RESTORATION OF LOWLAND PEATLAND IN ENGLAND AND IMPACTS ON FOOD PRODUCTION AND SECURITY

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Executive Summary

RESTORATION OF LOWLAND PEATLAND IN ENGLAND AND IMPACTS ON FOOD PRODUCTION AND SECURITY.

Context

Lowland peatlands provide a range of benefits which are of value to society. In England, there are about 325,000 ha of lowland peatlands, with soils which formed under waterlogged conditions in fens and raised bogs. Of these, about 240,000 ha (74% of the total stock) is used for farming and food production. Much of this has been intensively drained for high value cropping, especially in eastern England.

Concern about the continued loss of peatland habitats, the degradation of agricultural peatlands, and the associated release of soil carbon, has led to calls for the large scale restoration of peatlands to peat forming vegetation, in order to provide a range of environmental benefits such as nature conservation, water resource protection, carbon storage and recreation. Simultaneously, however, it is recognised that taking English peatlands out of agricultural production could affect national production of food, which potentially is worrying given the prospect of increased global demand for food and uncertainties associated with climate change.

Aim and Approach

In this context, and sponsored by Natural England, this study explored the case for peatland restoration in four study areas (and within these specific 'target' areas identified for restoration as part of the aspirational 'Wetland Vision'). These were the East Anglian Fens, The Humberhead Levels, The Somerset Moors and Levels, and the Lyth Valley in Cumbria. Alternative scenarios of peatland management were compiled to consider the impact on: (i) agricultural output and food security, (ii) farm incomes and profitability, and (iii) environmental costs and benefits, with particular reference to carbon emissions and landscape benefits. The scenarios focus on the direct impacts of land use change. Estimates of agricultural and environment benefits and costs (£/ha/year) are derived for each scenario assuming that they are in a steady state at full operation. Changes in capital and operating costs at the landscape scale, such as investments in drainage infrastructure, and linked industry effects have not been included. This analysis drew on multiple sources of data such as Defra Agricultural Statistics, the Land Cover Map 2000, Farm Business Survey Results, Natural England records, published science literature and discussions with key informants, especially in the study areas.

Peatland Management Scenarios – Agricultural and Environmental Performance

Land use varies within and between the study areas, characterised by arable production in the case of the Fens and Humberhead, and by mainly grassland production for dairy and fatstock in the case of Somerset and the Lyth Valley. Peatlands in these areas have been 'reclaimed' for agriculture over many years, often supported by public investments in arterial drainage and pumping schemes. Where drainage standards are high, peatlands are often classed as Grade 1 or 2 Agricultural Land, reflecting their potential for high value cropping

The use of peatlands for agriculture inevitably leads to their degradation. Grassland farming can 'conserve' existing peats because soils are wetter and are less disturbed than when used for arable cropping. But the removal of vegetation for animal feeding limits the formation of new peat soils. Arable farming, with intensive drainage and cultivation, can result in rapid peat wastage, and associated loss of soil carbon. Appropriate soil and water management can slow down but not halt this process.

Under the current *Baseline* situation, farming on remaining deep peats in the Fens and Humberhead, is relatively profitable with net margins, that is financial value-added, of about £360 - £420/ha/year, rising to £1000 - £1300/ha/year where vegetable and salad production approaches 60% of the cropped area. In predominantly grassland areas of Somerset and the Lyth Valley, net margins of between £170 - 220/ha/year are achieved, and this can be higher where there is more dairying. Environmental costs, particularly associated with carbon released from arable peats and carbon emissions from farming systems, are estimated at between £450 and £950/ha/year, resulting in overall negative returns from peatland farming.

Continued Agricultural Production, involving intensive drainage and cultivation of arable peats will eventually result in wastage of peat soil. Depending on underlying soils, cropping would be limited to mainly cereal-based arable farming with low and possibly negative returns. Remedial drainage investment would probably not be financially viable. High value cropping is, however, likely to relocate onto nearby mineral soils supported by irrigation, utilising existing regional capacity in production and marketing expertise, networks and infrastructure. By comparison degradation rates on continued grassland use are low and net margins can probably be sustained at near current levels.

The combined agricultural and environmental effects of continuing agricultural production in the Target Areas gives an estimated net annual cost of between -£200 and -£500/ha/year, mainly due to the impact of GHG related emissions associated with loss of soil carbon on arable land.

Peatland Restoration assumes peat-forming conditions under permanently high ground water levels and surface flooding, and excludes agriculture (other than some cattle grazing to help manage habitats). Peatland restoration could generate a net benefit of about £950/ha/year, due to a combination of assumed carbon sequestration and the 'cultural' benefits of landscape, wildlife and recreation. Relative to the Continued Agricultural Production, this gives a net benefit, including changes in the value of environmental effects, of about £1,200/ha/year - £1,500/ha/year in the study sites. For arable land, the 'opportunity cost' of taking land out of agricultural production is likely to reduce over time as peatlands are degraded and become less agriculturally productive.

Two *Peatland Conservation* scenarios were considered. *Peatland Conservation I* involves extensive livestock grazing on wet grassland in the summer in accordance with BAP priorities, with winter water flooding and high ground water levels for most of the year. It is unlikely to be commercially viable without support payments to farmers. The overall combined benefits of farming and peatland conservation could be about £500/ha/year once environmental effects are taken into account, possibly justifying agri-environment type payments.

Peatland Conservation II involves semi-intensive grassland that attempts to reconcile farming and peatland conservation objectives. Here, flooding and ground water levels are managed to allow silage making and grazing from April to October. These systems could prove commercially viable, especially for dairying, and peat soils can be conserved with appropriate management. However, environmental burdens associated with livestock production, such as the risk of pollution to water, and methane and ammonia emissions to atmosphere, could be high.

Running alongside the above analysis, estimates of environmental (commonly called ecosystem) benefits, including contribution to water quality, flood control, biodiversity and recreation, but excluding carbon storage, were derived for each target area using a research-based wetland 'benefit transfer' function. These were between £500 and £2,000/ha/year for the study areas, highest where population densities and hence potential beneficiaries are greatest. While these estimates must be treated cautiously, they are positive, substantial and compare favourably with the financial performance of most farming systems on peatlands.

Impacts on food production and security in the UK

Restoring peatlands to their natural condition will take land out of farming. Global food shortages in 2006/7 prompted a resurgence of interest in national food security and the role of UK agriculture. UK policy on food security currently aims to 'guarantee households access to affordable nutritious food', not only by strong national production, but also by establishing and maintaining international supply chains. Although self sufficiency in food production is not a policy aim, the Government recognises the importance of UK agriculture's contribution to the national food basket and the need to improve the productivity of farming.

The Target Areas identified here total 66,500 ha and only account for about 0.5% of the mainly lowland crop and grassland areas in the UK (12.1 million ha, excluding rough grazing) and about 0.9% the value of total agricultural production. However, they account for around 3% of each of the total national areas for sugar beet, potatoes, vegetables grown in the open, and salad crops.

Peatland farming, especially in eastern England has comparative advantage in the production of vegetable and salad crops, consumption of which is expected to rise with a move to more healthy eating habits. The areas and production of vegetable and salad crops in England have declined over the last 20 years, offset by increased imports, especially from Europe. The withdrawal of peatlands could further exacerbate this decline. However, it is likely that high value cropping would relocate to mineral soils, requiring overhead rather than sub-surface irrigation. Indeed, relocation has already happened where peats have degraded. Such relocation is most likely to displace wheat.

