Environmental RTDI Programme 2000–2006

CLIMATE CHANGE – Modelling Carbon Fluxes from Irish Peatlands: Towards the Development of a National Carbon Fluxes Inventory for Irish Peatlands

(2000-LS-5.1.2b-M1)

Synthesis Report

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Prepared for the Environmental Protection Agency

by

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CLIMATE CHANGE

The Climate Change Section of the Environmental RTDI Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in this area. The reports in this series are intended as contributions to the necessary debate on climate change and the environment.

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1 Summary

Peatlands are thought to contribute significantly to the greenhouse gas (GHG) fluxes in Ireland. The accumulation of carbon in stable peatlands can be regarded as sequestration to a store, while emission of carbon due to decomposition of long-term carbon stores would be regarded as a source. The balance between carbon storage and emission is dependent on peat type and change in use through time. To understand the role of peatland in the inventory of Ireland's GHG emissions it is necessary to quantify the national peatland resource and its associated fluxes.

The aims of project 2000-LS-5.1.2b-M1 were to quantify and classify the national peatland resource, and to assess the GHG fluxes associated with each peat class. These data would then permit estimation of the contribution of peatlands to national GHG fluxes. These aims have been addressed by:

- The development of a rule-based GIS methodology, **PEATGIS**, to quantify the national peat resource based on existing data sets

- The partial development of a carbon flux model, **PORTACH II,** to determine the GHG fluxes associated with various peatland classes

- The combination of map and model data to produce a preliminary estimate of national GHG fluxes associated with peatlands. Given that some uncertainty exists regarding the magnitude of fluxes, the data have been placed within a best- and worst-case scenario range to aid interpretation.

The estimate of the peat resource in the Republic of Ireland, derived from PEATGIS, suggests that peatlands cover *ca* 0.95 Mha or *ca* 14% of the total land area, and that around 74% of peatlands are disturbed in some way. These area estimates are similar to those of CORINE (Coordination of Information on the Environment), while the disturbance data are somewhat lower than the Irish Peatlands Conservation Council (IPCC) estimates of 82% for blanket bog and 92% for raised bog. The PEATGIS tool was designed to be used with new digital data sets as they become available.

The preliminary results derived from the PORTACH II model are subject to some uncertainty because the modelled system has not captured all the important processes that occur. While some detail in the model may not be exact, the general values derived indicate that, on balance, it is quite possible that the level of disturbance of Irish peatlands might be causing a release of long-term stored carbon. For example, sequestration rates of raised bogs were estimated to range from around –16 g C m^2/year for disturbed situations (i.e. loss of long-term stored carbon) to around +60 g C m^2/year for undisturbed situations (i.e. sequestration of carbon). A revision of modelled processes is ongoing.

As there is uncertainty associated with the GIS/modelling approach, the method was used to evaluate whether, on balance, it was more likely that Irish peatlands are acting as carbon sinks or sources. Best- and worst-case scenarios were evaluated to estimate the range of results possible: best case +0.6 Mt C/year, worst case –0.1 Mt C/year. Land-use scenarios based on IPCC- and PEATGIS-derived disturbance rates were used to estimate that the carbon balance is probably close to neutral: IPCC –0.02 Mt/year, PEATGIS +0.04 Mt/year, which are small deviations from neutral compared to the total possible range. The results showed that peatlands and their status significantly affect carbon fluxes and underline how important this issue is for Ireland considering that 74% of Irish peat bogs are probably disturbed.

The project has facilitated the development of two new quantitative methodologies that can predict the total peatland area as well as estimate carbon fluxes from these peatlands. Future work will develop these ideas to permit estimation of total peatland carbon storage, and improved formulation of the peat carbon flux model.

2 Objectives

The objective of this project was to make an assessment of the extent and status of Irish peatlands and the associated carbon fluxes. This was to be achieved by addressing three sub-objectives:

1. The spatial extent of peatlands was to be estimated using remote sensing and survey data.

2. Carbon fluxes were to be estimated based on modelling of carbon processes in bogs. The objective was to make a first estimate based on revision of the PORTACH model.

3. Emissions predictions were to be estimated by combining both parts of the work and testing using published data.

The main tasks that were carried out in order to achieve the objectives were:

- The development of a novel rules-based GIS methodology, PEATGIS, which allows the use of combinations of remote sensing and digital map source data to estimate the extent and status of the Irish peatlands. The methodology has been evaluated using specifically collected ground truth data. As new data sets become available the methodology can be applied to them, and the quality of the resulting maps can be evaluated following short field campaigns to collect ground truth data.

- The development of a static carbon flux model (PORTACH II) that could be parameterised for both blanket peatlands and raised bogs. The model encompasses many of the processes included in the PORTACH model but is reformulated to be better suited to the task at hand. The model predicts steady-state carbon fluxes under defined conditions and can be initiated at any stage of peat development. The model, developed as a spreadsheet, can include all major Irish peatland forms and is formulated for large-scale application and is easily used. Due to time constraints, the processes modelled do not capture the real world as well as could be achieved, so the results presented have to be viewed as somewhat tentative.

