4 and N_2O) emissions vs the mean water table depth (Stoffels, 2009; Jurasinski et al. 2016 – see Figure 1), whereas other focus on the CO_2 emissions vs the mean water table depth (see Figure 2: Fritz et al. 2017). All these approaches were mainly developed based on literature study.

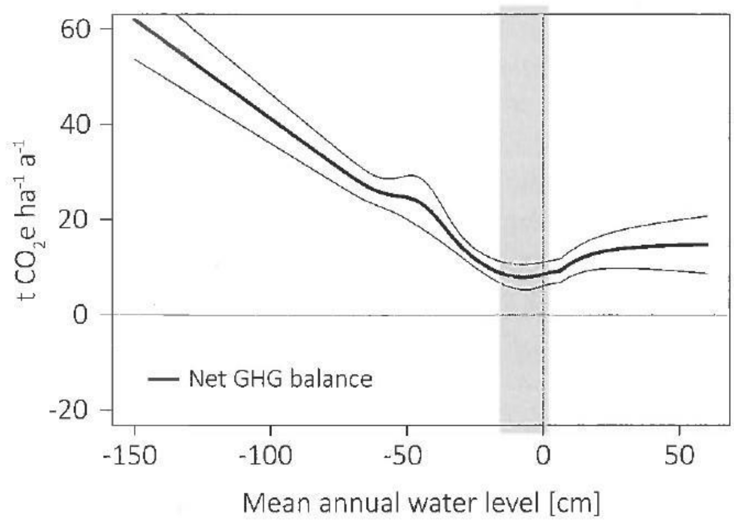


Figure 1: Relationship between groundwater level and greenhouse gas emissions (from Jurasinski et al., 2016). The hairline graphs illustrate the 95 % confidence intervals, respectively. For this graph, CO_2, CH_4 and N_2O emissions were combined and expressed in CO_2 equivalents. CO_2 emissions occur primarily when water levels are below floodplain level (grey zone), CH_4 emissions when water levels are above floodplain level and N_2O emissions primarily when fertiliser is applied or grazing takes place.

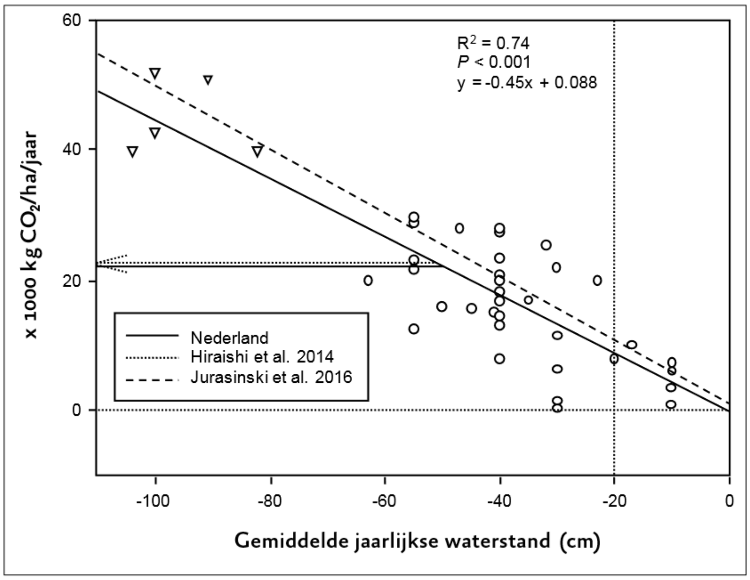


Figure 2: Relationship between mean water level (X-axis) and CO_2 emissions (Y-axis), for Dutch peatlands (continuous line) and elsewhere in the world (dashed line). The slope of the line determines the emission change for a change in water level. The emission reduction is 0.45 ton CO_2-eq/ha/year per cm water level rise. Source: Fritz et al. (2017), with data from Jurasinksi (2016).

These different approaches were tested by Motelica-Wagenaar and Beemster (2020) on the agricultural peatland of Groot-Wilnis Vinkeveen and Wilnis-Veldzijde to estimate the current GHG emissions of these zones. They also applied the method proposed by Van den Akker et al. (2008) based on the subsidence rates. The authors showed that the calculated GHG emissions according to the different methods are comparable with however some important differences especially on N_2O emissions.

1.2. GEST MODEL

The GEST approach was developed in 2008 at the University of Greifswald on behalf of the federal state of Mecklenburg-Western Pomerania to assess GHG fluxes across large peatland sites in Central Europe without comprehensive measurements on-site.

This model is a combination of plant species indicating long-term water table depths and other characteristics relevant to GHG fluxes (e.g., peat type, pH, nutrient status), associated with annual mean GHG fluxes of carbon dioxide and methane (expressed as CO_2-eq) based on literature or country-specific measurements. In absence of vegetation, water table depth is used as the main proxy (Couwenberg et al., 2011). The GEST approach describes mean annual groundwater table in soil moisture classes (Figures 3 and 4).

Soil moisture class		water table relative to surface (+ above, - below)
7+	Upper sublitoral	WLw/WLd: +250 to +140 cm
6+	Lower eulitoral	WLw: +150 to +10 cm; WLd: +140 to +0 cm
5+	Wet (upper eulitoral)	WLw: +10 to -5 cm; WLd: +0 to -10 cm
4+	Very moist	WLw: -5 to -15 cm; WLd: -10 to -20 cm
3+	Moist	WLw: -15 to-35 cm; WLd: -20 to -45 cm
2+	Moderately moist	WLw: -35 to-70 cm; WLd: -45 to -85 cm
2-	Moderately dry	WD: <60 l/m^2
3-	Dry	WD: 60-100 l/m^2
4-	Very dry	WD: 100-140 l/m^2
5-	Extremely dry	WD: >140 l/m^2

Figure 3: Soil moisture classes and associated water tables (modified after Koska et al. 2001). Soil moisture classes are characterised by: WLw: long-term median water table in the wet season; WLd: long-term median water table in the dry season; and WD: water supply deficit. Seasonally alternating wetness is indicated by a combination of different classes, e.g. 5+/4+ refers to a WLw within 5+ range and a WLd within 4+ range. Strongly alternating wetness is indicated by a tilde-sign, e.g. 3~ refers to a WLw within 4+ range and a WLd within 2+ range.

GEST approach was applied to assess the climate effect of individual peatlands in different federal states (e.g. Weber, 2010 for Baden-Württemberg, Hargita and Meißer 2010 for Brandenburg). At international level, the GEST approach is being applied and further developed. A VCS methodology for the rewetting of peatlands based on the GEST approach is currently in the second phase of validation (Couwenberg et al. 2011; www.v-c-s.org).

Soil moisture class	2+	3+	4+	5+	6+
	Moderately moist	Moist	Very moist	Wet	Lower eulitoral
Median annual water table	ca. 35 to 5 cm below surface	ca. 15 to 45 cm below surface	ca. 5 to 20 cm below surface	ca. 10 cm below to 10 cm above surface	ca. 10 to 50 cm above surface
GEST	Global warming potential in t CO_2e ha^{-1} y^{-1}				
High intensity grassland	24	15	7.5		
Forb meadows	20	12.5	7.5		
Reeds			3.5	8.5	8.5
Rewetted (short) grassland				5.5	

Figure 4: Relationship between some Greenhouse Gas Emission Site Types (GEST – see Figure 3) and associated Global Warming Potential estimated in t CO_2-eq/ha/y (after Couwenberg et al., 2011)

1.3. SITE EMISSION TOOL (SET)

The Site Emissions Tool (SET) was developed in the INTERREG NWE Carbon Connects project. It aims to help farmers, landowners, and policy makers to assess the effects of drainage, crop and management choices on greenhouse gas emissions from peat soils. The tool is meant to be robust enough to be used as a basis for payment of emission reduction (Van Belle and Elferink, 2019). The approach is based on the GEST system (Couwenberg et al., 2011).