Although significant at the regional scale, the withdrawal of the Target Areas considered here is unlikely to threaten national food security. Taking the whole 240,000 ha of agriculturally managed peatlands would, however, account for about 2% of total lowland agricultural land in England, over 3% of total value, and probably between 5% and 8% the area of the aforementioned specialist crops. Taking this amount of crop land out of high value production could affect national supply if relocation elsewhere in the UK were not possible.

Proposals to withdraw land from agriculture must take account of the general availability of land. Recent reviews of the demand for and supply of land for agriculture in the UK (and in Europe as a whole) conclude that there appears to be sufficient land to meet likely future needs. Much depends however on assumptions regarding demand for land for non-agricultural purposes, including human settlements and natural habitats, and the productivity of land retained in farming. Future relative strengthening of agricultural prices would favour agricultural production on peatlands whereas relatively high future carbon prices will act against land use options for peatlands that generate high levels of carbon release.

Although the scale of the peatland restoration considered here would probably not make a major impact on current total food production, projections for global food demand and supply suggest that food security might become more critical in 30 to 50 years time. Future food security could be enhanced by conserving agricultural peatlands, taking them out of agricultural production now, or farming them extensively, so that they could be returned to agricultural production should the need arise.

For the assumptions made, it seems that taking land out of intensive farming in peatland areas could result in an overall welfare gain. This is because the net environmental costs generated by continued agricultural use (indicated by environmental burdens and the loss of potential benefits from peatlands in a restored condition) are greater than the net benefits of retaining farming (indicated by value added). Famers would, however, suffer loss of incomes, unless they were compensated in some way, either through land purchase or through payments for environmental services under new land management regimes.

Recommendations

A number of recommendations are made as a result of the preceding analysis that could help to improve the sustainability of lowland peatlands in England.

Detailed assessment of locally relevant farming systems, drawing on local knowledge, would help to identify opportunities for reconciling agricultural and environmental outcomes, balancing for instance food production with the maintenance of soil carbon and landscape/biodiversity/recreation benefits. Identifying the scope and practicability of measures to conserve peatlands in arable usage in order to reduce carbon loss would enable better targeting of management options, especially regarding cultivation practices and management of field water levels.

Identification of the likely “switching points”, where the financial benefits of continued intensive use of peatlands decline to the point where alternative land uses and funding options become attractive, would inform land management decisions, taking account of the wider environmental and economic benefits and costs. Such switching points are likely to occur before peatlands are fully degraded.

The development of grassland systems suited to peatland conservation, especially in areas that are currently mainly arable, would help to identify feasible and potentially attractive agricultural options for farmers. This could help achieve the multiple objectives of food production, soil conservation, nature conservation, enjoyment of the countryside and support for rural livelihoods.

An exploration of the scope for markets in environmental (often referred to as ecosystem) services provided by peatlands could help to design policies to promote and reward beneficial change in peatland management. This would also help to lessen the financial burdens that otherwise might be placed on existing farmers and land managers as they adopt more sustainable land management practices. Policies might include environmental charges for emissions, such as carbon release from land and farming, or environmental receipts for environmental services, such as avoided emissions, carbon sequestration, flood regulation, biodiversity and recreation.

Case study examples, produced in more detail than has been possible here, would help to provide more robust and comprehensive estimates of outcomes. These would use farming and other land use data obtained locally, applying an environmental accounting and ecosystems framework. Case studies would seek to involve farmers and associated agri-business in participatory workshops in order to integrate the modelling of farming systems, peat degradation, and environmental and economic assessments. The case studies would provide a platform for further collaboration amongst the range of stakeholders with interests in peatland management.

While parts of England's remaining peatlands are amongst the most intensively farmed areas, continued intensive cropping and drainage is degrading their productive capacity, such that their comparative advantage for agriculture will decline. The restoration or conservation of peatlands can reduce the current environmental burdens associated with intensive use and potentially provide a range of environmental benefits that serve the public interest. The analysis here suggests that this could be achieved without a major impact on food security. It will, however, require a realignment of incentives to reward farmers for managing peatlands in the public interest.

None-the-less, England's peatlands remain an important strategic agricultural resource that can be drawn on to help feed the nation should the need arise. Thus, restoration and conservation strategies should consider how to retain an option (and an option value) for future 'agricultural reclamation' if required, possibly including maintenance of critical drainage infrastructure. The peatland scenarios identified above have potential to do this to varying degrees.

Taking land out of farming is a sensitive issue, especially in arable areas where farming productivity is obvious. It is important therefore that any review of options for future peatland management should fully engage the farming communities involved, taking a long-term view that respects the interests, livelihoods and history of those who work the land.

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1 Introduction

Lowland peatland systems in the UK provide a range of ecosystem benefits which are of value to society. Peatlands are among the world's most productive ecosystems[1]. They regulate ecological processes and life-support systems[2], provide habitats for plants and animals and provide many goods that are beneficial to humans, including food, fuel and fodder, raw materials, and genetic resources. They are also areas where humans derive well-being through aesthetic pleasure and recreation.

Many goods and services that flow from peat soils are under threat. In Europe, 100,000km^2 of peatland has been lost and the remainder are at risk[3]. In England, there are about 325,000 ha of lowland peatlands, with soils which formed under waterlogged conditions in fens and raised bogs. In England, these have been widely drained and used for food production, with some 240,000 ha (74%) of lowland peatland under cultivation/temporary grass. In the Fens an estimated 16% of the peat stock recorded in 1850 remains and much of the remaining stock will be irreversibly degraded in the next two to three decades[4]. In the Somerset Levels, there has been extensive subsidence and shrinkage estimated to be 1 to 1.5 cm per year, even under extensive grazing regimes[5]. Despite this, peatlands remain an important store of terrestrial organic carbon, which has been sequestered from atmospheric CO_2[6]. Protected and extensively farmed areas of peatlands retain important wetland habitats that are promoted through the UK Biodiversity Action Plan, agri-environment schemes and other management arrangements[7].

In this context, there is growing interest in the large scale restoration of peatlands in order to provide a range of ecosystem services associated with, for example, nature conservation, water resource protection, carbon storage and recreation. Peatlands are, however, of strategic agricultural importance, particularly given the prospect of increased global demand for food and uncertainties associated with climate change. In the UK peatlands are an important component of Grade 1 and Grade 2 agricultural land. Here, their agricultural potential critically depends on the management of water regimes, including irrigation, intensive drainage, pumping and protection from river and coastal flooding. Although these areas have comparative advantage in intensive agriculture, this strategic role is placed at risk unless measures are taken to conserve peat soils under agricultural management[8].

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[1] Maltby, E. (1986) Waterlogged Wealth: Why Waste the World's Wet Places? Earthscan: London.
[2] Clarke, D. and Joosten, H. (2002) Wise use of mires and peatlands: background and principles including a framework for decision-making. International Mire Conservation Group and International Peat Society.
[3] Rawlins, A. and Morris, J. (2009). Social and economic aspects of peatland management in northern Europe:, with particular reference to the English case. *Georderma*, doi:10.1016/j.geoderma.2009.02.022
[4] Oates, R. (2002) Restoring The Fens. The Fens Floodplain Project.
[5] Brunning, R. (2001) Archaeology and Peat Wastage on the Somerset Moors. Somerset County Council.
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[7] Clarke, D. and Joosten, H. (2002) Wise use of mires and peatlands: background and principles including a framework for decision-making. International Mire Conservation Group and International Peat Society, Helsinki.
[8] Defra, 2009 Safeguarding Our Soils: A Strategy for Soils in England Department for Environment, Food and Rural Affairs, London

Thus, there is a conundrum. Peatlands have considerable agricultural value that could increase in future due to concern about food security. Their continued agricultural use, however, could hasten their degradation. Conversely, restoring peatlands to their original peat-forming vegetation and wetland conditions has potential to deliver a wide range of environmental services that are highly valued by society[9]. Indeed, these services, particularly associated with carbon storage and the protection of wildlife and water resources, are likely to increase in value in future, especially in the context of demographic change, economic development and change in climatic conditions. The question here is whether large scale restoration of peatlands in England is beneficial from an overall welfare point of view, particularly allowing for the potential loss of agricultural production capacity and implications for food security.

