Measure 39: Restoring Organic Soils and Paludiculture

(see also follow up work: "MacLeod, M. (2020) Additional analysis on peatland restoration and paludiculture, November 2020, London: Defra")

Category
Management of organic soils

Overview
Paludiculture, from the latin 'palus' for swamp, refers to the harvesting of plant and/or animal biomass from water-saturated peatland sites. Wet peatlands potentially act as a carbon sink, but certainly emit less than degraded peatlands suffering from drainage, burning, over-grazing and intensive cultivation (Bain et al., 2011; Bonn et al., 2016). Switching from current, damaging, land uses to alternatives that are more compatible with wet peatland ecosystems offers a means of avoiding continued carbon losses from further degradation plus (possibly) future net sequestration and/or displacement of other emissions, whilst still enabling some income generation (Verhoeven & Setter, 2010; Wichtmann et al. 2016).

Paludiculture encompasses traditional plant-gathering, game-hunting and low-intensity farming activities but also activities related to modern bioenergy generation. For example, seasonal harvesting of fruits, berries and wildfowl, but also removal of biomass for fodder, fuel and building materials or low intensity grazing. For lowland, groundwater-fed fens, biomass plant species include reeds (Phragmites australis), sedges (Carex spec.), cattail (Typha spec.), alder (Alnus glutinosa) and willow (Salix spec.), all of which can potentially be used for bioenergy. Grass as fodder for off-site feeding to livestock or in-situ, low-intensity grazing is also possible. On rainwater-fed peatlands (bogs, mainly in uplands), cultivating peat mosses (Sphagnum spec.) as a constituent of growing media for horticulture has some potential (Abel et al. 2013; Sweers et al., 2014; Wichmann & Köbbing, 2015; Wichtmann et al. 2016; Musarika et al., 2017; Gaudig et al. 2018).

Mitigation summary

Effect on GHG categories*	Rating	Notes
Enteric CH_4		If any displaced ruminant livestock not farmed elsewhere, then will decrease
Manure CH_4		As above
Manure N_2O		As above
Soil N_2O: applied N		As above
Soil N_2O: grazing		As above
Energy CO_2: fieldwork		Depends on how biomass harvested
Energy CO_2: other		
CO_2 liming and urea	-	Not applied
CO_2 sequestration below ground	-	Potentially if functioning peatland recreated (note that most of the mitigation is reduced losses rather than sequestration)
CO_2 sequestration above ground	-	If bioenergy crops grown
Pre-farm emissions		Although reduced use of inputs will lower pre-farm emissions

Post-farm emissions	-	If biomass used for energy or building
Substitution of higher C products	-	If biomass used for energy or building
Production increases by more than the emissions		Non-food production increases, food decreases
Confidence in mitigation effect	high	
Cost-effectiveness**	moderate	
Confidence in cost-effectiveness	moderate	

* ”-“ GHG reduction, “+”: GHG increase, “ ”: no significant effect

** low: =< £0/tCO_2e, moderate: £0/tCO_2e< >SCC, high: >SCC

Related measures and potential synergies

Measure	**Impact on other measures**
Rewetting of degraded peatlands	Complements rewetting by offering potential income source to partially offset displaced activities

If it involves reduction of production on organic soils, then the abatement rates of all other measures applied to organic soils will be reduced.

Incompatible with improved drainage, which should not be applied to organic soils.

Inclusion in other marginal abatement cost curves

UK 2008	**UK 2010**	**UK 2015**	**Ireland 2012**	**France 2013**	**France 2019**
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What does the measure entail?