The tool is available on line at the following address: https://drive.google.com/file/d/1P8SMGX2M215NWEcYLzjyGguoFjymIn2t/view

This SET tool allows calculating GHG fluxes according to input data. Other than general site data, some inputs are allowing calculating GHG fluxes in baseline conditions (like water table depth, vegetation type, fertilizer use) whereas other inputs allow calculating fluxes after restoration works. Then, some outputs (such as graphics) allow a better interpretation of the benefits of restoration works.

Chapter 2: Choice of a Decision Support Tool

All the modeling approaches reported above allow predicting GHG fluxes from peatland. However, for peatland managers or owners, one major issue is to have an accurate representation of their peatland. Indeed, because of the heterogeneity of their bogs (variations of water levels upstream and downstream, heterogeneity of the vegetation …), the GHG fluxes at the peatland scale are not uniform. This is why we propose to have an approach based on a GIS (Geographical Information System) in order to visualize the spatial heterogeneities.

Discussions with peatland managers have shown that it is important to characterize the GHG emitting zones. However, these emissions are often due to a combination of many factors and it is important to propose a large set of maps. Indeed, only a cross analysis of all these information will allow selecting the most adapted restoration works. This is why we present in this chapter a list of data and indicators useful for managers.

2.1 - METHODOLOGICAL APPROACH

The various data collected, hydrological, hydrogeological or geomorphological, provide an overview of the hydrogeological functioning of the peatland. We propose a conceptual diagram (Figure 5) which enables identifying all the data produced from different treatments such as interpolation. Finally, based on this conceptual scheme, a quantitative approach can be tested to calculate the flows (water and gaseous) and their spatial distribution within the peatland.

The main input data tested in this methodological approach are the DTM (Digital Terrain Model), the river network, the piezometric level and the peat thickness.

2.1.1 DTM TREATMENTS

A Digital Terrain Model (DTM) is a representation of the relief and elevation in a form suitable for use by georeferenced data processing software (= topographic surface). For calculation purposes, the DTM is a data set in the form of a grid of points on a square mesh. Each point is labelled with the elevation of the nearest point assigned to the grid of which it is the centre.

- ***Endoreic areas***

The endoreic zones correspond to preferential infiltration zones but also to the lakes. The appearance of these basins is often due to structural (relief) or functional (climate and soil) mechanisms. The endoreic zones are deduced from the DTM by applying specific numerical treatments. Areas that form basins usually pose a difficulty in determining flow directions, as there is no way out of these areas. A simple pre-processing of the DTM is thus necessary; it is a matter of filling these basins until an adjacent cell is found that allows flow. This cell will become the output cell when calculating the flow. The treated area becomes an artificially flat area.

Endoreic areas can be treated differently if it is possible to assign a dummy outlet at their lowest point. On a large scale, this alternative reduces artefacts in the network calculation. On a smaller scale, and especially on a national scale, this alternative brings little precision to the final treatment.

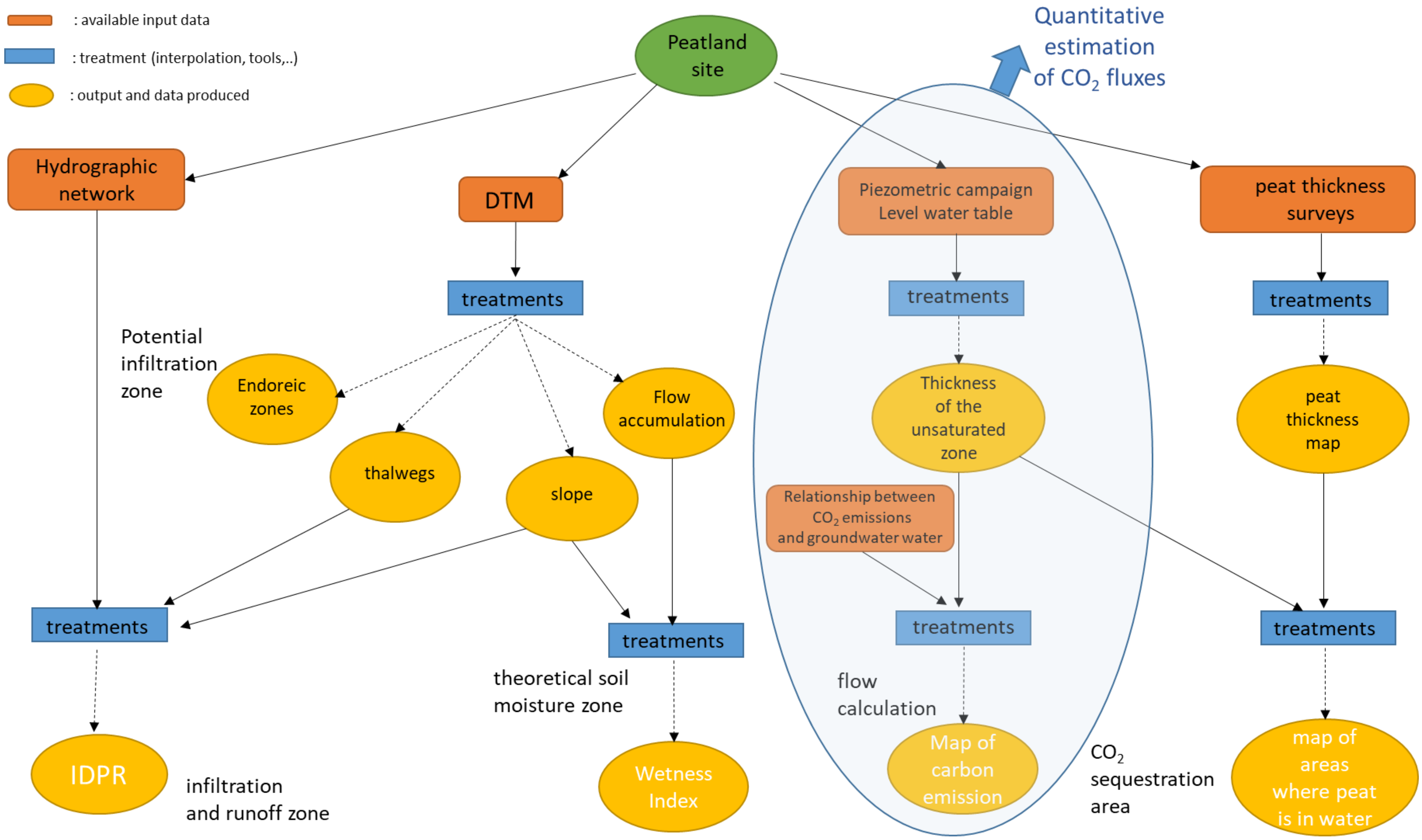


Figure 5: Conceptual diagram of input data, processing and output data. IDPR stands for "The network development and persistence index"

- ***Slope***

The slope function identifies the direction of the steepest slope at a location of a surface. The slope is calculated for each cell in the raster.