- The combination of PEATGIS and PORTACH II to estimate the total carbon fluxes associated with Irish peatlands. Different scenarios to estimate future carbon fluxes dependent on various land-use management scenarios have also been run in order to account for uncertainties that are associated with both the formulation of PORTACH II and the parameter and state data available for Ireland.

2.1 Peatland Classification

Peatlands in this project are defined according to Immirzi *et al.* (1992) as the physiographic, geomorphological or biogeographic setting of peat and it may include areas that are no longer carrying peat-forming communities but where peat soils still remain.

Peatlands are typically classified by the degree of hydrologic isolation, or trophy, from the relative source of water (precipitation, surface, or groundwater) they receive. There are three main classes (Mitsch and Gosselink, 1993):

1. Minerotrophic fens – receive water that has passed through mineral soil, have a high groundwater level and a lower elevation than the surrounding area.

2. Ombrotrophic (ombrogenous) bogs – raised from the water surface, only receive water and nutrients from precipitation, and have a higher elevation than the surrounding area.

3. Mesotrophic (transitional) bogs – show qualities of both the minerotrophic fen and ombrotrophic bogs. They are precipitation dominated but may also receive water from other sources such as surface streams and groundwater.

As un-degraded organic matter accumulates, a peatland is raised further from a mineral water source, thereby gradually becoming more ombrotrophic. Therefore, many peatlands begin as minerotrophic fens and transition to ombrotrophic raised bogs. The majority of Irish bogs are ombrotrophic. A classification is outlined in Table 2.1 and details are given overleaf.

Table 2.1. Types of peatland found in Ireland and some commonly used subclasses.

Blanket bog	Raised bog
Montane	Cutover
Oceanic	Cutaway
	Virgin bog
	Transitional woodland scrub
	Coniferous forests

Blanket bog. Blanket bogs initially develop in discrete locations which ultimately coalesce into a widespread peat landscape ranging in depth from 2 to 8 m (Feehan and O'Donovan, 1996). In general, this peat type follows the underlying topography except on very steep slopes. Blanket bog profiles are more homogeneous in their morphology than raised bogs. Irish blanket bogs are subdivided into upland blanket bog (High-Level Montane, HLM), and oceanic blanket bog (Low-Level Atlantic, LLA). The HLM peat type occurs extensively above 152 m along the western seaboard, and at much higher levels on the major mountain masses throughout the country.

Raised bog. Raised bogs are complex biogenic structures attaining depths of between 3 and 12 m in the undrained state with an average depth of 7.5 m (Moore, 1962; Hammond, 1981). Hammond (1981) describes the stratigraphy of a raised bog as comprising three tiers: a basal tier of peat types formed under the influence of minerotrophic groundwater, a subsurface tier comprising humified sphagnum and an upper tier of poorly humified sphagnum. Raised bogs occur extensively across the Central Plain of Ireland and in their natural state two sub-types are recognised, a True Midland Type and a Transitional Type (Moore, 1962). The peat formation process is strongly influenced by climatic conditions (Charman, 2002). The close correlation between peatlands and precipitation patterns can be seen in Fig. 2.1.

2.2 Accumulation in Peatlands

In undisturbed functioning peatlands, the inputs to the system normally exceed the outputs thus resulting in peat accumulation. Peatlands therefore show a remarkable capacity for carbon storage. Matthews (1984) estimates that peatlands may store more than three times the carbon stored in tropical rainforests globally, and half of the total carbon stored in all terrestrial biota (737 Gt). The most recent detailed estimates suggest that the boreal and arctic peatlands contain 455 Gt of carbon (Gorham, 1991). This represents 40–60% of the current atmospheric carbon pool and 20–30% of global organic carbon in soil (Bolin, 1986). Peatlands therefore have a significant role in maintaining the global carbon balance (Bramryd, 1979; Bridgham *et al.,* 1995), particularly in the boreal region where they have been amassing carbon since the glacial period.

The annual gain in energy and matter by the plants is represented by net primary production (NPP). The balance between NPP and the rate of decomposition determines the accumulation rates of organic matter within the ecosystem. Mires in general and raised bogs in particular represent a special case where a partial failure of decay has resulted in the accumulation of organic matter. The carbon sequestering potential and accumulation rates of organic material of a given bog depend on a range of factors, including its age, trophic status, hydrological status and climatic regime (Feehan and O'Donovan, 1996).

2.3 Peatland Models: An Overview

There are five main simulation models for peatlands, including a simulation model implementation of Clymo's conceptual model (Clymo, 1984a,b).

1. Forrester's (1961) model is an integrated whole-system model using a system modelling approach. It is conceptually similar to Clymo's model, in that it is not spatially explicit. The model does, however, require several parameters that may be difficult to obtain, and no validation or test of the model is provided.

2. Wildi's (1978) model, on the other hand, is designed for testing at a specific site. Its major drawback is the large number of site-specific parameters required, including nutrient information. It simulates a two-dimensional cross-section of the peatland, and is designed for investigating controls on bog form. It is partially validated.

