Drained Peaty Soils are a Wasting Asset for Farmers

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1. Introduction

"Rewetting" of farmed peaty soils is a controversial topic at present, with fears among the farming community that it has the potential to cause significant socio-economic impacts. Raising the water level in drained peatlands has a major role in achieving Ireland's climate, water quality and biodiversity obligations, as well improving our environment generally. Engagement with farmers and achieving agreement and collaboration will be critical to achieving the progress needed. While factors such as incentivisation and payments for environmental services are likely to be essential to achieving this progress, the engagement will also need to be based on a clear understanding of all the factors involved. One factor is that drained peaty soils overlying peat, with a maintained water table several tens centimetres below ground level, will result in subsidence and an inevitable and eventual reduction in the productivity of these soils. This Briefing Note describes the critical role of water in peatlands and peaty soils and draws attention to the situation that drained peaty soils are a 'wasting asset' for farmers.

2. Water and Peat

Peat is an extraordinary geological material. A striking characteristic is its high water content – 5 m of undisturbed peat may contain 4.7 m of water and as little as 0.3 m of solid plant material (as often mentioned, "there are more solids in milk than in peat"). Water in peat, as with other mineral soils/subsoils and bedrock, is present as free water in the pores and cracks, but unlike mineral soils/subsoils and bedrock, it contains a significant quantity of water bound physically, chemically, colloidally and osmotically such that water is an essential part of the structure of the peat. Only a small proportion of the water is mobile, although this varies with the hydraulic conditions. For hydrogeologists, an interesting consequence is that the Darcy equation[1] on flow of water in porous media probably does not apply to peat, particularly well decomposed peat.

Peat forms in water-logged conditions, which slows the decomposition of the dead plant matter due to the absence of oxygen. The mineral content of undisturbed raised and blanket bogs may be as low as 2% by weight, whereas fen peat generally has a somewhat higher mineral-matter content because mineral-enriched groundwater is an important water source (Lindsay, *et al*., 2014).

The water level is a key environmental supporting condition for undisturbed and intact peatlands. The water level requirements are as follows:

- Raised bogs: within 10 cm of ground surface for approximately 90% of year (Gill *et al*. 2022).
- Blanket bogs: within 10 cm of surface in Winter and 20 cm in Summer (Flynn *et al*. 2021).
- Fens: 2.9 to 28 cm <u>above</u> ground level, sustained for at least 60% of the year, with the mean annual water level always above the surface (Gill *et al*. 2022).

3. Drainage and peat

Drainage of peat means a disturbance of the natural conditions. It removes the excess water, stops peat accumulation, causes peat subsidence and changes the physical properties, such as permeability, of the peat. The causes of peat subsidence are: i) shrinkage due to drying; ii) consolidation by loss of buoyant force; iii) contraction by capillary force; and iv) biochemical oxidation.

i) ***Shrinkage:*** Peat holds a relatively large volume of water, which, although it depends on the degree of decomposition (humification) of the peat, is greater than 80% and often 90% by volume. Drying or dewatering causes a loss of some of the water thereby reducing the volume

[1] Darcy's law is an equation that describes the flow of a fluid through a porous medium.

of the peat and a lowering of the peat surface. If drainage lowers the groundwater table to a relatively shallow depth, the shrinkage may be reversible, but if the lowering is appreciable and prolonged then the shrinkage will be irreversible.

ii) ***Consolidation by loss of buoyant force***: Peat is formed in and under water. As the specific weight of organic material is only slightly above 1.0, its weight under water is very low. The pressure of overlying layers on the underlying ones is only slight due to the buoyant force of the water. When the water table is lowered this buoyant force is lost and the effective pressure increases to a greater degree than for normal mineral soils. This causes compression of peat layers below the water table. The degree of compression depends on the thickness of these layers, their compressibility and the depth to which the water table is lowered. Thus, thicker peat areas will compress more than thin areas. This can change the surface topography of an area, and therefore the drainage pattern.

iii) ***Contraction by capillary force:*** Peat has a high pore volume, most of which is filled with water. After drainage, the peat dries out and the resulting capillary forces causes compression of the soil skeleton and a decrease in the pore volume. Vertical contraction leads to subsidence and horizontal contraction to crack formation. The importance of this factor will depend on the depth to which the water table is lowered.

iv) ***Biochemical oxidation:*** When the water table is lowered by drainage, oxidation of organic matter by aerobic soil micro-organisms converts this solid fraction into water, carbon dioxide (CO_2), nitrous oxide (NO_2) and ammonium (NH_4), thereby causing peat wastage. The rate of wastage due to oxidation depends on the depth of the water table, land use (grassland or arable), climate, fertilizer application and type of peat. Depth and intensity of drainage are the two most important factors because they allow air to enter the peat. Tilling increases aeration of the soil. Oxidation is greater in warmer climates. High pH values accelerate the oxidation process so liming of the soil has this effect. Fen peat is oxidised more readily than acid bog peat. The addition of nitrogen fertilizer aids oxidation.