For each cell, the slope is calculated with the maximum rate of change of the values of that cell relative to its neighbours. In other words, the maximum variation in altitude over the distance between the cell and its eight neighbours identifies the steepest descent from the cell.

- ***Flow accumulation***

This calculation determines a flow direction grid, then an accumulation grid from which a drainage grid will be extracted. The threshold value used to determine if a surface is apt to produce significant flow is estimated by an overall analysis of the study area.

These flow directions then make it possible to calculate accumulation values for each cell of the initial grid. The accumulation value represents the number of cells that flow into a given cell (Figure 6). The calculation is done at the scale of the initial DTM grid.

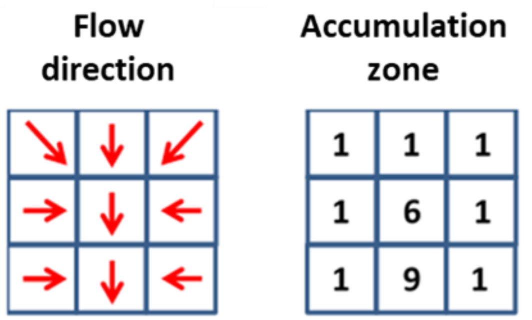


Figure 6: Sample flux accumulation calculation

- ***Theoretical thalwegs network***

To calculate the theoretical thalweg network from the DTM, the method used is based on the algorithms of Tarboton (1997) and distributed by the Environmental Systems Research Institute (ESRI). The calculation processes are simple and can be summarized into a data treatment set largely described in the bibliography available in GIS tools.

The Figure 7 retains only the cells in which the number of accumulated cells is greater than or equal to four. They make it possible to extract a first drainage network for which the value 4 represents the minimum number of cells necessary for accumulation of a quantity of water sufficient to define a thalweg. In other terms, they represent the sum of cells necessary and sufficient to initiate flow. If these cells have a surface of 100 m^2, then the elementary drainage basin has an area of 400 m^2.

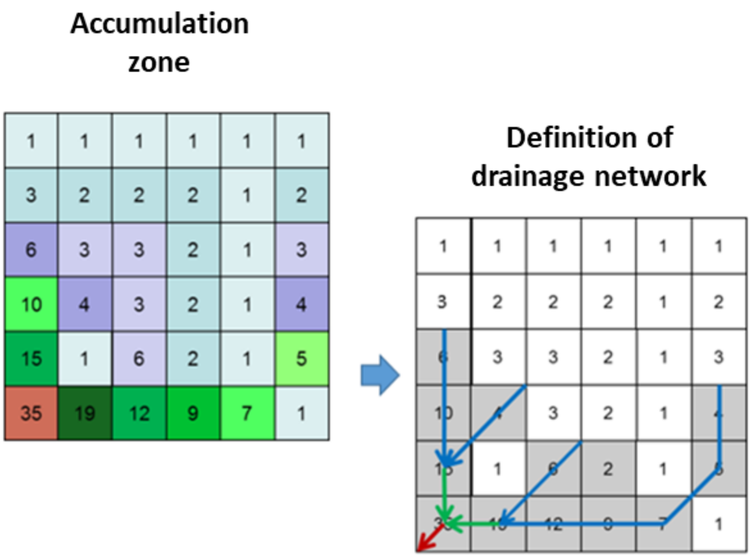


Figure 7: Example of drainage network definition

The choice of the necessary and sufficient accumulation threshold to establish the upper end of the basins results from a simple statistical analysis of the assumed distribution of sources in the natural river system.

These assumed sources correspond to a single upstream point forming the headwaters of the river course. In order to reproduce an equivalent reality as close as possible to a natural river, it is necessary to look for a minimum basin area capable of initiating a river in an average climatic environment. This initial basin area depends on the resolution of the DTM and is based on expert judgement.

2.1.2 CALCULATION OF INDICATORS FROM THE DTM

- ***Calculation of IDPR (network development and persistence index)***

The network development and persistence index (IDPR) was developed by BRGM (Mardhel et al., 2021) to qualify an area in terms of "pathways used" by meteoric water. Rainfall that flows across the surface of natural terrain (because it is not absorbed by plants or subject to direct evaporation) leaves its drainage basin in two different ways:

- It flows along the surface and concentrates in streams and rivers;
- It infiltrates into the subsurface, is concentrated into an aquifer, and leaves the aquifer through an outlet that is often different from that of the river network.

The IDPR provides a qualitative approach to the relationship between these two "pathways". It provides an indication of ability of surface and subsurface formations to promote surface water infiltration or run off toward or away from the underground environment.

The idea behind IDPR comes from the following hypothesis: the organization of the hydrographic network depends primarily on the hydrological and hydrogeological properties of underlying geologic formations.

Using the hypothesis of a perfectly homogeneous and isotropic medium, only slope and thus landscape morphology will control the emplacement of watercourses. But in the natural environment, the geologic structures, the lithological composition of the subsurface, the pedology, and the plant cover have a significant influence on the establishment of hydrographic networks. These factors control the permeability and roughness of the surface, which in turn affect runoff velocity and the ratio between flow and infiltration.

The drainage density in an area is thus a relevant indicator of the properties of the geologic formations. Generally, a basin composed of highly permeable materials will have a low drainage density. Conversely, a basin composed of impermeable but loose and erosive rocks, such as marls and clays, will often have a higher drainage density.

Following this hypothesis, the IDPR calculation is based on a comparison between a theoretical hydrographic network which considers the presence of a river in each thalweg (Development Index) and the natural hydrographic network (Persistence of Networks).

The network development and persistence index (IDPR) used in this study quantifies the offset between an observed natural network that results from complex factors and the theoretical network calculated solely by topography (Figure 8).

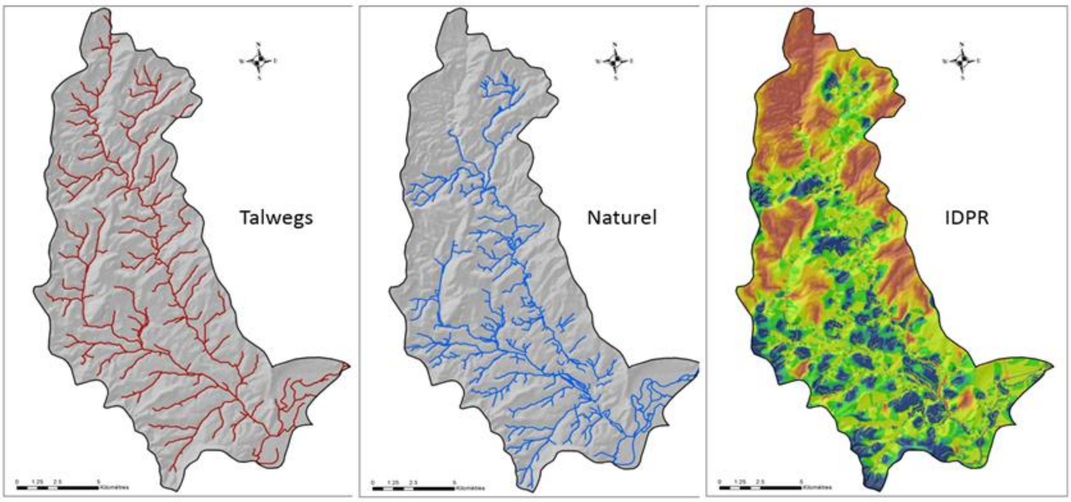


Figure 8: Thalweg network, natural hydrographic network and corresponding IDPR

- ***Wetness index***

The so-called "topographic soil moisture index" (TWI) or Wetness Index combines the local upstream contribution area and the slope. It is generally used to measure the effect of topography on hydrological processes.