Peatland restoration requires reinstatement of a high water table, to return the soil to a permanently saturated state. This typically entails blocking of drainage systems, either with plastic or wooden dams or on-site materials such as bales of heather or peat. For severely degraded sites, additional efforts may be required to stabilise and revegetate deep gullies and areas of bare peat (Bonn et al., 2016). Once wet conditions have been reinstated, previous forms of land use – notably arable/horticultural cultivation and intensive livestock grazing - may no longer be feasible, and the net profits from any foregone production represent an opportunity cost (Smyth et al., 2015; Moxey, 2016). This can be at least partially offset by engaging in paludiculture. For example, the gathering of wild plants and animals, or more managed stocking and harvesting, in particular of fast-growing plant species suitable for bioenergy production or water-tolerant ruminants such as water buffalo. Such land uses were practiced historically on many peatlands prior to widespread drainage and agricultural improvement (Wichtmann et al., 2016). Paludiculture cannot be implemented without prior rewetting.

Abatement rate

Potential abatement takes four forms. First, net sequestration. Functioning peatlands can act as carbon sinks. Indeed, this is why peatlands represent a significant carbon store, representing the cumulative effect of net sequestration over extended periods of time. Annual sequestration rates are, however, relatively modest, perhaps 0.5t to 1.0t CO_2e /ha/yr and it is not certain that a restored site will achieve this, at least not rapidly. Second, and more significantly, restoration of degraded sites can avoid emissions that would otherwise have occurred if degradation had continued. These avoided emissions can be large, reaching between 20t and 40t CO_2e /ha/yr for heavily degraded (usually drained and cultivated) sites, including those under intensive lowland cultivation, but between 2.5t and 5t CO_2e/ha/yr for more lightly degraded sites (Graves & Morris, 2013; Smyth et al., 2015; Evans et al., 2017; Thomson et al., 2018).

Third, if paludiculture biomass is used to generate energy and/or building materials that displace fossil fuel usage, some additional emissions may be avoided. This is likely to be less significant than emissions avoided (e.g. c.5t to 10t CO_2e/ha/yr) but more certain than new sequestration (Günther et al., 2015; Karki et al., 2016; Wichtman et al., 2016). Fourth, depending on the extent to which previous land uses cease or are displaced to other locations, some further emissions may (or may not) be avoided. For example, lower methane emissions from ruminant livestock. However, this is somewhat speculative and depends on demand-side changes as well as the relative emission-intensity of production at other sites (Ferre, 2018).

The following Table summarises some reported mitigation estimates from peatland restoration plus additional mitigation from paludiculture implemented alongside restoration.

Table 1Summary of studies of the mitigation effects of peatland restoration and paludiculture.

System	Parameter	Effect	Country	Year	Reference
Lowland peat restoration	Avoided CO_2e emissions	Savings of up to 22t CO_2e/ha/yr	UK	2013	Graves & Morris (2013)
Upland peat restoration	Avoided CO_2e emissions	Savings of up to 22t CO_2e/ha/yr	UK	2015	Smyth et al. (2013)
Lowland peat restoration	Avoided CO_2e emissions	Savings of 17t CO_2e/ha/yr	Germany	2015	Günther et al. (2015)
Paludiculture	Biomass displacing fossil fuel	Savings of 7t CO_2e/ha/yr	Germany	2015	Günther et al. (2015)
Lowland peat restoration	Avoided CO_2e emissions	Savings of up to 30t CO_2e/ha/yr	UK	2016	Evans et al. (2016)
Lowland peat restoration	Avoided CO_2e emissions	Savings of 24t CO_2e/ha/yr	Denmark	2016	Karki et al. (2016)
Paludiculture	Biomass displacing fossil fuel	Savings of 10t CO_2e/ha/yr	Denmark	2016	Karki et al. (2016)
Lowland peat restoration	Avoided CO_2e emissions	Savings of up to 22t CO_2e/ha/yr	UK	2018	Thompson et al. (2018)

Cost-effectiveness

Blocking drains to rewet a peatland is relatively cheap, at c.£150/ha to c.£500/ha. Stabilising and revegetating areas of bare peat, including haggs and gullies, can be much more expensive at over £5000/ha (but typically only required on relatively small parcels of land). For upland bogs, the income forgone from current land uses is typically low, perhaps £20 to £150/ha/year. However, reflecting greater agricultural productivity, opportunity costs for lowland fens can be much higher at £500/ha to £1600/ha[1] (Graves & Morris, 2013; Moxey & Moran, 2014; Smyth et al., 2015; Artz et al., 2018). Switching to paludiculture on rewetted peat can offset some income foregone, but requires some investment in specialist machinery and establishment of market outlets for different produce. Wichmann (2016 & 2017) reports net margins for different paludicultural enterprises ranging between c.-£400 and c.+£800/ha/year.