1.1 Aim and Objectives

The aim of the study is to assess the implications for food security of the large scale restoration of lowland peat areas in England, interpreting the finding for policy. More specifically, the study objectives are to provide answers to the following questions.

Objective 1: What is the range of different farming practices (including variation in peat drainage) in agriculturally managed peatland at present and, with consideration of the sustainability of such practices, what are the costs and benefits particularly regarding food production and the environment?

Objective 2: What are the likely scenarios for change in peatland management (given potential, planned and existing landscape scale restoration projects) and what are the likely scenarios for change in farming practices on peatland?

Objective 3: What impacts would the restoration of agriculturally managed peatlands have on food production in the UK and how would this impact UK food security, in particular, given issues surrounding current cultural food preferences and future population changes?

Objective 4: In the light of the above, what conclusions can be drawn concerning the impact of restoring agriculturally managed peatlands to peat-forming vegetation?

Objective 5: In the light of the above, what recommendations can be made on the benefits and costs of current and (potential) future agricultural management on peatlands, particularly in comparison with peatland restoration and alternative, more sustainable farming practices?

[9] Worrall F. and Rowson J.G. (2008) Carbon fluxes from managed peat – year 1 report. Report to Natural England and Moors for the Future. Natural England. Peterborough
English Nature (2002) Peat bog conservation: the importance of lowland raised bogs. English Nature, Peterborough, UK.
Freibauer, A., Rounsevell, M., Smith, P. and Verhagen, J. (2004) Carbon sequestration in the agricultural soils of Europe. Geoderma, 122, 1-23

1.2 Approach

The following approach was adopted to address the study objectives:

- Target Areas for peatland restoration were identified by Natural England and defined by GOS shape files. These comprise areas in the East Anglian Fens, The Humberhead Levels, The Somerset Moors and Levels, and the Lyth Valley (Cumbria).
- Existing land use, cropped areas and livestock numbers in the Target Areas were determined using a combination of Defra Agricultural Census Data (2004 and 2009) and Land Cover Map Data (2000).
- Estimates of agricultural yields, production and financial performance were derived for the Target Areas drawing on a range of secondary sources including the Regional Farm Business Survey results, supported by discussion with key informants.
- Estimates of environmental emissions by crop and livestock type were drawn from lifecycle analysis (Williams et al, 2006). Carbon emissions due to peat degradation were based on Natural England estimates.
- Existing biodiversity and potential biodiversity outcomes were reviewed in each of the Target Areas
- A review of food security as a policy theme was undertaken, together the implications of talking land out of agricultural production in the Target Areas.
- Alternative future scenarios for peatland management were used to consider the impact on (i) agricultural outputs and food security and (ii) farm incomes and profitability. A spreadsheet model was constructed for this purpose.
- The ecosystems framework was used to explore the possible effect of land use change on the environment, with particular reference to carbon emissions, and wildlife and landscape benefits. Two approaches were used – one involving estimated of selected individual service flows and one involving a ‘benefit transfer’ model for wetlands.

2 The Characteristics, Role and Importance of Lowland Peatlands in England

This section reviews the definition of peat soil and peatlands, and their origins in peat forming vegetation. The extent and condition of peats In England are reviewed. Attention is drawn to the importance of soil water and drainage conditions as these affect peat forming processes as well as their use for agriculture. The contribution of peatlands to ecosystems services is reviewed, especially regarding food production, carbon storage, water supply and purification, and biodiversity. The large scale restoration of peatlands would take land out of agriculture, with implications for national food supplies. The concept of national food security is explored in this context.

2.1 Peat Soils

Peat is the accumulated remains of plant materials formed under waterlogged conditions caused by climate, high groundwater levels or by topographical conditions[10]. The characteristics of peats reflect their source vegetation, which in turn depends on the hydrological, chemical and climatic condition of a site.

Soils with more than 50% organic matter by content are defined as peats[11]. Soils with 35-50% organic content may be termed peaty sands or peaty loams depending on the type of mineral content, and soils with organic concentrations between 25-35% as sandy or loamy peats respectively.

Peat formation can take place in deep water (limnic), at the edge of a water-table from plants subject to period flooding (telmatic), and from plants forming above the water table (terrestric). Peat formation takes place in mires. , which can be defined as a wetland where peat is still being formed[12]. This can be further divided into bog or fen [13].Bogs are those mires dependent entirely on precipitation for water supply, whilst fens rely on groundwater, and comprise various sub-categories[14].

[10] Burton, R.G.O. and Hodgson, J.M. 1987:3. Lowland Peat in England and Wales, Special Surevy 15. Soil Survey of England and Wales, Harpenden
[11] Burton and Hodgson, 1987: 7. op cit:
[12] Joosten, H. and Clarke, D. (2002), *Wise use of mires and peatlands - Background and principles including a framework for decision making.* , International Mire Conservation Group and International Peat Society, Saarijarvi, Finland.
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[14] van Diggelen, R., Middleton, B., Bakker, J., Grootjans, A. B. and Wassen, M. (2006), "Fens and floodplains of the temperate zone: present status, threats, conservation and restoration.", *Applied Vegetation Science,* vol. 9, no. 2, pp. 157-162.
[16] Burton and Hodgson, 1987:6, op cit

There are six main types of plant remains that form peat. *Sphagnum* mosses (bog mosses), *Hypnum* mosses,, sedges, grasses, woody plants and humified material. The type and condition of peat are described in terms of the fibre content and its state of decomposition. The more decomposed is the plant material, the darker is the peat soil and the less is the fibrous content[15]. Peats can be subdivided into three classes based on fibre content that generally reflect the degree of decomposition- fibrous or fibric (which corresponds as H1-H3 on the modified Von Post scale of decomposition), semi-fibrous or mesic (H4-H6) and humified or amorphous (H7-H10)

A two-staged approach can be used to classify peat soils, usually reflecting the extent to which they have been developed for agriculture. 'Raw' peats occur in undrained sites under natural or semi natural vegetation where peat is still accumulating or where climatic or hydrological conditions have suppressed superficial humification. 'Earthy' peats have an earthy-textured peat topsoil or ripened mineral topsoil overlying organic material. Earthy peats occur in most of the lowland peats that have been drained, or drained and cultivated, including those in the Fens, the Somerset Moors, the Humberhead Levels and the Lancashire Mosslands.

Thus for the purposes here, the concern is with restoring peatlands that have been developed for agriculture to their original peat-forming vegetation, as well as the reversion to grassland habitats that can conserve remaining peats, in accordance with local site conditions[16]. In a given location, the types of earthy peats, whose characteristics are described under their soil series, indicate the type of vegetation that is likely to have formed the peat in the past, but need not be the only option for future peat-forming vegetation.

2.2 Conditions for Peatland Generation

Peat can only form where oxidation of organic matter is restricted due to saturated or near saturated conditions. Therefore peat formation requires a high and stable water table and high soil moisture content is required in the unsaturated zone, >50% by volume, i.e. close to saturation[17]. In contrast, carbon dioxide emissions of 15-50 t CO_2 ha^{-1} yr^{-1} are reported for watertable depths between 0.4-0.3 m below soil surface[18,19,20] In lowlands, it has been observed that the spread of peat forming plants has been associated with long-term, shallow inundated sites[21].