It is commonly used to measure/evaluate the spatial distribution of moisture states and only requires that the elevation data is well distributed over the study area.

The calculated model is independent of time and composes a static representation of the landscape.

The TWI is a soil moisture calculation performed by automatic processing in ARCGIS. It is based on two essential parameters, deduced from the Digital Terrain Model: the slope and the accumulation zones.

Some studies at the catchment scale have shown that the average values of the Soil Moisture Potential Index (TWI) are related to those of the useful soil reserve and in these conditions, a good correlation between the two parameters can be observed.

2.1.3 PIEZOMETRIC LEVELS

The term groundwater refers primarily to water in the saturated zone of the subsoil. The water in the unsaturated zone (UZ), between the base of the soil and the surface of a water table, is also part of the groundwater, but does not constitute an exploitable resource (Figure 9). However, this interface can be the site of biophysical-chemical transformations of mineral and organic compounds and plays a major role on peatlands.

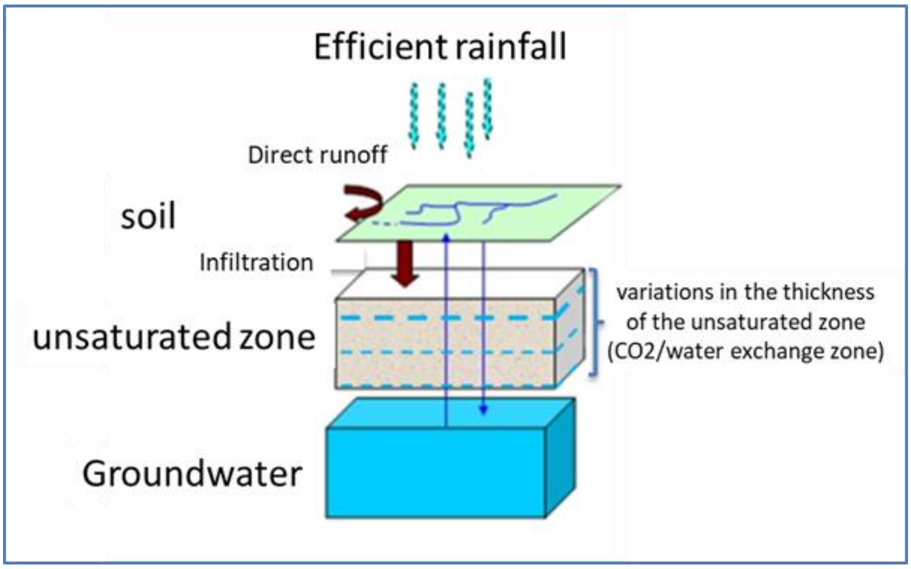


Figure 9: Conceptual diagram of the different interactions between surface and groundwater

- ***Thickness of the unsaturated zone***

Mapping the thickness of the unsaturated zone at the scale of the peatland should be done mainly on the basis of point data (water levels in the structures). The surface data available is interpreted and often heterogeneous (local piezometric maps, hydrogeological references).

In order to have continuous information at all points in the peatland, groundwater levels can be interpolated from point measurements.

These piezometric levels may be representative of, for example:

- a campaign at a given time (high water or low water);
- a particular or exceptional climatic year (dry, wet);
- maximum levels reached in any given year.

It is therefore of main interest to know the distribution of rainfall and to qualify the representativeness of the aquifer levels.

The thickness of the unsaturated zone at high water is obtained from

- the values of ground elevations, deduced from the interpolation of the DTM
- the groundwater elevations at all points in the peatland, deduced from the interpolation of the piezometric data.

The difference between these two values gives a grid at the DTM step, which represents for each pixel the thickness of the unsaturated zone expressed in metres.

- ***CO_2 and GHG fluxes***

As explain in Section 1, the thickness of the unsaturated zone (or the water table depth) is a relevant proxy to estimate the gas (CO_2 and GHG) fluxes at the interface between peatland and atmosphere. Therefore, from the previous map of the thickness of the unsaturated zone, it is possible to estimate the CO_2 fluxes only based on this parameter. As shown in Figures 1 and 2, the relationships between CO_2 emissions and groundwater can be applied on each pixel of the map and it is possible to calculate CO_2 fluxes from the thickness of the unsaturated zone and visualize them at the peatland scale. Moreover, a sum on each pixel of the studied area allow an estimation of gas fluxes at the peatland scale.

2.1.4: THICKNESS OF THE PEAT

Peatlands are very rich in organic matter and it is of main interest to know the carbon content in such ecoystems. An estimation of the amount of carbon contained in the system can be obtained by determining the peat thickness.

Consequently, we propose to plot maps of peat thickness obtained from campaigns of measurements. These thickness maps will allow interpolating the measurements and characterizing the distribution over the peatland.

A cross analysis of the peat thickness map with the unsaturated zone thickness map will allow deducing the areas where the peat is in water and conversely the areas where it has been drained. These information are of main interest in terms of gas emissions.

2.2 AN APPLICATION CASE: THE LA GUETTE PEATLAND (FRENCH SITE)

The conceptual scheme presented in Section 2.1 was tested at La Guette site in France. This is a site with the following input data: a DTM, a river network, piezometric levels recorded on many years and peat thickness measurements within the wetland.

2.2.1 THE INDICATORS

- ***IDPR***

The input data for the calculation of IDPR are the hydrographic (river) network and the theoretical network of thalwegs (deduced from this DTM and a natural river network). For the calculation of the la Guette IDPR, the natural hydrographic network comes from the French BD TOPO © (IGN). To model the valley floor, the DTM with a step size of 2.7 m was used (Figure 10).

From these information, we can plot the map showing the infiltration areas located at the edges and upstream of the la Guette site (Figure 11). The areas with the highest runoff are found in the central axis of the studied area and in particular in connection with the hydrographic network.