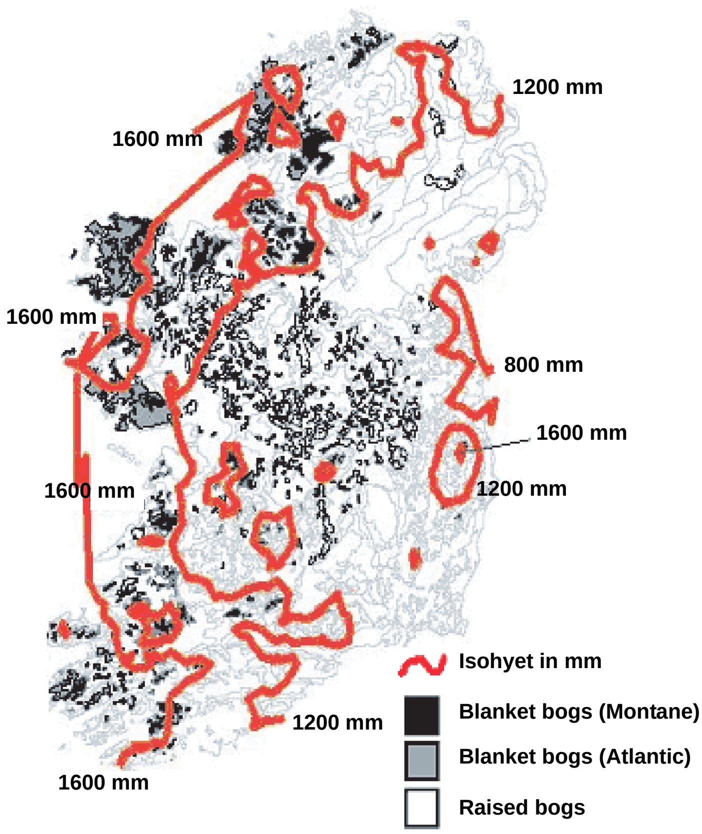

Figure 2.1. Peat classification map of Ireland (as derived in this project) with rainfall isolines overlaid.

3. Winston's (1994) general, hydrology-oriented model is based on Clymo's and Ingram's models, but includes special consideration of the initial growth phase. Like Wildi's model, it is implemented as a two-dimensional cross-section model, and is designed for investigating the controlling factors of bog form and coal formation. It has been validated using real data.

4. Korhola *et al.* (1996) developed a topography-driven three-dimensional peat initiation, growth and expansion model. There are no explicit climate or water table drivers in this model, making it unsuitable for investigating effects of climate change.

5. Hilbert *et al.* (2000) model the interactions between different components of a peatland using a system dynamics approach. This model shows two possible steady-state configurations for a peatland, depending on water relations, to which the authors ascribe the characters of bogs and fens. This model is well suited for further development for investigating the impacts of climate change on a peatland and is the only one able to simulate fens as well as bogs. This model can also be seen as an outgrowth of Clymo's conceptual model, but with considerable additions of explicit functional relationships.

2.4 The Need for PEATGIS and PORTACH II

Northern peatlands are unique ecosystems for the study of biosphere–atmosphere–climate interactions. Any global warming or cooling will probably be enhanced in northern latitudes with direct effects on emissions of CH_4 and therefore direct consequences on global CH_4 and climate cycles. Current estimates, based on inverse modelling of the global CH_4 cycle (Fung *et al*., 1991) and on reviews of data from field campaigns (Bartlett and Harriss, 1993), have converged around a total CH_4 emission of 35 Mt CH_4/year from northern wetlands and tundra. Thus, an understanding of the mechanisms that control and regulate CH_4 and CO_2 fluxes from northern peatlands is of particular importance. This is why it was necessary to create an assessment of the area and status of peatlands in Ireland. Since peatlands in Ireland are in an array of forms and display severe disturbance mostly due to anthropogenic effects, this is of particular importance. The IPCC estimates figures of 82% disturbance for blanket bog and 92% for raised bog in Ireland (IPCC, 1996). There is an obvious need for the development of a static carbon-flux model that can estimate current steady-state fluxes from all peatland forms of Ireland. The models also need to take into account ecological mechanisms, thereby giving a better understanding of the peatland role in the global carbon budget at present and in the future. This has been attempted in this project with the development of the two tools: PEATGIS – a method for estimating the extent of peatlands in Ireland and PORTACH II – a peat carbon model.

3 Spatial Inventory of the Irish Peatland Resource: PEATGIS

The rules-based GIS methodology, PEATGIS, was developed to examine the extent of peatlands in Ireland. The model relies on a decision tree that was devised to implement algebraic combinations of several source maps. The main objective of this work was to establish baseline data regarding the current extent and status of peatlands in Ireland using GIS and multi-source data. This was achieved by the creation of a rules-based decision tree in GIS to determine the likelihood of a certain location in Ireland containing peat.

3.1 Maps

The three digital maps acquired for this project were the General Soil Map (GSM) (Gardiner and Radford, 1980a), the Peatland Map (PM) (Hammond, 1979) and CORINE (O'Sullivan, 1994).

1. *GSM.* The GSM classification system is based on parameters from the USDA soil classification system first developed in 1938 (Soil Survey Staff, 1960). Several categories called Great Soil Groups were used to create the map boundaries for the GSM (Gardiner and Radford, 1980b). Several counties, including Kerry, Wicklow, Galway, Roscommon, Longford, Mayo and parts of Donegal, containing substantial tracts of peatlands were not fully surveyed. This lowers the reliability of the GSM.