Peat formation requires that rates of deposition of organic material exceeds rates of decomposition and mineralisation of this material in a given area. Therefore, to maximise

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[16] Lucchese, M., Waddington, J.M., Poulin, M., Pouliot, R., Rochefort, L., Strack, M. (2010) Organic matter accumulation in a restored peatland: Evaluating restoration success. Ecological Engineering, 36:482–488.

[17] Price, J.S. and Whitehead, G.S. (2001), Developing hydrologic thresholds for *Sphagnum* recolonization on an abandoned cutover bog. Wetlands 21:32-40.

[18] Kechavarzi C, Dawson Q, Leeds-Harrison PB, SzatyŁowicz J, Gnatowski T 2007. Water table management in lowland UK peat soils and its potential impact on CO2 emission. Soil Use and Management, 23: 359–367.

[19]Moore, T.R., Dalva, M. 1997. Methane and carbon dioxide exchange potentials of peat soils in aerobic and anaerobic laboratory incubations. Soil Biology and Biochemistry, 29, 1157–1164.

[20] Verhagen, J., van den Akker, J., Blok, C., Diemont, H., Joosten, H., Schouten, M., Schrijver, R., den Uyl, R., Verweij, P., Wösten, H. 2009. Peatlands and carbon flows. Outlook and importance for the Netherlands. Netherlands Environmental Assessment Agency, Bilthoven. Report 500102 022, 52 pp.

[21] Timmermann, T., Margóczi, K., Takács, G., and Vegelin, K. (2006) Restoration of peat-forming vegetation by rewetting species-poor fen grasslands. Applied Vegetation Science 9: 241-250.

peat formation, vegetation should not be removed by cutting (harvesting) or grazing. Water quality is also of great importance in determining the type of vegetation[22]. Nutrient rich water may encourage domination by tree species, potentially drying out the surface layers.

Therefore, peat formation is not compatible with agricultural production due to;

- the removal of most of the new plant organic matter through cropping and grazing
- controlled lowering of water tables and reduced surface flooding to facilitate crop production, grazing and machine travel
- soil disturbance through cultivation and/or compaction

The use of peat soils for agriculture has resulted in their degradation and loss, commonly referred to as 'wastage', of which there are several components:

- Shrinkage – the removal of large amounts of water from the peat produces rapid initial shrinkage, with rates of 18 cm/yr in Holme Fen, Cambridgeshire, between 1850 and 1860[23]
- Compression – drainage also reduces the buoyancy effect of water which causes compression of peat under its own weight and increased bulk density. Passage of machinery increases the compaction;
- Oxidation – under the ensuing aerobic conditions, decomposition (biochemical oxidation) becomes the dominant processes, mainly affecting the peat above the watertable;
- Other lesser components of wastage, including:
    - Wind erosion – where spring-sown crops offer a bare, loose soil surface to strong winds
    - Removal of soil on root crops
    - Accidental burning of dry peat.

Thus, although careful management can help to conserve peats under agricultural use, especially under extensively grazed wet grassland, the restoration and reformation of peat soils generally exclude agriculture.

2.3 Peatlands in England

The term peatland is used to denote situations where there are at least 40 cm of peat material in the soil profile. Natural England [24]distinguishes three types of peatland on the basis of the vegetation responsible for forming the peat, namely:

- Fen peatlands usually forming where groundwater meets the surface. Vegetation varies according to local conditions, commonly comprising reeds, sedges, tall herbs and woody species in more nutrient-rich sites

[22] Gorham, E., Rochefort, L., (2003) Peatland restoration: a brief assessment with special reference to Sphagnum bogs. Wetlands Ecology and Management 11, 109–119.
[23] Hutchinson, J.N. 1980. The Record of peat wastage in the East Anglian fenlands at Holme Post, 1847-1978 AD. J Ecology, 68, 229-249
24 Natural England, 2010. England's Peatlands: carbon storage and greenhouses gases. (NE257). Natural England. Peterborough

- Blanket Bog associated with high rainfall upland areas comprising bog mosses, cotton grasses and heathers
- Raised bogs, also fed by rainfall, which comprise raised terraces of peat formed largely from bog mosses, but which may form over previous fen peats.

According to Natural England[25] there are a total of 14,185 km^2 of peatlands in England (1.4 million ha, 11% of England's total land area) of which about 6,800 km^2 are deep peaty soils (Table 2.1). Of these, just over half are mainly upland blanket bogs and the remainder (about 3,250 km^2, 0.33 million ha) are lowland peats comprising mainly fens and raised bogs.

Table 2.1: Area of different peatland types in England (Source: Natural England[26])

Peat Class	Area (km^2)
Deep peat soils	6,799*
Shallow peaty soils	5,272
Soils with peaty pockets	2,114
Total	**14,185**

*Includes 1,922 km2 of lowland wasted peat – a technical term for deep peat that has been substantially degraded following years of drainage and cultivation so that the peat becomes influenced by underlying mineral material

Figure 2.1 shows the distribution of peatlands in England. In the lowlands, the deep fen peats are mainly located in the Fens of East Anglia, the Somerset Levels and the Lancashire Mosslands. Lowland raised bogs occur in the West midlands, Manchester Mosslands, the Somerset Moors, Solway Mosses and parts of the Fens. Shallow peaty soils are mainly associated with wet heaths and grasslands around upland plateaux. Lowland soils with peaty pockets are commonly associated with springline mires and wet valley bottoms. About half of the total area of lowland peat in England is cultivated, and a further 17% is occupied by improved grassland (Table 2.2).

Table 2.2: Type and Use of lowland peats in England (Source: Natural England[27])

Land use/attribute of peat	Raised bog		Rich fens/reedbeds (deep)		Rich fens/reedbeds (wasted)		Grand Total	
	ha	%	ha	%	ha	%	ha	%
Afforested	6159	17%	1086	1%	2321	1%	9566	3%
Cultivated	8749	24%	37369	39%	115033	60%	161151	50%
Improved grassland	5286	15%	21208	22%	26605	14%	53099	16%
Pristine	338	1%	572	1%	341	0%	1251	0%
Restored	1687	5%	3804	4%	1379	1%	6870	2%
Scrub	802	2%	830	1%	140	0%	1773	1%
Wooded	3631	10%	6882	7%	6959	4%	17472	5%
Semi-natural non peat forming	5233	15%	11164	12%	6599	3%	22995	7%
Total*	**35721**		**95804**		**192205**		**323730**	

*Note that sum of the above does not equal the totals as there is overlap in the above land use and attribute categories and not all the categories are included

[25] Natural England (2010): op cit
26 Natural England (2010):op cit
[27] Natural England (2010): opcit

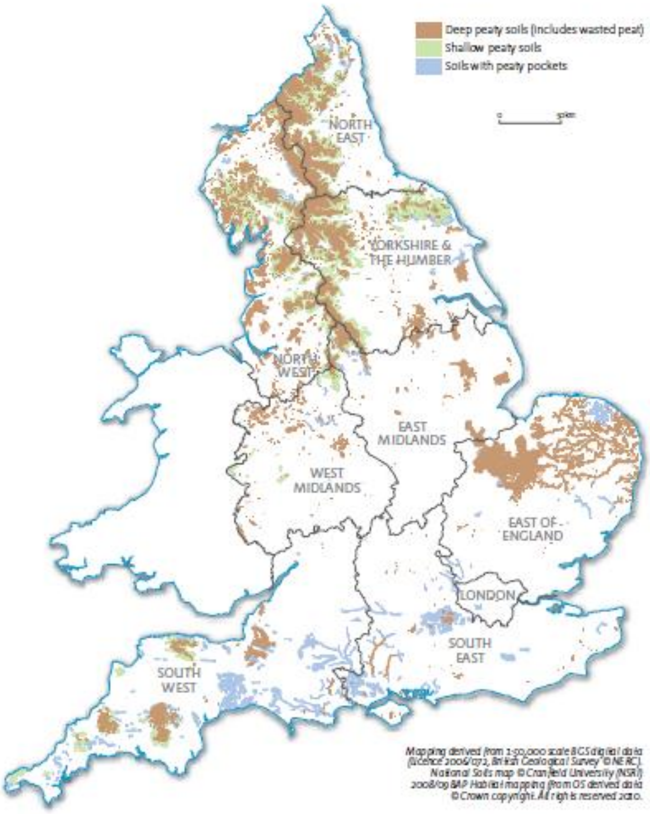


Figure 2.1: The distribution of different types of peat in England (Source: Natural England[28])