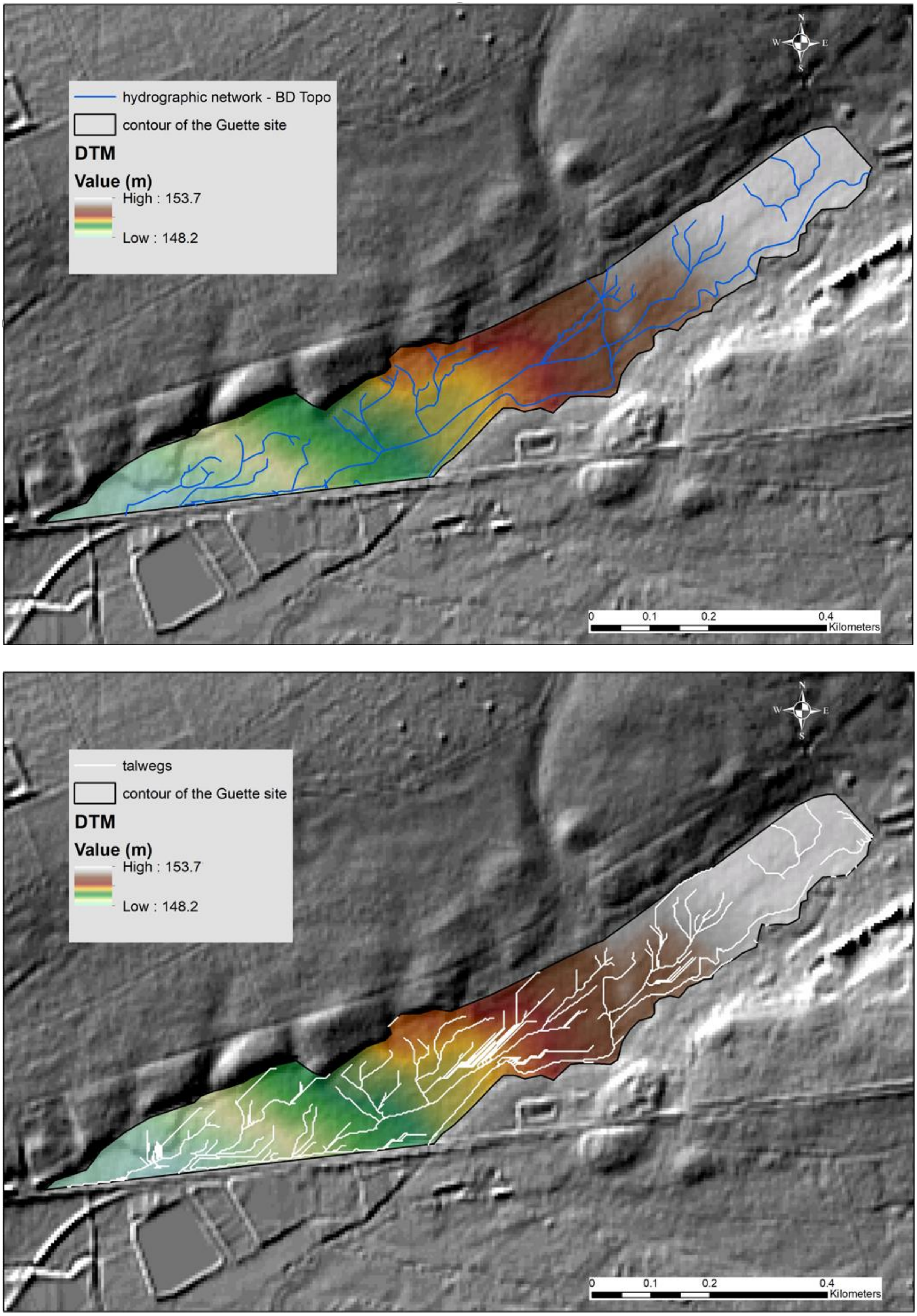


Figure 10: Hydrographic network and theoretical network of thalwegs on la Guette site

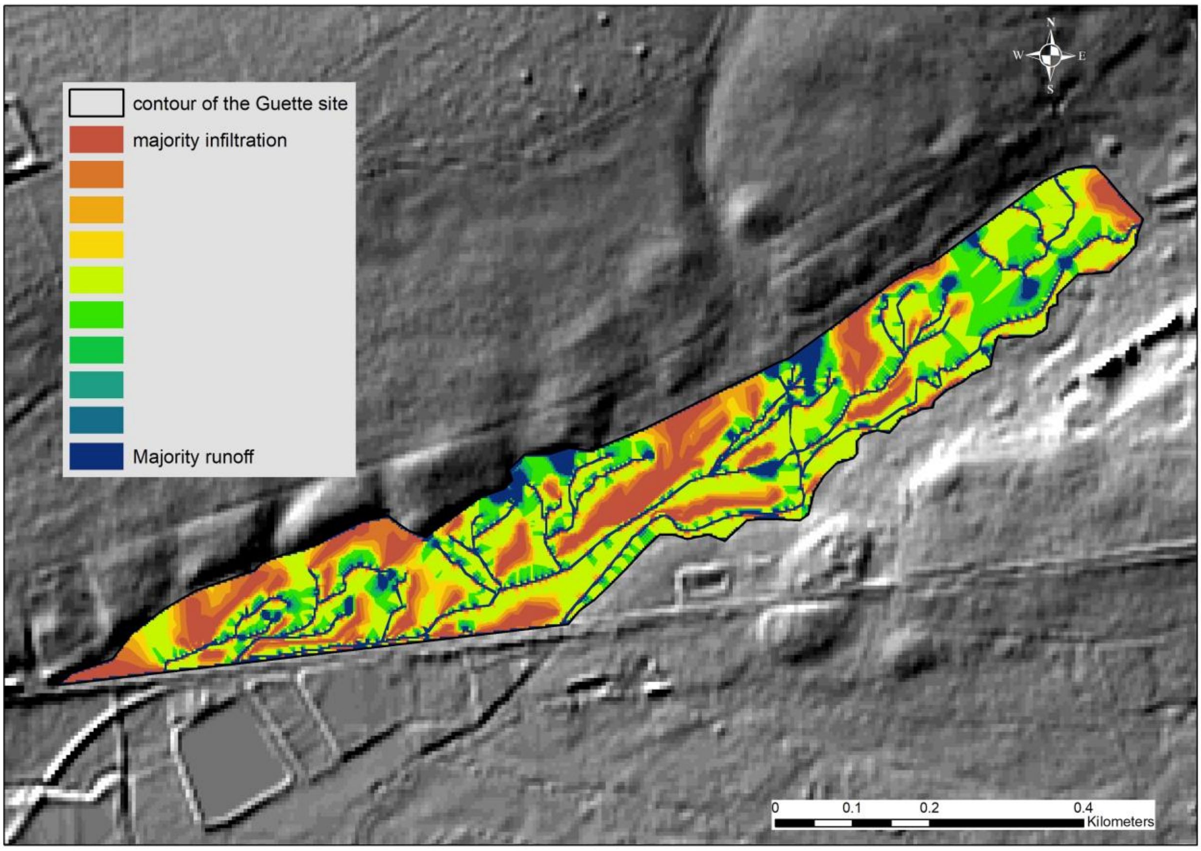


Figure 11: IDPR calculated on la Guette site

The reader's guide in Figure 12 provides a key for interpreting the calculated IDPR, considering the entire permanent and intermittent network as flowing.

IDPR		Interpretation	
0	< 1000	Primarily Infiltration rather than surface runoff	There is non-conformity between the availability of drainage axes linked to thalwegs and observed hydrologic axes. Runoff on natural terrain joins a drainage axis defined by thalweg analysis without showing a concrete expression of a natural hydrologic axis. Development of a thalweg network of higher density than the expression of the natural drainage network.
	= 1000	Infiltration and surface runoff of equal importance	There is conformity between the availability of drainage axes linked to thalweg and in-place flows.
1000	> 1000	Primarily surface runoff as compared to infiltration toward the subsurface.	Runoff on natural terrain rapidly joins a natural hydrologic axis without it presence being directly justified by a thalweg.
2000	> 2000	Primarily comparable to a wet environment.	Transitory or permanent water stagnation, which leads to two different interpretations. If the water-bearing layer is near the natural ground surface (watercourses and humid zones), the land is saturated and water will not infiltrate. If the waterbearing layer is deep, the flowing nature m demonstrate impermeability of natural terrain. We offer the hypothesis that IDPR values higher than 2000 are primarily applicable to wet environments (possibility of flooding by the hydraulic barrier effect).