Subsidence rates are positively correlated with the depth to the water table – the higher the water table, the lower the subsidence rate. **Lowering the water table by drainage is the single most important factor in causing subsidence.** Subsidence rates also depend on the thickness of the peat, climate, type of peat, land use and fertiliser, including lime, application:

- Thicker peats subside more than thinner peats.
- Higher temperatures increase the rate of oxidation, consequently climate is important.
- Fen peats subside more rapidly than bogs – they are more susceptible to oxidation.
- Peat under grassland and forestry subside at a lower rate than peat under arable crops.
- Fertiliser application, especially lime and nitrogen, can exacerbate subsidence by increasing oxidation and peat wastage.

In the 1970s, An Forás Talúntais researchers estimated that subsidence after drainage of intact peatlands would be 4 cm/yr in the first few years, 2.5 cm/yr or less over the next seven years and down to 0.9 cm/yr or less later on (Barry *et al.* 1973). Lindsay *et al.* (2014) quote that after the initial rapid effects of primary consolidation, long-term subsidence of bog peat is typically 1-2 cm/yr. Following drainage, average subsidence rates of 2 cm/yr are reported from the Netherlands and Canada. Two examples, in particular, illustrate the impact of drainage on peatlands:

- The Holme Post in East Anglia provides a unique record of peat subsidence. In 1851 a cast iron column was driven through 6.7 m of fen peat into the underlying clay, with the top of the column cut off at ground level. Due to successive stages of drainage since then (using windmills initially and then pumps), the post now rises over 4 m above the ground – a graphic (there are many photos of the Post) illustration of peat subsidence (Waltham, 2000).
- Clara Bog in County Offaly is one of the largest remaining relatively intact raised bogs in Ireland and is a natural heritage area of international importance. It formed as one dome. However,

a road with associated drainage channels on each side was constructed approximately 200 years ago. Since then, continuing drainage has caused subsidence of more than 8 m at the road as well as subsidence for several hundred metres on each side of the road, and has converted the original dome into two domes (Schouten, 2002).

Where do the peat components go following drainage? Water is drained to local watercourses, together with NH_4, dissolved organic carbon (DOC), particulate organic carbon (POC) and, in certain circumstances, sediment, phosphorus and heavy metals (Fe, Mn and Al), all of which can impact on aquatic ecosystems. DOC and POC are sources of colour in water and if high levels of organic matter enter drinking water treatment systems, chlorination can produce trichloromethane, which may pose a threat to human health and is costly to treat as colour needs to be removed. Biochemical oxidation causes emissions of NO_2 and CO_2 (both are greenhouse gases) to air.

4. Farming on peatlands

Approximately 28% of peatlands (420,000 ha) (or ~5% of the total land surface) in Ireland are used for agricultural activities (Pschenyckyj *et al*. 2021) and therefore potentially have a water table generally tens centimetres to over 1 m below ground level. Photo 1 shows a typical scenario where drainage channels in and alongside peatlands are usually >0.5 m and often >1 m deep. This is negatively impacting on water quality by releasing pollutants to watercourses, as well as NO_2 and CO_2 to the atmosphere[2], is leading to a reduction in both aquatic and terrestrial biodiversity and is reducing the capacity of peatlands to mitigate flooding in the Autumn and early Winter.

Farmed peaty soils[3], are mainly utilised as pasture in Ireland. In the Good Agricultural Practices Regulations (2022)[4], an organic matter content greater than 20% has implications for fertilisation rates. Irrespective of the percentage in the upper 20-30 cm of the soil, the underlying material is invariably a varying thickness of peat with a high organic matter content.

While farming on peaty soils may often be more challenging than on mineral soils, peaty soils are nevertheless a productive growing medium for grass and vegetables, and are therefore important economically for farmers with peaty soils areas. Therefore, they are a significant asset for these farmers.

A personal reflection

I grew up on a farm in County Offaly. A significant proportion of the farm was cut-over bog. Over a number of years in the 1960s and 1970s my parents, with my assistance at times, drained this land and converted it to productive pastureland. This was not only vital for the economic wellbeing of the family, but also a source of pride for my parents. Therefore, I know the importance both economically and psychologically of farmed peaty soils for farmers and rural communities.

[2] Estimates of the percentage of national GHG emissions from agricultural grassland on peat range from 5.9-14.8%. A recent paper by Tuohy *et al*. (2023) recommends the lower value as being more realistic due to the inefficiency of drainage in many grassland peat soils.

[3] 'Organic soils' are defined as having a high organic matter content (greater than 20%) and a depth >30 cm (Renou-Wilson *et al*., 2018). As this definition may not be generally known and may be applied by some to all peatlands, I am using the term 'farmed peaty soils' for the circumstances I am describing.

[4] https://www.irishstatutebook.ie/eli/2022/si/113/made/en/print

5. Wastage of peaty soils

While farming on peaty soils has significant detrimental implications for water quality, biodiversity and climate, it is also not a viable medium- to long-term use of the soil in many circumstances. The lowering of the water table in these areas will already have resulted in subsidence by three of the processes mentioned above – shrinkage, consolidation by loss of buoyant force and contraction by capillary force. However, wastage by oxidation is occurring and will continue to occur. For instance, the area of peatlands in the Fens in East Anglia are less than half of what it was 400 years ago (Waltham, 2000). **Peat is a wasting asset** – it can be drained and farmed only at the cost of its inevitable destruction[5].