   There were several problems associated with the incorporation of the GSM into the GIS. The GSM needed extensive geo-rectification to align the map with the other two maps. Over 60 tic points were used to georeference the map; however, the spatial coincidence of some areas was low with errors of up to 500 m, especially on the east and west coasts.

2. *PM.* The PM (Hammond, 1979) contains several categories of peat including HLM blanket bog, LLA blanket bog and raised bog (RB). Each of these categories are subdivided into different classes including industrial bogs, potential industrial bogs, transitional raised bogs, man-modified raised and blanket bogs, True Midland Type raised bogs, and blanket bogs (Table 2.1). Like the GSM, the PM used older sources of information and maps as well as field surveys, but it may not have been exhaustively surveyed.

3. *CORINE.* CORINE is the only national land-cover map available for Ireland but some of the land-cover classifications are artificial constructs and include a mix of land uses (Water Framework Directive Ireland, 2005). CORINE is based on interpretations to identify different land-cover types either by eye or using computer-assisted interpretation to reveal extra details and resolve ambiguities (Water Framework Directive Ireland, 2005). This land-cover map was produced in 1990 as part of a Europe-wide project on land cover. As such it has 44 land classes, of which 33 are relevant in Ireland. The classification of peatlands was only to Level 3 and with no greater detail. Moreover, this is not a soil map but a land-cover map and therefore peat soils with vegetation such as grassland or coniferous forest will not be classified as peat in CORINE.

3.2 Conceptual Framework

This rule-based GIS model was designed as a decision tree with a filtering system that allows pixels that do not comply with the initial rule not to be discarded but to be re-examined by the subsequent rules. There are three main rules in the decision tree. Both the first and second steps rely solely on primary data while the third step relies on secondary processed data. The first step is the most rigorous as it examines pixels that are present on all three maps (CORINE, GSM, PM). The second rule examines peat pixels found in two out of three maps. This step is less rigorous but it includes the largest area of peat and it will further recover pixels that were falsely excluded in the first step. However, to ensure that no peat pixels were falsely discarded a third rule was devised. Rule 3 is subdivided and more complex. It contains a number of sub-rules allowing peat pixels that appear in only one map but fulfil certain criteria to be recovered by the model. The third step thereby recovers those pixels that are uncertain as they rely on secondary sources of evidence.

As stated above, Rule 2 examines pixels that are stated to be peat outright on all three maps. Similarly, Rule 3 requires that peat is present on two out of the three maps but it is not as simple to define peat pixels in this rule. Two criteria were examined in relation to the third rule, peat-associated vegetation class (PAVC) and peat soil associations (PSAs). The CORINE classes – Transitional Woodland Scrub and Coniferous Woodlands – are located predominantly on peat bogs in the midlands of Ireland. The sub-rules state that if a pixel is peat in either the GSM or the PM and coincided with a CORINE class that contained elements of peat, i.e. a PAVC, it should be included. Likewise, the GSM contains soil associations that in some cases have a very high percentage of peat, and are therefore termed PSAs. Therefore, if the percentage of peat is higher then 10% and these pixels coincide with the peat bog pixels in CORINE, they are to be included. The PAVCs and the PSAs were derived from extensive processing of the maps; therefore they could be called secondary data as opposed to the primary data of the defined peat pixels in the first two rules.

3.3 Determining PAVCs

A sensitivity analysis was conducted to identify CORINE classes that could be classed as a PAVC and hence used to include uncertain pixels in Rule 3. The PAVCs are a derived class. They were derived from pixels that were peat in both the GSM and PM. Essentially, a PAVC is a pixel that is not classed as peat in CORINE but is classed as peat on both the PM and the GSM. Two sources of the evidence of peat are apparent, therefore CORINE pixels that coincide with these may be classed as a PAVC. To determine the classes in CORINE that have PAVC elements, a series of calculations using map algebra were undertaken in ArcGIS (Fig. 3.1).

Both the GSM and the PM were multiplied together using the raster calculator function. This resulted in a map, GSM_PM, that shows the location of peat on both maps.