Figure 12: IDPR Reader's Guide

- ***Wetness Index***

By combining the flow accumulation grid and the slope grid calculated on the la Guette site, we can obtain a soil moisture index - TWI (Figure 13) whose values vary between 0 (dry) and 100 (wet). On some sectors of this peatland, there is a fairly good consistency between the infiltrating sectors and those of low humidity.

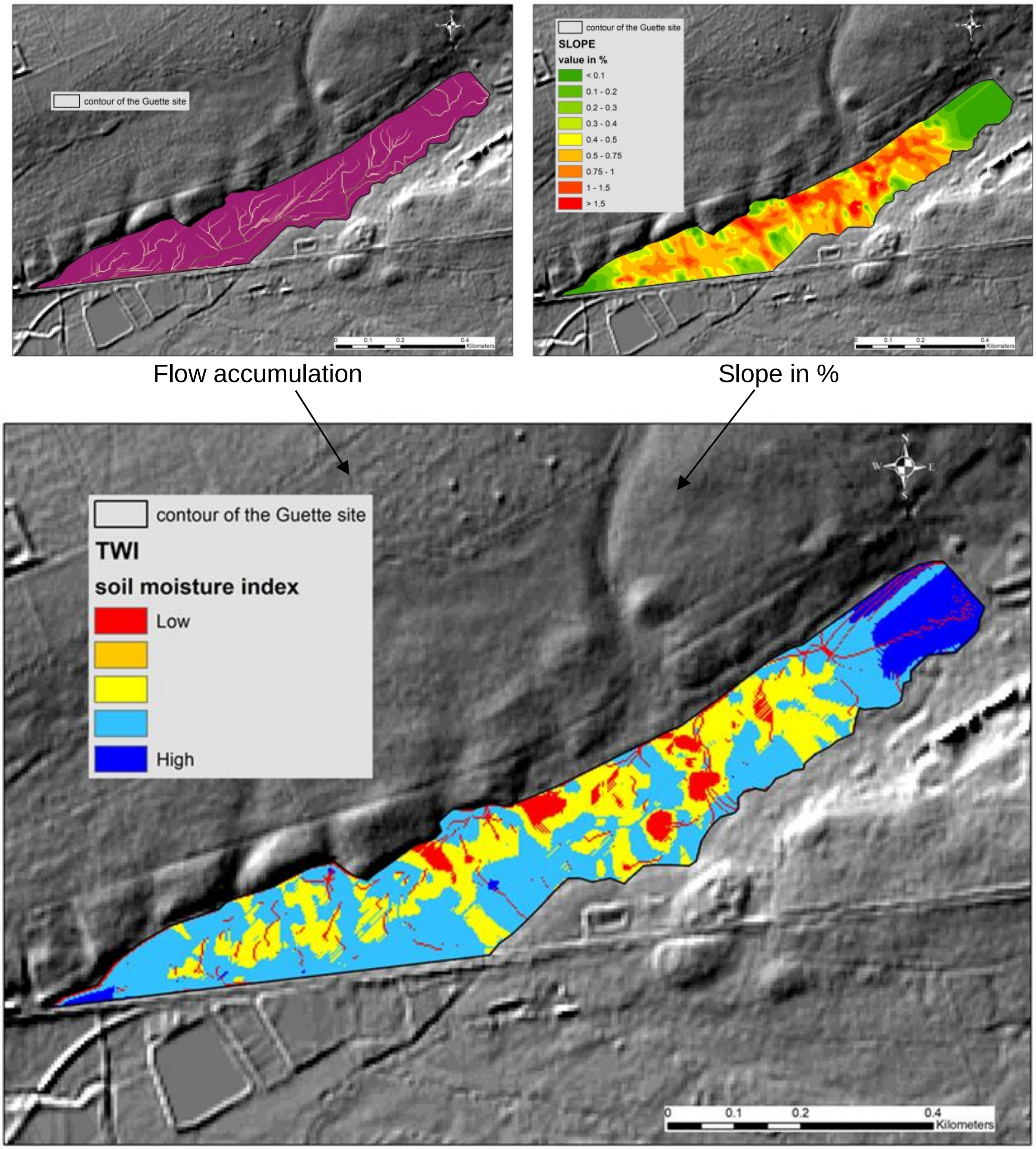
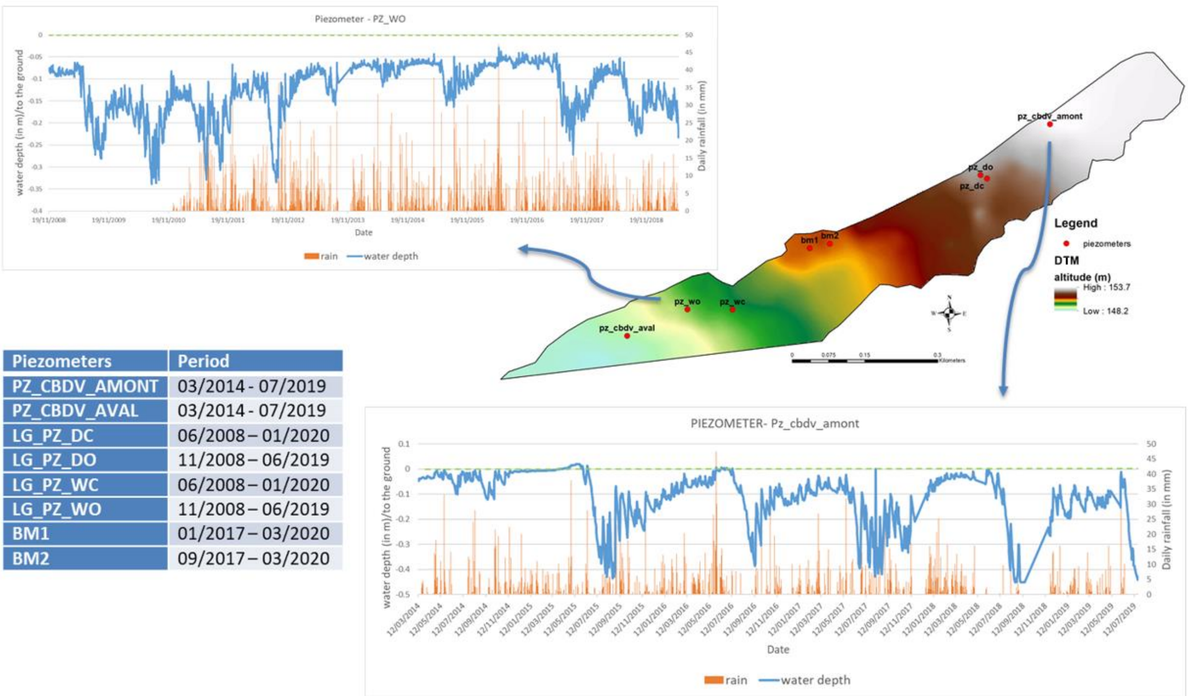


Figure 13: TWI calculated on la Guette site

2.2.2: PIEZOMETRIC LEVELS

- ***Thickness of the unsaturated zone***

La Guette site has eight piezometers with continuous measurements (Figure 14). During periods of high water (like in March 2009), the water table levels were measured with a correct density and distribution over the wetland (except in the upstream area), which allowed interpolation



Piezometers	Period
PZ_CBDV_AMONT	03/2014 - 07/2019
PZ_CBDV_AVAL	03/2014 - 07/2019
LG_PZ_DC	06/2008 – 01/2020
LG_PZ_DO	11/2008 – 06/2019
LG_PZ_WC	06/2008 – 01/2020
LG_PZ_WO	11/2008 – 06/2019
BM1	01/2017 – 03/2020
BM2	09/2017 – 03/2020

Figure 14: Piezometers with continuous measurements

An elevation map of the water table was plotted, giving access to the main flow directions (Figure 15a) from upstream to downstream. By combining the interpolated data with the DTM, a map of the thickness of the unsaturated zone was obtained (Figure 15b). At la Guette site, in high waters, the water table is close to the surface (dark and light blue areas) with an unsaturated zone thickness mainly lower than 20 cm.