2.4 Peatlands and Agricultural Land Grade.

The existing suitability of land for different agricultural purpose is shown by the Agricultural Land Classification (ALC), reflecting a combination of the inherent properties of land (such as soil type, climate and topography) and the extent to which these favour or impede agricultural use. Grade 1 and 2 are considered prime agricultural land, suitable for intensive arable production, including roots crops and horticulture. Grade 3 is suitable for either arable or improved grassland, whereas Grade 4 and 5 are mainly confined to grassland, in the lowlands usually because of drainage problems. ALC grade also indicates the flexibility available in land management options, being greatest for Grade 1.

Peat soils cover the extremes of the agricultural land classification system. The agricultural role of peatlands and their contribution to food production and economic output are critically

[28] Natural England (2010).

dependent on the management of surface and ground water levels, supported by major investments in flood defence and land drainage over many years. They are commonly classed as Grade 1 and 2 where they have been reclaimed for agriculture under intensively managed, typically pumped, drainage regimes. The East Anglian Fens, Humberhead levels and Lancashire Mosses provide examples of the intensive farming of field-scale vegetables and salad crops.

Agricultural peatlands are typically classed as ALC Grade 4 where they are subject to seasonal flooding and waterlogging. These areas, such as those found in the Somerset Levels and Moors and the Cumbrian Lyth, are usually grassland. Controlled drainage on grasslands, combined with artificial fertilisers and silage, can support relatively high livestock stocking rates on peatlands, including dairy production. Wet conditions on peatlands are, however, usually associated with extensive grazing of beef and, to a lesser extent, sheep.

2.5 Food Security and the Role of Peatlands

The global food shortages and rapid rise in food commodity prices in 2006/7, brought about by successive harvest failures in major food exporting countries, placed the security of food supply back on the political agenda in many countries, including the UK. At the time, the situation was exacerbated by strong demand from newly industrialising countries, such as India and China, by unprecedented redirection of food crops into bio-fuel markets, commodity speculation and, to a degree by the success of policies in developed countries to cut back on agricultural production [29],[30],[31]. Higher food prices in the UK reportedly had a deleterious effect on patterns of food consumption, especially amongst poor and vulnerable social groups, reducing standards of nutrition and disposable income for non food items[32].

Food insecurity, however, may not necessarily arise because of shortfalls in production. Earlier, in 2000, concerns in the UK heightened when protests by transport operators against high fuel prices resulted in empty supermarket shelves[33]. In this case, food security was threatened by disruption of domestic supply chains, even when overall food production and available market supplies were adequate.

For much of the last 100 years, food security in the UK has been measured in terms of productive ‘self-sufficiency’; the proportion of the UK’s total food requirements sourced from UK farms. In 2009, the UK was 59 per cent self-sufficient for all food consumed in the UK and 73 per cent self-sufficient for indigenous food that can be grown in the UK. Self-sufficiency has declined from its peak in 1984, when for all foods it was about 78 per cent and 95 per cent for indigenous food[34].

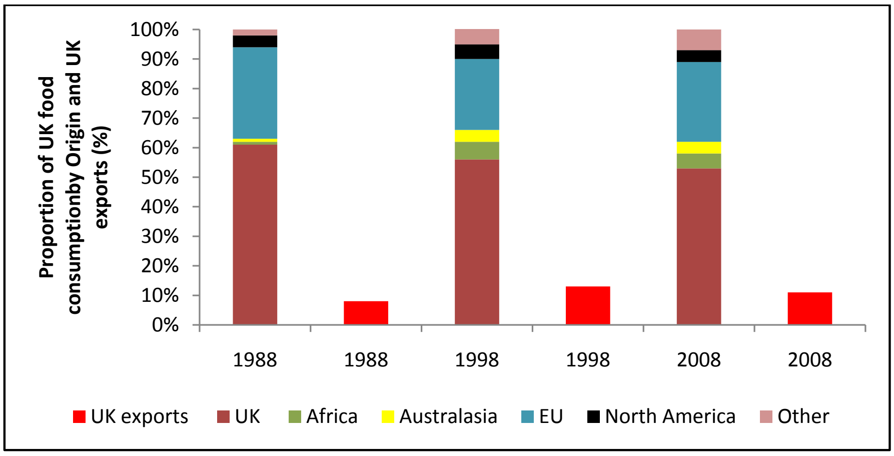
[29] OECD, (2009). *OECD-FAO Agricultural Outlook 2009-2018*. OECD Publishing. France.
[30] Piesse, J. and Thirtle, C. (2009). Three bubbles and a panic: An explanatory review of recent food commodity price events. *Food Policy*. **34**, 119-129.
[31] Trostle, R. 2008. Global agricultural supply and demand: factors contributing to the recent increase in food commodity prices. USDA economic research service. http://www.ers.usda.gov/Publications/WRS0801/ Accessed 2/07/2009.
[32] Defra (2010e). Family food: report on the 2008 family food module of the living costs and food survey. http://www.defra.gov.uk/evidence/statistics/foodfarm/food/familyfood/index.htm Accessed 10/06/201
[33] Defra (2006). Food security in the UK: an evidence and analysis paper. defra.gov.uk/evidence/economics/foodfarm/reports/.../foodsecurity.pdf Accessed 10/06/2010.
[34] Defra (2010a). Agriculture in the UK 2009. http://www.defra.gov.uk/evidence/statistics/foodfarm/general/auk/latest/documents/AUK-2009.pdf Accessed 10/06/2010.

Table 2.3 shows UK self-sufficiency and exports as a percentage of domestic production in 2009. Figure 2.2 shows the origins of food consumed in the UK and the relative proportion of food commodities exported. Additionally, about 3 per cent of fruit and vegetables consumed in UK households in 2008 came from non-commercial sources, such as gardens and allotments. The UK has an overall trade deficit for food, feed and drink, the value of imports in 2007 was £26.6 billion compared with £11.4 billion for exports, giving a trade gap of £15.2 billion. Between 1995 and 2007, this gap increased by 80 per cent. In 2007, the largest trade deficit was for fruit and vegetables (£5.8 billion). Whereas 90% of meat imports are sourced from 4 countries, 90% of fruit and vegetables are sources from 24 countries, indicating much greater diversity of produce and supply chains (Figure 2.2).