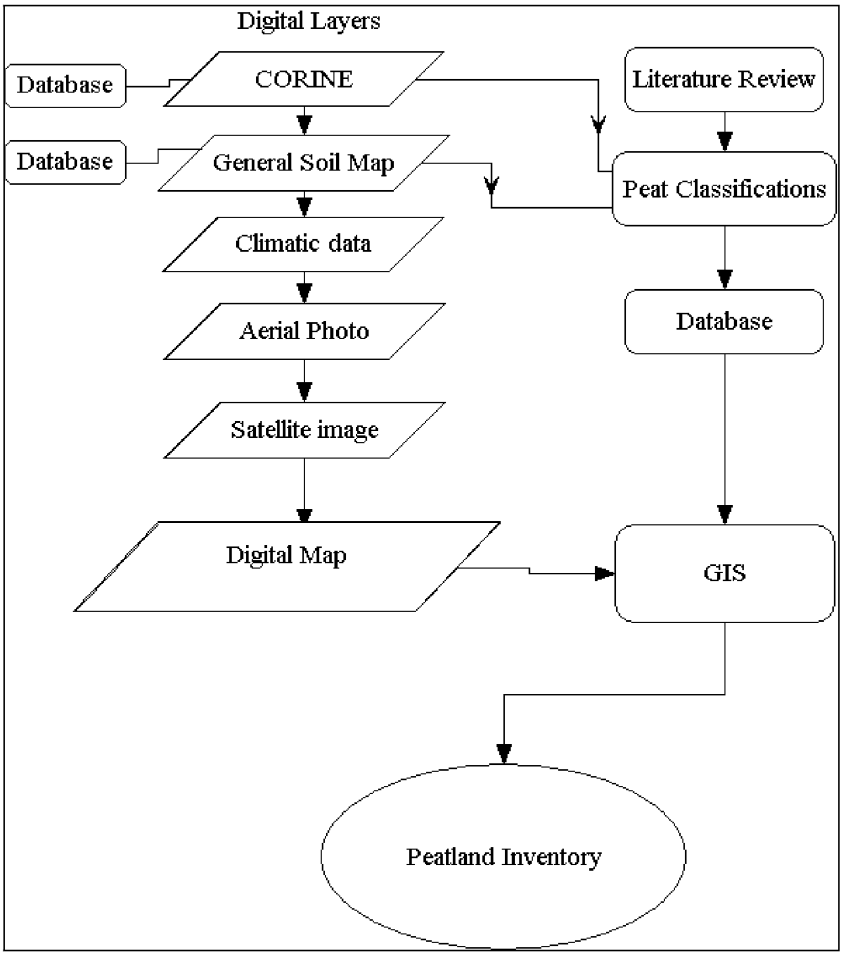

Figure 3.1. Schematic of the GIS rules-derived methodology (this study).

3.4 Determining PSAs

A large number of pixels in the CORINE Peat Bogs class did not coincide with peat pixels on the GSM or the PM. Therefore a sensitivity analysis was conducted to determine whether or not these CORINE pixels coincided with a PSA from the GSM. By performing several calculations using map algebra the GSM soil types that were related to exclusive CORINE Peat Bogs were extracted. The map algebra used was cartographic modelling as a means of combining two or more input map layers to produce a final map output layer (http://www.geo.ed.ac.uk/agidexe/term?709). Both maps were then joined and the attribute tables were exported to Excel to allow further analysis. Within Excel, the data were examined and soil associations that contained at least 10% peat were extracted. Twenty-four GSM classes had relevant elements of peat. These were exported back to the GIS and displayed as a new map that showed pixels that were peat exclusively in CORINE but coincided with PSA from the GSM. The final output from the decision tree was the derived Irish peat map (DIPM) depicting an aggregation of the organic materials (OMs) from each stage of the decision tree. This map showed the extent of peatland in Ireland derived from the decision-tree rules.

3.5 Results

The methodology in the PEATGIS model is based on a maximum likelihood method. Each of the steps in the decision tree produces a map. This hypothesis was borne out through field validation, where 300 randomly selected sites were ground truthed. These sites represent pixels that have been classed as peat by the GIS rules-derived map. There is a 67% agreement between the DIPM map and the ground truthing, clearly validating the DIPM. Reliability maps were produced for each of the data sources and for the final map (Fig. 3.2).

3.6 Discussion

Earlier estimates according to Hammond (1979) state that peatlands comprise 17% of the national land area, while the GSM estimate is 16.7% and CORINE 13.2%. The latter is in close agreement with the DIPM estimate of 13.8% (this study).

The use of the rules within the GIS allowed a greater flexibility in utilising disparate sources of data to examine the spatial extent of peatlands in Ireland. The integration and geo-processing of these maps produced a DIPM that shows the spatial extent of peatlands in Ireland. The result from this is that 13.8% of the area of the Republic of Ireland is allocated to peatlands, which is similar to CORINE’s estimation of Peat Bogs (13%) and smaller than Hammond’s Peatland Map’s estimation (17%).

The novelty of this methodology is that it may be used as a generic method that can be applied with any such digital data sets and can be used to recalculate peatland extent as new data sets become available. The PEATGIS output has given a more accurate estimate of the peatlands of Ireland (DIPM), and can be used as a map for developing an inventory of GHG/carbon fluxes in peatlands. This is very important in relation to Ireland’s Kyoto obligations and the GHG fluxes from Irish peatlands – it is necessary to have good spatial inventory data on the extent of peatlands.