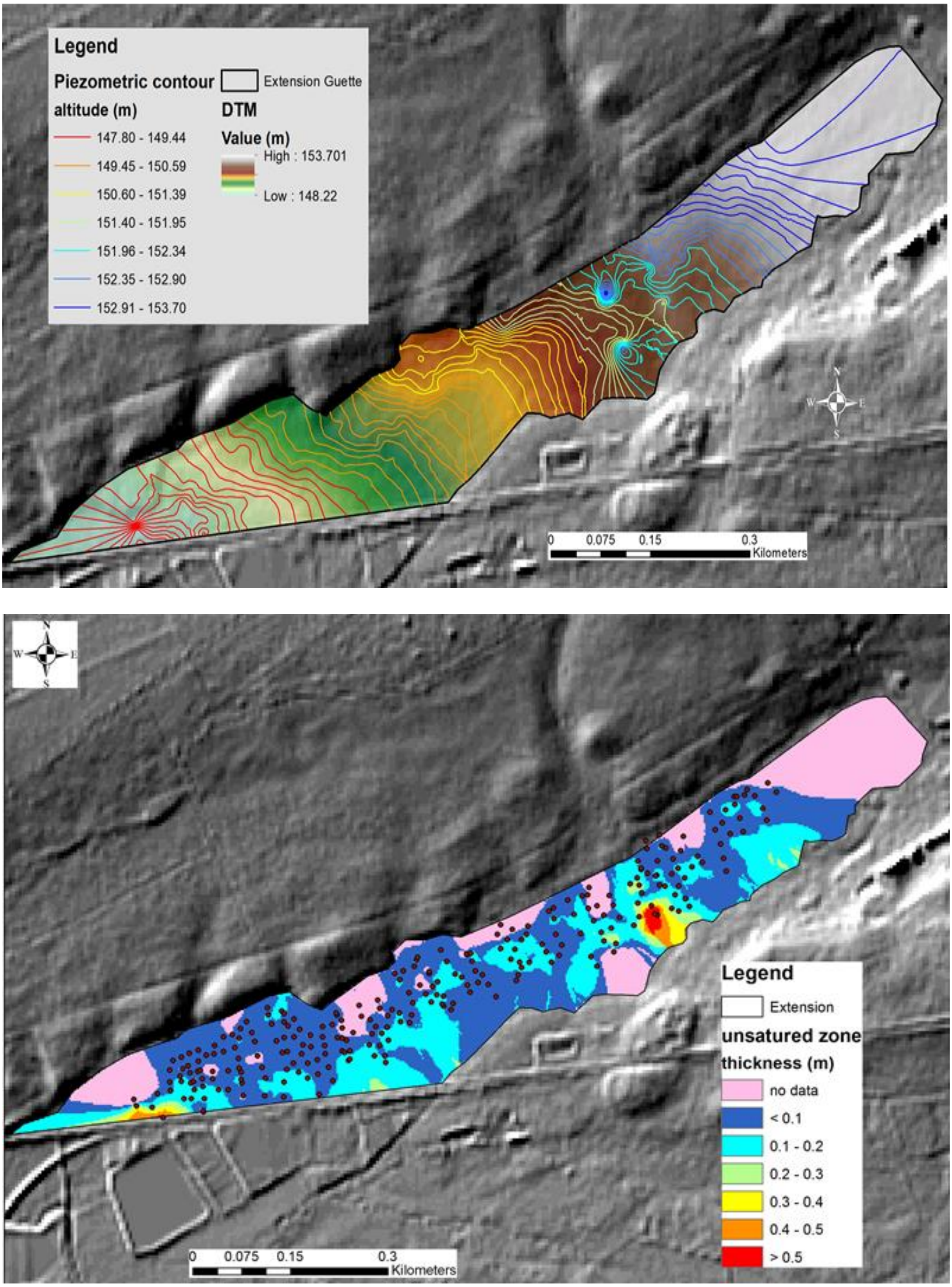


Figure 15: (a) Piezometric contours of water table depth ; (b) thickness of the unsaturated zone

- ***Estimation of CO_2 emissions***

From the thickness map of the unsaturated zone (Figure 15b), we applied the relationship described in Figure 2 to estimate the CO_2 fluxes emitted from la Guette site with the following equation y = - 0.45 x + 0.088 (x is the thickness of the saturated zone in cm and y corresponds to CO_2 emissions in ton CO_2-eq/ha/year, Figure 2).

The result is a map (Figure 16) that shows an estimate of the CO_2 fluxes emitted for each pixel of the study area and for groundwater levels measured in March 2009.