Table 2. Costs/savings of the operation (figures in brackets are savings)

Costs/savings	Total cost	Source
Restoration capital works	c.£1000/ha	Smyth et al. (2015), Artz et al. (2018), Okumah et al. (2019)
Upland restoration opportunity cost	c.£20 to c.£140/ha/year	Moxey & Moran (2014)
Lowland restoration opportunity cost	c.£500 to c.£1600/ha/year	Graves & Morris (2013)
Paludiculture	c.£400 to (£800)/ha/year	Wichmann (2016)

The cost-effectiveness of restoration combined with paludiculture is categorised as being in category 2, moderate cost (Moxey, 2011; Röder & Osterburg, 2012) but this will vary across sites according to their current usage and suitability for different paludicultural enterprises.

Applicability, current uptake and potential additional maximum uptake

The UK Peatland Strategy (IUCN, 2018) has set ambitious restoration targets, of 1m ha by 2020 and 2m ha by 2040. Realisation of such targets will require significant additional enrolment in restoration programmes, in both upland and (particularly) lowland areas. If this is to be achieved through voluntary enrolment of private land, sufficient financial incentives will have to be in place to cover not only upfront capital investments plus any on-going costs arising from monitoring and management requirements (e.g. dam repairs, scrub clearance) but also importantly income forgone. Current progress in upland areas is reasonable, but the comparative lack of enrolment in lowland areas largely reflects high opportunity costs arising from displacing current intensive cultivation and grazing. Paludiculture is not currently widespread but could potentially offset some income foregone, yet increasing uptake will require awareness-raising plus direct support to bridge the gap between paludicultural profits and those of (particularly) current lowland activities.

[1] Although Grave & Morris (2013) also suggest that profitability will decline over time as peatlands become depleted.

Assumptions used in the MACC
The assumptions used in the MACC are given in Table 3 It is assumed that the lowland peat is heavily degraded and the upland peat is lightly degraded.

Table 3 MACC assumptions

	Lowland peat	**Upland peat**	**Units**	**Notes**
Change in emissions				
Net sequestration	-1.0	-0.5	tCO2e/ha/yr	See "Abatement rate" section
Avoided degradation	-25.0	-3.5	tCO2e/ha/yr	
Substitution of higher C products	-10.0	-5.0	tCO2e/ha/yr	
Indirect LUC	10.3	1.5	tCO2e/ha/yr	Calculated
Net emissions, inc. indirect LUC	-25.7	-7.5	tCO2e/ha/yr	Calculated
Net emissions, not inc. indirect LUC	-36.0	-9.0	tCO2e/ha/yr	Calculated
Change in net margin				
Restoration capital works	-43	-43	£/ha/year	£1000/ha, amortised at 3% over 40 years
Income foregone	-1500	-130	£/ha/year	See "Cost-effectiveness" section
Net margin of paludiculture enterprise	400	0	£/ha/year	See "Cost-effectiveness" section
Total change	-1143	-173	£/ha/year	Calculated
Cost-effectiveness				
Cost-effectiveness (inc. indirect LUC)	44.5	23.0	£/tCO2e	Calculated
Cost-effectiveness (not inc indirect LUC)	31.8	19.2	£/tCO2e	Calculated

In order to estimate the abatement potential, Thompson et al. (2018) developed a series of scenarios. The "High ambition" scenario involved:

- Peatland rewetting occurs on 50% of the area of intensively managed lowland peat (Cropland and Improved Grassland)
- Peatland restoration occurs on 75% of the area of degraded Unimproved Grassland and on 50% of the area of forest on peat (deforestation) with less than Yield Class 8 by 2050.
- Rewetting/restoration is phased in, with the rewetting rates between 2016 and 2023 at 50% of the rate in subsequent years." Thompson et al. (2018, p38)