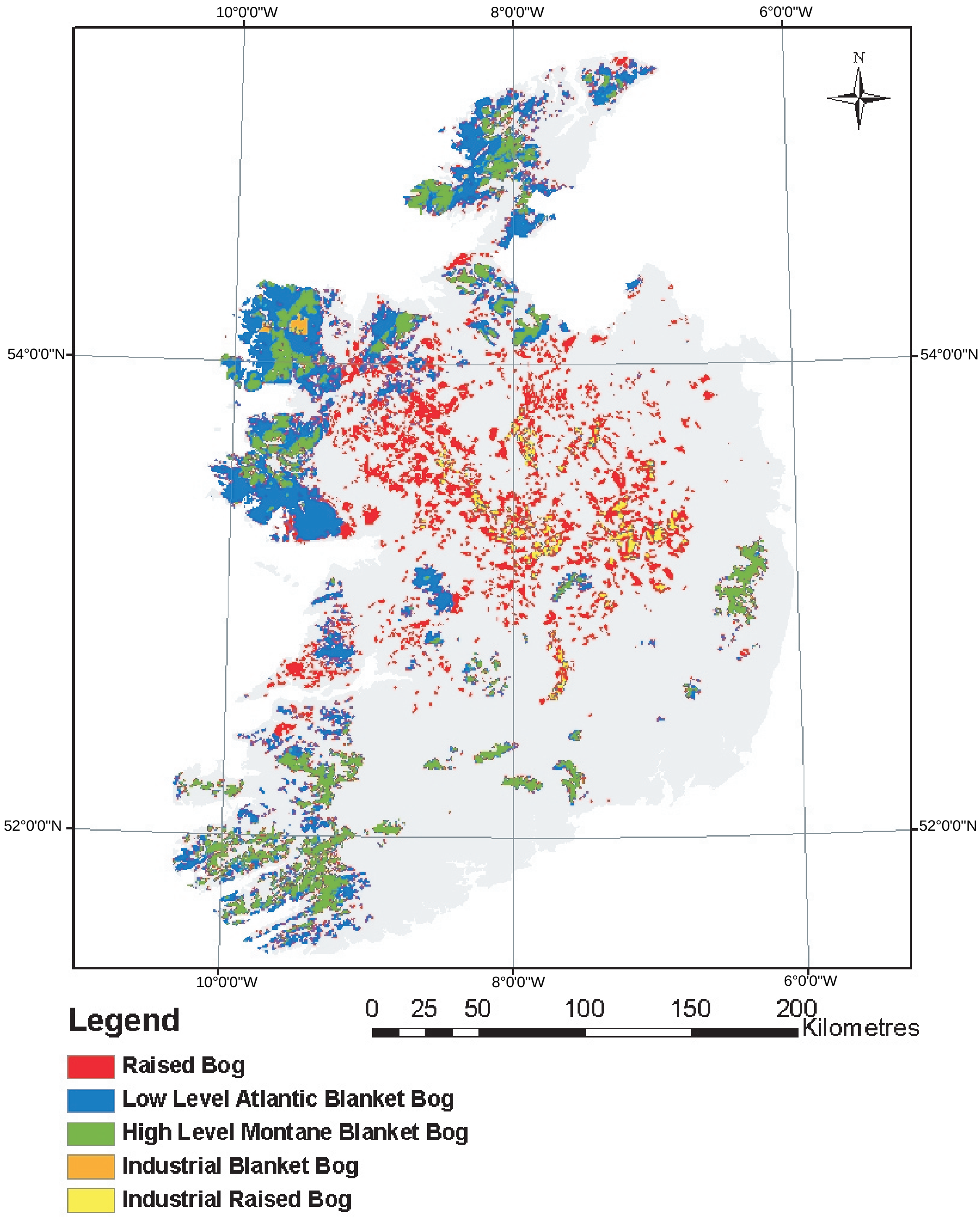

Figure 3.2. The DIPM peatland map identifying *ca* 0.95 Mha of peatland (13.8% of the total land area) (this study).

4 A Model for Estimating Peatland Carbon Fluxes: PORTACH II

The PORTACH II model was developed as a static model that could predict steady-state carbon fluxes for peatlands under broadly defined conditions, i.e. the model was designed for national, rather than local-scale applications. By changing parameters, the model could also be used to predict future carbon fluxes in response to altered land-use and management plans. Such an application may, however, require further refinement of the model.

The PORTACH II model provides a description of steady-state carbon fluxes and carbon pool sizes associated with various peatland ecosystems under set conditions. While the model nominally considers time, it is effectively a static model that predicts system state when the system is in equilibrium with its environment. In its current form, it is always assumed that an equilibrium state has been achieved. The sustainability of this assumption has not been explicitly tested. The calculations start with a specified initial condition, with an initial value for the carbon pool associated with the vegetation, litter, acrotelm and catotelm pools. The biosphere is divided into a vegetation pool, two litter pools (woody and herbaceous) and two soil pools (acrotelm and catotelm). The parameters chosen for initialisation of the model are associated with the three peat types defined in the legend of PEATGIS and were estimated from literature sources.

4.1 Model Structure

The model addresses the steady-state accumulation and loss of carbon to evaluate the associated carbon cycle of peatland ecosystems. The model approach involves the construction of a compartmental model mechanism, incorporating organic matter input and change in output functions, thereby giving the carbon balance for a peatland. Figure 4.1 shows the five carbon pools associated with a peatland ecosystem: (i) atmosphere, (ii) vegetation, (iii) litter (split into two pools), (iv) acrotelm, and (v) catotelm. The input parameters describe the carbon stock, the decay rate, the mortality, and the carbon transfer between each pool.

PORTACH II represents a simple simulation model of a steady-state peatland. It was developed from an initial conceptual model where known components, interactions and mechanisms of the system were assembled and considered within the framework of the whole system. PORTACH II was broadly parameterised using data gathered from published literature that correspond to the Irish geographical and climatic situation. The parameter values were then harmonised to bring the model into internal equilibrium. It is important to compare the findings of this model with data reported from field observation in Ireland and in other temperate and temperate boreal regions, in order to evaluate the robustness of the modelling concepts used within PORTACH II.