Table 2.3: UK agricultural production, self-sufficiency and exports as a proportion of domestic production in 2009[10]

Product	Production ('000 tonnes)	Self-sufficiency (%)	Exports as a proportion of domestic production (%)
Cereal	22 037	104	15
Wheat	14 379	80	17
Barley	6 769	112	12
Oats	757	102	4
OSR	1 938	88	6
Linseed	56	153	46
Sugar (refined basis)	1 280	64	41
Fresh Veg	2 597	59	3
Potatoes	6 423	83	11
Fresh fruit	415	12	34
Cattle, calves, beef, veal	856	83	11
Pork	703	52	18
Sheep, lambs, mutton	315	88	31
Poultry and poultry meat	1 459	91	17
Hen eggs	747	79	2

Source: Defra 2010a



Source Defra 2010a

Figure 2.2: Origin of UK food imports and relative proportion of UK exports of agricultural commodities based on farm-gate value of raw food[10]

By comparison, the EU as a whole has a high level of self sufficiency in food, with the notable exception of soya products for animal feeds [35]. The degree of self sufficiency in agricultural commodities varies across the member states (Table 2.4). Overall the EU is self sufficient in temperate cereals, selected vegetable oils and most livestock products. The overall EU trade position in agricultural and food commodities has oscillated around a near balance, although net exports of finished and intermediate food products have tended to offset net imports of raw commodities.

Table 2.4: Self-sufficiency of selected agricultural products in selected EU Member States (%) (from Barling et al, 2008)

Product	Denmark	France	Germany	Italy	Netherlands	Portugal	UK
Cereals	105	213	129	87	22	27	106
Potatoes	n/a	108	109	62	n/a	71	83
Eggs	80	97	73	106	n/a	75	88
Meat	351	109	99	76	n/a	75	88
Oils and fats	0	89	n/a	37	n/a	n/a	n/a

Source: Agriculture in the European Union Statistical and Economic Information 2007, chart 8.3: http://ec.europa.eu/agriculture/agrista/2007

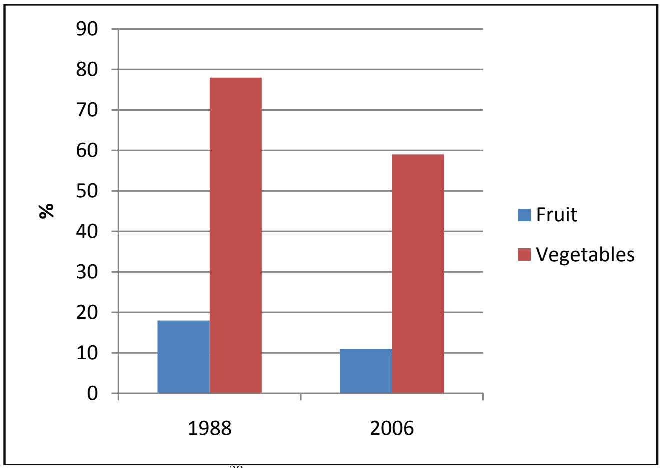
For most indigenous horticultural crops the areas planted and production declined between 1998 and 2006, as did overall UK self-sufficiency in fruit and vegetables during the period (Figure 2.3). The exceptions have been carrots, onions (dry and green), leeks, apples and plums, where a reduced planted area was more than offset by increases in yields on retained areas. There are no data regarding how land released from cropping has been used, but it is reasonable to assume that the proportion of wheat production has increased on areas previously occupied by vegetables. Strawberries and asparagus were the only crops that increased in terms of planted area and production over the period (Barling et al. 2008). The restoration of peatlands would result in further decline in the area of vegetables in particular, unless this production moves onto other soils.

Reflecting a broader concern, the UK Government adopted the concept of 'food security' that is to be achieved by 'guaranteeing households access to affordable nutritious food'. The UK Food 2030 strategy[36] charges UK agriculture, along with the food industry as a whole, with 'ensuring food security through strong UK agriculture and international trade links with EU and global partners'[37]. In this respect, UK agriculture is expected to be domestically efficient and internationally competitive. From an economist's perspective, this implies that UK

[35] Barling, D., Sharpe, R., and Lang, T. 2008. Rethinking Britain's Food Security. Report to Soils Association. City University, London

[36] Defra (2010b). Food 2030. http://www.defra.gov.uk/foodfarm/food/strategy/ Accessed 10/06/2010.
[37] Defra (2010c). UK food security assessment: detailed analysis. http://www.defra.gov.uk/foodfarm/food/security/ Accessed 10/06/2010.

farmers should focus on types of farming and land use in which they have comparative economic advantage. In this competitive world view, domestic agricultural production is required to compete with potential imports, in the absence of subsidies. Furthermore, assuming unrestricted international markets, UK agriculture can export where it has significant competitive advantage.



Source: Barling et al. 2008[38]

Figure 2.3: UK home production of fruit and vegetables as a proportion of new supply 1988 and 2006

However, the reality is that international agricultural commodity markets are not 'free' [39]but subject to a legacy of agricultural protectionism previously justified in terms of (i) feeding the nation (often borne out of major international conflicts) and (ii) alleviating rural poverty through income support. The traditional view of food self sufficiency, giving primacy to increasing domestic food supply and minimising reliance on imports, has given way to the contemporary concept of food security based on trade and co-operation throughout food supply chains that deliver healthy and nutritious food at affordable prices and minimal environmental impact.

The adoption of 'food security', set in an international context, appears compatible with trends in agricultural policy. The 2005 Reforms to the Common Agricultural Policy, with the 'decoupling' of production and income support, now mean that UK farm commodity prices are for the most part determined by world market conditions (although some EU market protection remains for livestock products and proteins). A review by Defra[40] concluded that food security was not a major concern, because the UK would be able to purchase food in world markets should the need arise, especially as most food is sourced from 'friendly'

[38] Barling, D., Sharpe, R., and Lang, T. 2008. Rethinking Britain's Food Security. Report to Soils Association. City University, London
[39] Potter, C. and Tilzey, M. (2007). Agricultural multifunctionality, environmental sustainability and the WTO: resistance or accommodation to the neoliberal project for agriculture. *Geoforum*, **38**, 1290-1303.
[40] Defra (2006). Food security in the UK: an evidence and analysis paper. defra.gov.uk/evidence/economics/foodfarm/reports/.../foodsecurity.pdf Accessed 10/06/2010.

trading partners (implying that other types of commodity securities , such as energy, may not be).

It was, however, the exposure to the risk of high food prices, induced by global shortages, that prompted Government to revisit the issue of self sufficiency, which had after all been a central plank in the UK's policy of 'Food From Our Own Resources'[41]. In the 2007/8 period, UK cereal prices more than doubled to almost £150/tonne. Higher foods prices reportedly had a deleterious effect on patterns of food consumption, especially amongst poor and vulnerable social groups, reducing standards of nutrition and disposable income for non food items[42] . Predictably, there was a surge in international supply in response to high commodity prices that in turn lowered prices, albeit not to their 2006 levels. The UK wheat output for example in 2008 rose by an 18% on the previous year because of increased plantings (13%) linked to the withdrawal of set-aside and higher yields (6%).

Reviews by Defra[43], however, favoured food security as one which (i) conforms with the principle of comparative economic efficiency in an international setting (ii) recognises the vulnerability of the population at large and poorer groups in particular to high food prices and constrained choice due to supply disruption.

Looking forward, a range of demand and supply side factors could threaten future food security[44]. These include demographic changes and economic growth in the UK and in emerging economies, harvest shortages, trade protectionism, disruption or conflicts, limited investment in agricultural technologies, and the effects of global warming and more unpredictable climates. The current consensus is that the UK is food secure. As a relatively rich nation, it can meet reductions in domestic food supply by importing. Worldwide, however, some 883 million people live in conditions of food insecurity[45]. Securing UK food supply could exacerbate shortages elsewhere. Under extreme circumstances, the UK could probably meet its own calorific food requirements, although this might require a switch from livestock to more cereals and crop proteins.