Under this scenario, emissions from peatland restoration and rewetting were estimated to reduce emissions across the UK (relative to the 2016 baseline scenario) by 4.9MtCO2e/year by 2030 and 10.9MtCO2e/year by 2050. Evans et al. (2017, p2) reported that: "current levels of ambition (low scenario) on peat restoration in all four countries could deliver over 4 Mt CO2e yr^{-1} of emissions reductions by 2050. A more ambitious restoration scenario, including removal of 50% of forest planted on peat since 1980, could deliver over 8 Mt CO2e yr^{-1} of emissions abatement.”. This more “stretch” scenario involves:

- Peat extraction: Cessation of all peat extraction 100% restoration by 2030.
- Restoration: 50% area restoration of degraded lowland peat, 75% area restoration of degraded upland peat; restoration of 50% of forest area planted on peat since 1980

Table 4 Change in total GHG emissions (in kt CO2e yr-1) from each UK administration, 2016-2050.(Evans et al. (2017, p53)

	England	**Scotland**	**Wales**	**NI**	**UK**
High	90	-456	54	54	-259
Baseline	-4	1	0	0	-3
Central	-3	-1,084	0	0	-1,088
Low	-2,131	-1,742	-118	-339	-4,331
Stretch	-4,214	-3,186	-201	-685	-8,286

Ancillary effects

Table 5. Ancillary effects of the operation

Positive effects		**Source**
Off-farm GHG	Possible displacement of fossil fuel emissions related to production of energy or building materials	Günther et al. (2015), Karki et al. (2016), Wichtmann et al. (2016)
Production	Increased non-food biomass	Wichtmann et al. (2016)
Adaptation	Unlike degraded sites, functioning peatlands can potentially self-adapt to climate change by naturally shifting the species mix of vegetation cover	Parish et al. (2008); Robroek et al., (2017)
Environment	Biomass harvesting can potentially remove surplus nitrogen from peatlands, further enhancing restoration benefits for habitats and biodiversity.	Schroder et al. (2013)
Negative effects		
Off-farm GHG	Reduced food production will displace emissions	
Production	Reduced food production	Ferre (2018)
Adaptation	None	
Environment	Change in landscape, and habitat/biodiversity mix; potential damage to sites through large scale harvesting	Seppel et al. (2011); Schroder et al. (2015); Wichtmann et al. (2016)

Identified implementation challenges and barriers

For upland sites, current land uses are typically economically marginal and the opportunity costs of peatland restoration are low. This may favour restoration, although challenging growing conditions and remoteness may limit uptake of paludiculture following rewetting. However, public funding is still needed for upfront capital investments (e.g. blocking drains) to rewet land and further funding may be required to encourage conversion to paludiculture. Moreover, cultural resistance to switching land uses and allowing land to revert to being “unimproved” can be strong – although this may be reduced if CAP Direct Payments are superseded by “public money for public goods”. For lowland sites, current land uses are often highly profitable and the commercial opportunity costs of peatland restoration are high and unlikely to be completely offset by paludicultural income. Cultural resistance to change is highly likely, implying that public funding of (e.g.) training and grant-aid may be required to encourage uptake in the face of the lower profitability and unfamiliarity of paludicultural enterprises.

Table 6 Potential barriers to uptake and key risks/uncertainties

Barrier to uptake	**Source**
High opportunity costs on lowland sites	Graves & Morris (2013)
Cultural resistance to change/reversion to “unimproved” land	Wichtmann et al. (2016)
Lack of supply-chain infrastructure upstream for specialist machinery and downstream for new products	Wichtmann et al. (2016)
Large scale harvesting of biomass under wet conditions can cause site damage	Schroder et al. (2015)
Other key risks/uncertainties	
Interaction between future agricultural support and future environmental support.	Wichtmann et al. (2016)
Market size for paludicultural outputs.	Wichtmann et al. (2016)

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