Carbon sequestration. PORTACH II estimated the rates of carbon accumulation for each of the peatland classifications in a natural and disturbed state. A raised peatland in a natural state has the greatest predicted carbon accumulation rate (60 g m^2/year) and when the peatland is disturbed there is a considerable reduction in the accumulation capacity (–17 g m^2/year), consequently changing the peatland from a net sink of carbon to a net source.

Although Irish data for the long-term rate of carbon accumulation for each of the peatland classifications have not been published, Gilmer *et al.* (2000) report an estimated sequestration rate of 18 g C m^2/year for Irish blanket peatlands. This is slightly less than the model (PORTACH II) projected value of 36 g C m^2/year for the LLA blanket bog. Franzén (1992) also presents data on an average (raised bogs and blanket bogs) carbon sequestration rate for Britain of 24 g C m^2/year, while across Europe it has been reported as ranging from 7 to 64 g C m^2/year. Thus it is evident that the scale of the PORTACH II generated projections are in general agreement with published data from nearby temperate and temperate boreal regions. In general, the predictions for undisturbed peatland tend to be slightly greater than those published, but always fall within reported ranges.

4.2 Assessment of Irish Carbon Fluxes

To allow an assessment of the current carbon sequestering potential of Irish peatlands, the outputs of

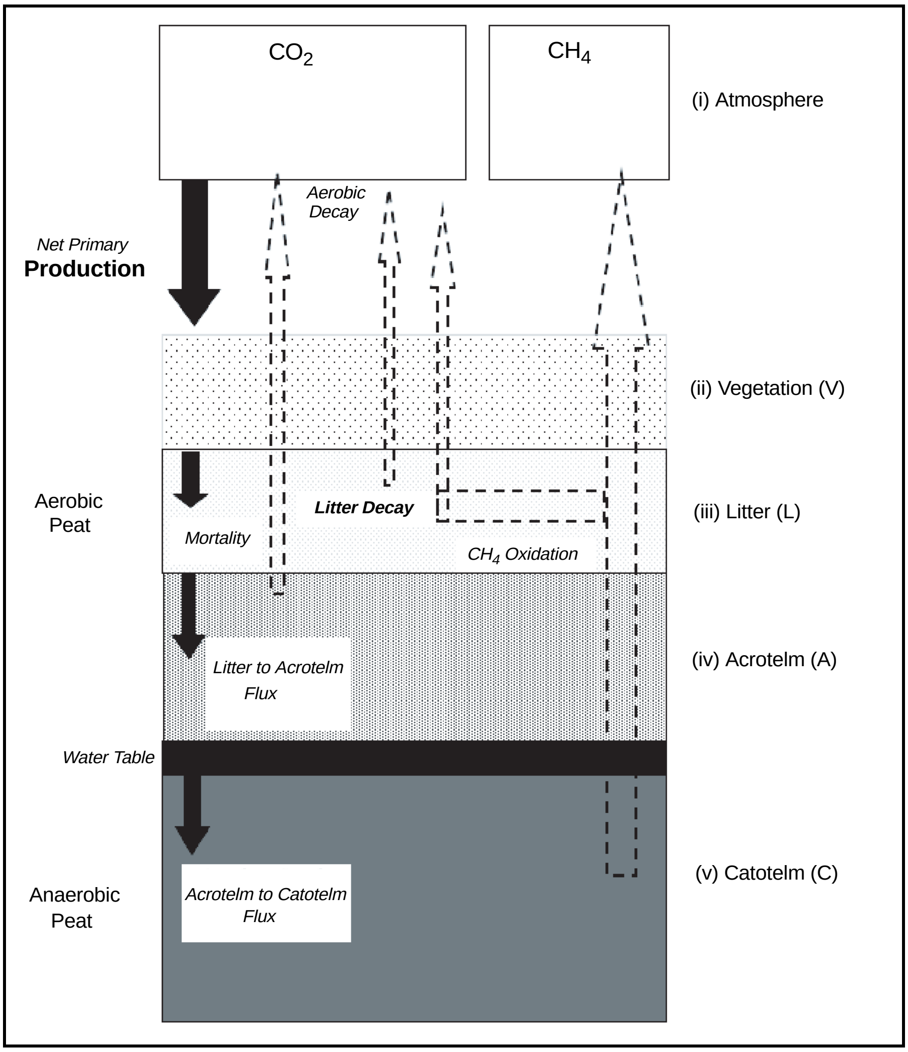

Figure 4.1. Schematic representation of the conceptual structure and carbon flows in the PORTACH II model (this study).