2.6 Changing diets

Food consumption is influenced by a number of factors including population, dietary requirements, income, food retail prices, and changing taste. Between 2001 and 2008 the UK population increased by almost 4% to approximately 61 million and is expected to grow to 71 million people by 2031[46]. An increase in population will tend to increase the demand for food. However, counteracting the consumption effect of an increase in population has been a long-term decline in rates of physical activity, which caused energy intake per person from

[41] MAFF 1975. Food from our own resources. HMSO, London.
[42] IFPRI 2007. The world food situation: new driving forces and required action. International Food Policy Research Institute, http://www.ifpri.org/pubs/fpr/pr18.asp Accessed 27/07/2009.
[43] Defra (2009c). UK food security assessment: our approach. http://www.defra.gov.uk/foodfarm/food/security/index.htm Accessed 10/06/2010.
[44] Defra (2010c). UK food security assessment: detailed analysis. http://www.defra.gov.uk/foodfarm/food/security/ Accessed 10/06/2010.
[45] USDA (2009b). Food security assessment 2008/09. http://www.ers.usda.gov/Publications/GFA20/GFA20_ReportSummary.pdf Accessed 10/06/2010.
[46] IGD (2010). Population trends. http://www.igd.com/index.asp?id=1&fid=1&sid=8&tid=30&cid=100 Accessed 10/06/2010.

food and drink to decline by 29% between 1974 and 2008[47]. The perceived healthiness of foods also influences consumption. For instance, the average consumption of fruit and vegetables was 3.7 portions per person per day in 2008, compared with 3 portions per person per day in 1975[27]. This is part of a trend to healthier eating, driven in part by government policy.

Food consumption varies amongst income groups. Low-income households tend to buy more bread and cereals, milk, cheese and eggs, sugar and confectionery but less meat and bacon (classified as a meat product), vegetables, fruit and other foods than more affluent families. In 2007 low income households in the UK consumed an average of 3.5 portions of fruit and vegetables per person per day, compared with an overall UK average of 3.9 portions. Price changes also influence consumption. When food prices increase, consumers buy less beef, lamb, cheese and fruit, but buy more bread, biscuits and cakes, bacon, butter, preserves and milk. As food is essential, consumers will tend to buy cheaper produce as prices increase; these goods that are "traded down" include: pork; poultry; eggs; sweets and chocolate; potatoes and vegetables[27].

Consumer choice has also changed over the last few decades. For instance, although the quantities of bread consumed per head fell between the 1940s and 2000s, there has been a large increase in the varieties of bread available and an increased in the consumption of speciality breads over the last few years. Total milk and cheese consumption has remained relatively stable over time, but within this category there has been a substitution of full-fat to skimmed milk. Similarly the quantity of meat consumed over time has remained relatively constant, but this masks large annual fluctuation caused by health issues, such as the BSE crisis and a large substitution from red to white meat; poultry now being the most popular meat. There have been long-term declines in the quantity of potatoes and vegetables consumed, although the fall in vegetable consumption has been reversed in recent years by government health campaigns[48]. Conversely there has been an increase in the quantity of cereal and fruit consumed per person.

These trends are likely to continue into the foreseeable future. For potato and vegetable crops grown on peat soils, population growth is likely to maintain demand for bulk supplies of cereals, potatoes and other field vegetables such as onions and carrots. There is however likely to be stronger growth in targeted, differentiated food markets, such as pre-pack potatoes and supermarket grade vegetables and salad crops. It is here that the arable peatlands can, combined with specialist skills and infrastructure, meet the high quality standards required by food markets. Rising incomes and greater awareness about food quality and healthy eating are likely to encourage greater differentiation of food products in future, including 'regional' food brands linked to quality assurance, ethics and environmental standards. This also offers opportunity for grassland dairy and fatstock farming, and fruit production that can target niche, regional markets. In terms of contribution to national diet, remaining peatlands have potential to deliver high quality and high value produce that target specific market requirements, including potatoes, vegetable, fruit and salad crops, rather than bulk general food products. The move towards healthy eating, with greater emphasis on fruits and vegetables, could increase the importance of the contribution of peatlands to the

[47] Defra (2010e). Family food: report on the 2008 family food module of the living costs and food survey. http://www.defra.gov.uk/evidence/statistics/foodfarm/food/familyfood/index.htm (Accessed 10/06/2010)
[48] Foster, R. and Lunn, J. (2007). 40th anniversary briefing paper: food availability and our changing diet. *Nutrition Bulletin*, 32, 187-249.

national diet. As noted earlier, a large proportion of the increased demand for fruits and vegetables has been met by imports as domestic production has declined.

2.7 Peatlands and Food Security

Peatlands have the capacity to contribute to food security in a number of respects. Peatlands and their constituent agricultural businesses, especially in arable areas, are characterised by:

- High incidence of cropping of high value potatoes, vegetables and salad crops.
- A large share of the UK (and England) Grade 1 and 2 agricultural land and the flexibility in production this supports
- Specialist knowledge, skills and organisational capacity for intensive, market-oriented, farming, including high competencies in labour and machinery management
- Well developed agricultural production and marketing networks, technology and infrastructure, including irrigation and drainage, storage and processing.
- Large-scale flood defence, arterial and field drainage systems, supported by private and public funds.

Peatlands that have been 'reclaimed', and the farming and food systems that they contain, constitute a strategic resource that has been built up over time[49]. While peat soils have been the foundation of this productive capacity, there are clear signs that the soils themselves are being rapidly 'farmed out'. Increasingly, the comparative advantage of farming in peatland areas rests, not so much on the peat soils themselves, but on the capacity of farmers and related agri-business to manage high value specialist production and marketing systems. Indeed, once peats have been degraded, high value production has tended to switch onto mineral soils, supported by irrigation, for the most part displacing wheat production in the process. Once degraded, depending on subsoils, agricultural peatlands tend to switch to more extensive farming: either grassland or a cereal-based rotation, possibly including sugar beet[50].

The 'restoration' of peatlands for the purpose of achieving non-agricultural benefits, involves rewetting and arresting the processes of peat degradation and wastage (as explained in 2.2 above). Peatland restoration will necessarily result in a reduced capacity for agricultural production, at least during the remaining life of cultivated peat soils, that is, before they would be degraded by continued intensive agricultural usage.

2.8 The future demand for agricultural land

The potential withdrawal of peat land from agricultural production needs to be put in the broader context of the future demand for agricultural land in the UK. Drawing on a number of other studies, the recent Foresight Land Use Futures Project[51] concluded that:

[49] National Farmers Union. (2008). Why Farming Matters in the Fens, NFU, London
[50] Morris, J., Gowing, D.J.G., Mills, J. and Dunderdale, J.A.L. (2000) "Reconciling Agricultural Economic and Environmental Objectives: The Case of Recreating Wetlands in the Fenland Area of Eastern England," Agriculture,Ecosystems and Environment, Elsevier Science, 79,245–257.
[51] Government Office for Science (2010) Land Use Futures: making the most of land in the 21st Century. HMSO, London.

- The use of land for agriculture in the UK (and Europe) is likely to decline either due to demands for other uses or because some types of farming are no longer viable. However, much depends on global commodity process and the incentives they provide, including inducement for new farming technologies.
- Commodity prices might rise because of strong demand for food and bio-fuels and possible constraints on some types of intensive farming. Under such conditions there could be strong demand for agricultural land to produce for domestic or export markets.

Authoritative sources predict that agricultural prices will remain strong for the foreseeable future (through to 2017), probably at about 25%-30% higher than their 2003-2006 levels. By 2009/10, commodity prices had settled back following the 2007 spikes due to enhanced supply, confirming the price responsiveness of international agriculture. There is evidence however, of greater volatility in agricultural commodity markets, making for an uncertain investment climate.