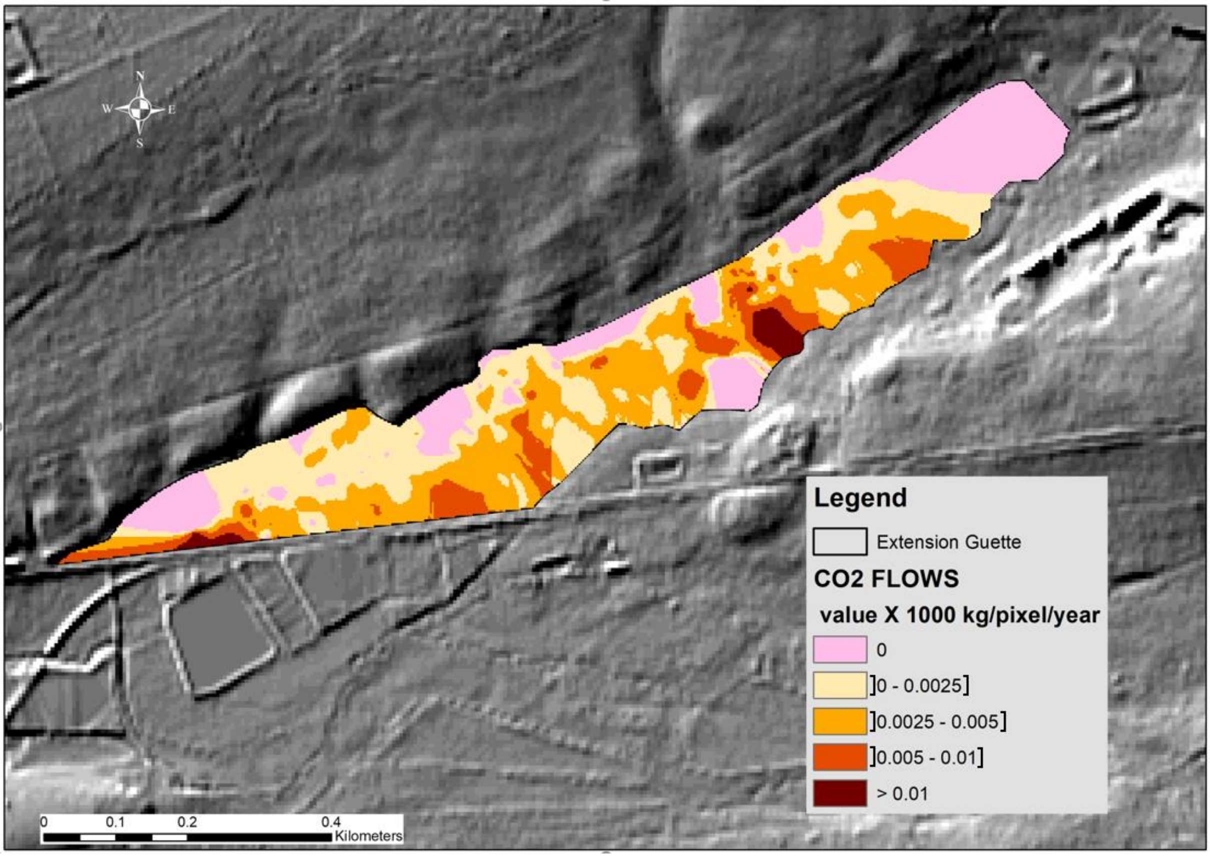


Figure 16: Map of the estimated CO_2 emission for each pixel (1 pixel = 7.26 m^2) in March 2009 at la Guette site according to the relationship proposed by Fritz et al. (2017).

From this map, it is possible to calculate the amount of carbon released on the whole selected zone. As an example, on this first calculation, the amount of carbon released by la Guette peatland in the atmosphere (net C source) is estimated to +73t CO_2/year, a value close to the one proposed by D'Angelo et al. (2021).

2.2.3 PEAT THICKNESS

By interpolating (kriging method) the peat thickness measurements made at la Guette site, we can produce a map of the peat thickness over the whole site.

By crossing this map with the thickness of the unsaturated zone (Figure 15b), we can spatially map the areas where the peat is partially wet in March 2009 (Figure 17).

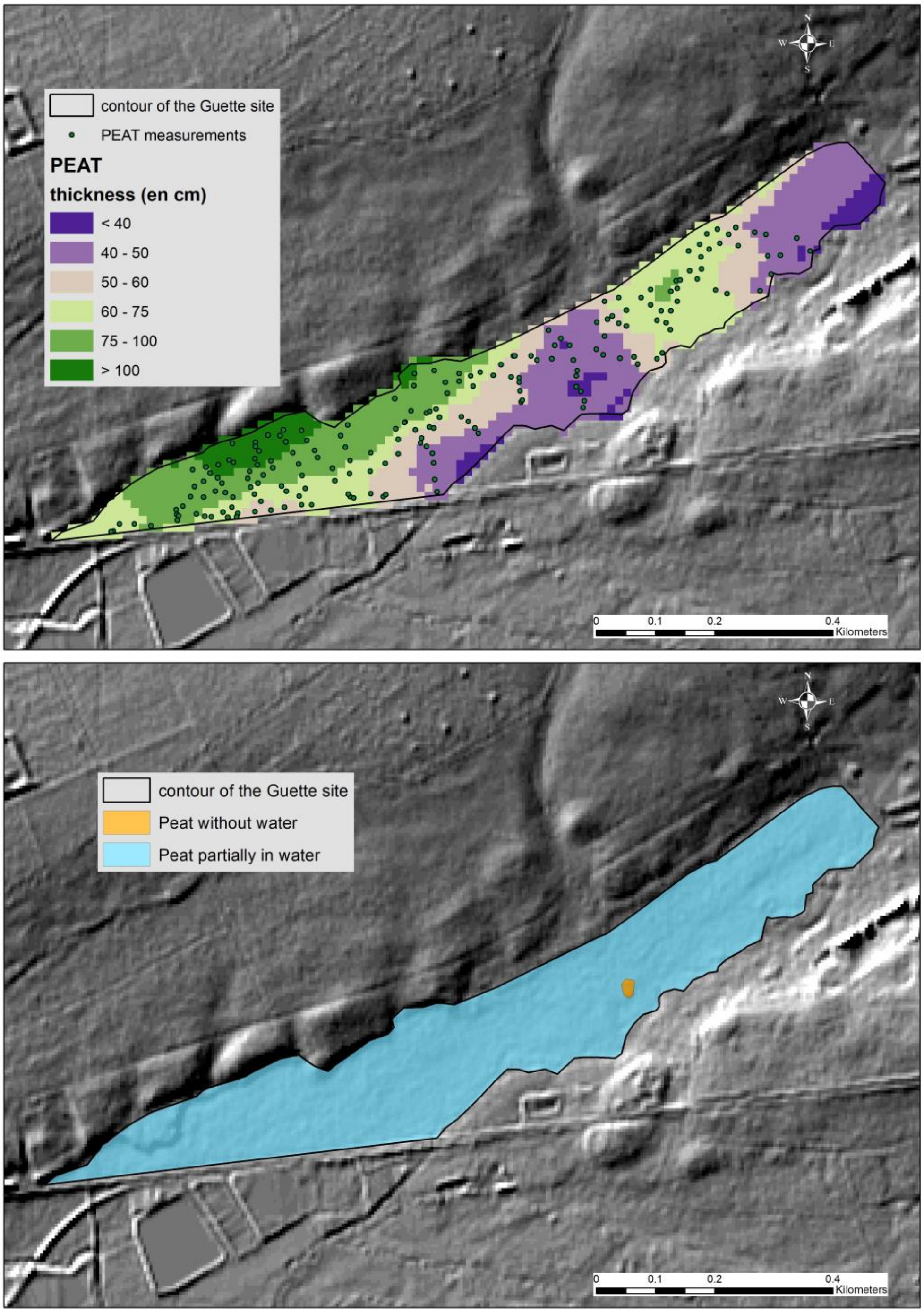


Figure 17: Maps of peat thickness and partially wet peat areas at la Guette site

Chapter 3: Conclusions

During the last decades, many modeling approaches allow predicting GHG fluxes from peatland. These estimations are mainly based on proxies like water table depth, vegetation… However, for peatland managers or owners, one major issue is to have an accurate representation of their peatland. Indeed, because of the heterogeneity of the peatlands (variations of water levels upstream and downstream, heterogeneity of the vegetation cover…), the GHG fluxes at the peatland scale are not uniform. This is why we propose to have an approach based on a GIS (Geographical Information System) in order to visualize the spatial heterogeneities.

Discussions with peatland managers have shown that it is important to characterize the GHG emitting zones. However, these emissions are often due to a combination of many factors and it is important to propose a large set of maps and only a cross analysis of all these information will allow selecting the most adapted restoration works. This report presents a list of data and indicators useful for managers, from hydrogeological data measured in the field up to CO_2 fluxes estimations.

As perspectives, this approach of estimating CO_2 fluxes will be refine during the project by integrating the numerical model developed in WP T1 - Activity 3. Up to now, we used data and relationships from the literature, but the next step will consist in implementing the model calibrated for each site of the project.

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