PEATGIS and PORTACH II were brought together. Four different scenarios were derived and tested. The four scenarios were: best case (no disturbance), worst case (100% disturbance), the IPCC estimate of disturbance by peat type and the DIPM estimate of disturbance. The best- and worst-case scenarios were derived to give the extremes of the possible range of carbon sequestering potential. The worst-case scenario simulates a complete disturbance of the total area of Irish peatlands whilst the best-case scenario simulates the restoration of all Irish peatlands to pristine conditions. The IPCC scenario estimates a disturbance rate of 82% for blanket bogs and 92% for raised bogs (IPCC, 1996). The DIPM scenario was produced from the ground-truthing procedure of PEATGIS and puts an overall disturbance rate of peat at 74%. The different disturbance rates for each scenario were combined with estimation of peatland area derived from the IPCC and PEATGIS, and carbon accumulation rates derived from PORTACH II. In each of the scenarios the same flux rate data were used.

4.3 Results

4.3.1 Best-case scenario

This scenario is purely hypothetical and simulates the restoration of all Irish peatlands to pristine conditions, giving no disturbance at all of the Irish peatlands, and based on the 1.2 Mha estimate (IPCC). The total amount of carbon sequestered annually is estimated to be *ca* 0.6 Mt. This scenario can be viewed as a control to examine the upper limits of carbon accumulation of Irish peatland.

4.3.2 Worst-case scenario

Again this scenario is hypothetical and it simulates a complete disturbance of the total area of Irish peatlands. The total amount of carbon emitted annually is *ca* 0.14 Mt.

4.3.3 IPCC scenario

Unlike Scenarios 1 and 2, this scenario was based on data from the IPCC website (accessed December 2004) http://www.ipcc.ie/bogsoccur.html to estimate relative disturbance as 92% of raised bogs and 82% of blanket bogs. These values were used in this scenario to estimate the carbon accumulation/emission rate for Irish peatlands. This scenario gave an estimate that peatlands were emitting *ca* 0.02 Mt of carbon, annually.

4.3.4 DIPM disturbance scenario

This scenario uses the disturbance factors that are derived from the field validation of the DIPM in the summer of 2004. Disturbance factors such as forestry, drainage, erosion and cutting were noted at each site in the sampling protocol. These were subsequently used to identify the ratio between disturbed and undisturbed peat for this scenario. From the sampling protocols of over 300 sampled points, the relative disturbance of Irish peatlands was estimated. The sampled points broke down into undisturbed peat (20%), disturbed peat (59%) and non-peat (21%). This scenario gave an estimation that peatlands in Ireland are currently sequestering *ca* 0.04 Mt carbon *per annum*.

5 Conclusion and Recommendations

This project has developed two useful tools for estimating national peatland carbon balance for Ireland: PEATGIS and PORTACH II. PEATGIS is a robust rules-based method for integrating digital map data sets for deriving a best estimate of the extent of peatlands in Ireland. It can be updated as new data become available. PORTACH II is a simple and robust model to estimate the carbon balance of the major peatland types. There are clearly some problems remaining with the formulation of the model and the data resulting from it have to be regarded with due caution.

The rules-based GIS-based model, PEATGIS, can, through the use of a decision tree, compile data from multiple and somewhat uncertain sources and derive a best-estimate map. This allows incomplete data to be laid together to give a more complete picture. This was a much-needed method as no holistic estimations of the current peatland resources have been available for some time. The integration of three maps (PM, GSM, CORINE) produced a map that shows the spatial extent of peatlands in Ireland. The result from this is that 13.8% of Ireland's national land area is peatlands. The peatland map developed in this study puts the disturbance of peat at 74%, which is somewhat lower than the IPCC (1996) figures of 82% for blanket bog and 92% for raised bog.

The PORTACH II model was limited because it had to be non-specific enough to be applicable to peatlands in general but the availability of field data to test and formulate the ideas was poor. It has become apparent in analysing the results that the model does not simulate the acrotelm carbon store very well. However, the consequence of this is that the model is probably underestimating carbon losses because more carbon is passed to the catotelm for anaerobic decay. Preliminary investigations have suggested that any inaccuracies in the estimations are not large and would not change the nature of the results presented here. This does however require further research.

PORTACH II and PEATGIS combined allowed assessments to be made of the current status, geographical extent and associated carbon fluxes of Irish peatlands on a national scale. PEATGIS and PORTACH II together estimate that Irish peatlands are today probably about neutral in terms of carbon accumulation/loss. The estimates from the PEATGIS and PORTACH II models contradict the previously believed carbon sequestering potential of Irish peatlands and thereby underline the urgent need to immediately start protecting undisturbed peatlands, and to acquire better data for model formulation and testing. In order to regain the carbon sequestering potential of this unique nature resource of Ireland the disturbance rate needs to be reduced significantly. The range in estimates between the best- and worst-case scenarios highlights that there may be a potential to achieve significant reductions in GHG fluxes through peatland restoration.

The work presented here using realistic scenarios (*viz.* IPCC and DIPM) estimates that the Irish national peatland carbon balance is in the range –0.02 to +0.04 Mt C/year. The fact that both estimates are near zero suggests that, on balance, Irish peatlands are possibly close to neutral in regard to acting as a net carbon sink, and that small changes in national peatland management and climate change might be sufficient to tip the balance one way or the other.

The main conclusion and recommendations are:

- Irish peatlands are possibly near neutral in terms of carbon accumulation/loss.
- Field data are urgently needed to help improve the formulation of a carbon balance model and to test it.
- Peatlands should be preserved as natural ecosystems where possible and restoration should focus on making them carbon accumulators.

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