The implications of drainage of peatland are shown in Photo 2 and Photo 3. The fields were drained by open drainage channels and piped drainage in the late 1970s. The fields have been used for pasture and silage ground. Subsidence has occurred. Now the fields are somewhat uneven due to differential subsidence, probably caused by varying peat thicknesses overlying an undulating mineral subsoil. In addition, tree trunks are now protruding in many places above the ground surface (see photo 2 and photo 3). These fields can no longer be used as silage ground unless they are removed. More importantly, in the coming years the peaty soil will continue to waste way, and the land surface will continue to subside until the water table is within perhaps 10-20 cm of the surface, significantly lowering the productivity of the land for the farmer.

6. Looking to the future

1. In a country where approximately 20% of our land surface comprises peatlands and organic soils, raising the water table in substantial areas is an essential means of achieving not only a significant national reduction of CO_2 and NO_2 emissions (for every 10 cm that the water table is raised, a reported reduction in greenhouse gas emissions of 5 tonnes/ha/yr occurs), but also improvements in both water quality and biodiversity.

2. Currently, farmed peaty soils are emitting CO_2 and NO_2 to air, and NH_3, DOC and TOC to watercourses. While these soils are beneficial for farmers in terms, for instance, of grass production, and are an asset currently, they are a 'wasting' asset.

3. While the emphasis in the short-term may be on 'rewetting' areas of cut-over bogs owned by public bodies, such as Bord na Mona, raising the water table in farmed peaty soils should also be prioritised as a means of achieving rapid environmental benefits. This might also give time for reductions in GHG emissions to be achieved from farming measures in areas of mineral soils. The Teagasc Marginal Abatement Cost Curve (MACC) 2023 (https://www.teagasc.ie/publications/2023/macc-2023.php) highlights that water table management of agricultural peat soils can have a significant potential role in reducing GHG emissions.

4. **Even if there were no environmental benefits, there are significant advantages for farmers in raising the water level in the drainage ditches and the water table in the peat underlying the peaty soil while still maintaining farm production, for instance, to within 30-40 cm of the ground surface (further research may be needed to find a level that is optimum for both reducing peat oxidation while maintaining productivity). This will slow down subsidence and peat wastage,**

[5] This will occur in circumstances where the water level in nearby watercourses is already lowered or can continued to be lowered until it is below the bottom of the peat. Where this is not feasible, the water level in the peat underlying the peaty soil will gradually get higher and higher as the ground subsides until eventually the productivity of the soils will reduce as it becomes more and more saturated.

and will ensure an economic benefit from the land, probably for many decades depending on the circumstances.

5. In a competitive global context for marketing farm products, GHG emissions from and the carbon footprint of these products are likely to become more and more relevant to the economic well-being of farmers and rural communities. Prioritisation of measures based on the range of environmental benefits and costs is urgently needed, followed by establishment of the higher priority measures. Raising the water table in farmed peaty soils areas deserves consideration, in my view, as a high priority measure (see details on this measure in Waters of Life (2023)).

6. The environmental benefits of raising the water table in peatlands are so great that a payment scheme for the environmental services provided by farmers is justifiable. Payments could be based on the water levels achieved, with the highest payments for circumstances where the water level is close to ground level, enabling no or minimal carbon losses and perhaps peat formation. (The FarmPEAT Project (https://www.farmpeat.ie/)) uses the results-based approach to pay farmers for raising the water level in drainage ditches. The outcomes of this project and the experience gained provide an exemplar for consideration of how future progress can be made.) The payments should take account not only of GHG emission reductions, but also the significant co-benefits of both reductions in pollutants entering watercourses and enhanced biodiversity – there are few, if any, measures that provide such a range of environmental services.

7. The negative 'atmosphere' in which so-called 'rewetting' is being considered and communicated currently needs to change if the required progress is to be achieved. Constructive collaboration between policy makers, public bodies and the farming community is needed. This will require, in my view, i) clarity on policy goals, ii) an understanding of the scientific aspects, iii) a highlighting of the role of raising the water table in peatlands in achieving the reductions in GHG emissions from the agricultural sector with additional co-benefits for water quality and biodiversity, iv) changing the term 'rewetting' to, for instance, 'water table management'[6] and v) a well-funded, long-term and comprehensive results-based payments scheme that takes account of the long-term implications for farmers as well as the environmental services that raising the water table will provide.

8. An element of the future 'story' is the issue of **peat wastage** due to drainage; realisation and understanding of this, and then raising of water tables in peaty soils areas to a level that still allows productive farming would alone have major environmental benefits. Let this be a starting point.

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[6] This is proposed in an article by Molleman and McMilian entitled 'Moor Returns – A Community Peatland Code for Ireland: Part 1 – The Science' at this link: https://greenrestorationireland.coop/moor-returns-a-community-peatland-code-for-ireland-part-1/

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Photo 1

Photo·2¶

Photo·3¶