2.9 Future Productivity of Agricultural Land.

The productivity of UK farms is an important determinant of the amount to land required to meet the demand for food. This (defined as the ratio of the value of agricultural outputs to all inputs) has doubled since the early 1960's, mainly as a result of increased yields and labour savings. There is much potential to increase yield performance of crop and livestock systems in UK agriculture, but the challenge will be to do this within the constraints and opportunities due to changing climate, water available, higher standards for food safety, environmental protection, and worker and animal welfare[52].

A review[53] of the potential for crop and livestock yield improvements in the UK suggested that yield increases of between to 20% - 60% were feasible over the next 25 years, depending on the inducements for technology change and the acceptability of intensive farming methods[54]. Improving the productivity of farming, both generally and in specialist farming areas, is an important component of any land management strategy. Maximising efficiency in areas which are best suited to farming and food production, may also enable options to reduce farming intensity or take land out of production in areas where other outcomes, such as nature conservation, are deemed more important.

2.10 Agriculture and climate change

Agriculture has an important role in the mitigation of adaptation to climate change by reducing its emissions, storing carbon in soils, and producing substitute energy products that

[52] Burgess, P and Morris J, (2009). Agricultural technology and land use: the UK case. Land Use Policy. S26S, S222-S229
[53] Sylvester-Bradley, R and Wiseman, J (2005). Yields of Farmed Species, Constraints and Opportunities in the 21st Century. Nottingham University press, Nottingham
[54] Morris, J., Audsley, E., Wright, I.A., McLeod, J., Pearn, K., Angus, A. and Rickard, S. (2005) Agricultural Futures and Implications for the Environment. Defra Research Project IS0209. Bedford: Cranfield University

have a low carbon footprint[55]. Agriculture also needs to adapt to changes in climatic conditions, water availability, and possible pest and diseases that might arise.

The management of peat soils has strong interaction with climate change effects. Carbon release from cultivated peats can add significantly to global warming. Furthermore their future condition, whether used for agriculture or conserved as a natural habitat, is highly dependent on water availability.

In broad terms, there is not a great difference between the water requirements per ha of different crop types, including grassland. Peatland restoration tends to have marginally higher water requirements than commercial cropping[56]. It cannot be assumed therefore, in the event of greater volatility in climatic patterns and generally rising temperatures, that sufficient water will be available to support future peatland management, including habitat restoration and peat formation, unless specific measures are taken accordingly. The latter may include, for example, strategic investments in water resources.

The majority lowland peatlands are located within the indicative floodplain[57]. Again, under conditions of climate change and greater incidence of extreme weather events, these areas have potential to contribute to flood alleviation, including the storage of flood waters that could damage downstream urban areas. Flooding with sea water or saline intrusion of groundwater in coastal areas could however affect not only the agricultural but also the restoration potential of peatlands.

2.11 Peatlands and Ecosystem Services

In their natural condition lowland peatlands are amongst the most ecologically productive and diverse ecosystems[58]. They have, however, as explained above, been 'reclaimed' for agriculture, with significant economic and welfare benefits, but this has been at the cost of the many other non-market services that peatlands can provide.

The Millennium Ecosystem Assessment (MA)[59] explored the link between ecosystems and human welfare and developed a 'checklist' of services provided ecosystems, broadly classified into provisioning, regulating, cultural and supporting services (Table 2.5). Peatlands provide a broad array of services. In their natural condition, in the absence of human intervention, they provide a number of 'supporting services', including the formation of peat soils themselves. They also provide a range of services of benefit to people, associated with, for example, food production, flood control, water purification, recreation and wildlife.

Table 2.5: The ecosystems framework as proposed by MA[60]

[55] Foresight 2010. Land Use Futures: making the most of land in the 21st Century, Govt Office for Science. London
[56] Estimates derived here using a an ET and water deficit model
[57] Environment Agency, 2009. Flooding in England. Environment Agency, Bristol
[58] Maltby, E. (1986). *Waterlogged Wealth: Why Waste the World's Wet Places?* Earthscan: London.
[59] Millennium Ecosystem Assessment, 2005@ http://www.milleniumassessment.org/en/index.asp:
[60] Millennium Ecosystem Assessment, 2005: http://www.milleniumassessment.org/en/index.asp:

Provisioning services
Fresh water
Food (e.g. crops, fruit, fish, etc.)
Fibre and fuel (e.g. timber, wool, etc.)
Genetic resources (used for crop/stock breeding and biotechnology)
Biochemicals, natural medicines, pharmaceuticals
Ornamental resources (e.g. shells, flowers, etc.)
Regulatory services
Air quality regulation
Climate regulation (local temperature/precipitation, GHG* sequestration, etc.)
Water regulation (timing and scale of run-off, flooding, etc.)
Natural hazard regulation (i.e. storm protection)
Pest regulation
Disease regulation
Erosion regulation
Water purification and waste treatment
Pollination
Cultural services
Cultural heritage
Recreation and tourism
Aesthetic value
Spiritual and religious value
Inspiration of art, folklore, architecture, etc.
Social relations (e.g. fishing, grazing or cropping communities)
Supporting services
Soil formation
Primary production
Nutrient cycling
Water recycling
Photosynthesis (production of atmospheric oxygen)
Provision of habitat

This approach is being further developed and applied under the ongoing national UK-UNEP National Ecosystem Assessment[61]. Here, the assessment seeks to identify and value those 'final goods' that are of benefit to people. Thus, while peat soil formation is a supporting service, it is rather the final goods generated by peatlands that generate an economic value, such as food (based on market prices), flood control (damage avoided) or biodiversity (willingness to pay).

The use of peatlands to generate particular services may compromise others. This report focuses on the trade-off between peatlands for agriculture and food production and peatlands as a provider of other services, notably carbon storage, wildlife and biodiversity, and recreation. Whereas market prices and profits from farming show the value of more or less peatland hectares used for agriculture, the value 'at the margin' of non–market services from peatlands requires a range of valuation methods, such as damage avoidance (eg flood control), willingness to pay (eg biodiversity) and abatement cost (eg carbon sequestration). The analysis that follows considers the trade-offs between the contribution of peatlands to food security and other services rendered by peatlands under alternative scenarios.

[61] UNEP-UK NEA (2010). UK National Ecosystem Assessment. http//uknea.unep-wcmc.org

3 The Target Areas

The impacts of peatland restoration on food security and consequences for other ecosystem services were explored through a number of regional 'study areas' and within these a number of selected aspirational restoration 'Target Areas'. Land use scenarios were constructed to assess the implications of differences in the scale and intensity of peatland restoration on agricultural production and national food security. An ecosystems framework was used to assess the social and economic outcomes of changes in peatland management. A 'benefit transfer' model was used to derive estimates of the environmental benefits of peatland restoration.

3.1 The Wetland Vision

The Wetland Vision (http://www.wetlandvision.org.uk/) is a partnership project supported by English Heritage, the Environment Agency, Natural England, The Royal Society for the Protection of Birds, The Wildlife Trusts, and the Wildfowl and Wetlands Trust. The project aims to present a 50-year vision for England's freshwater wetlands by showing where wetlands might be conserved, restored or created. The project also delivers improved and expanded wetlands through a number of targeted projects and collaborative partnerships, aiming to protect and enhance wetlands and the services they provide for the benefit of future generations. The project has developed targeting maps of past and potential future wetlands, and Natural England has committed £2m annually for 3 years since the projects's launch in 2008 to support delivery. The first £2m supported 15 projects, including the establishment of four "landscape scale" wetland initiatives in The East Anglian Fens, the Humberhead Levels, the Morecambe Bay Wetlands and the West Midlands Meres and Mosses. A further £4m has been spent during 2009-2011 on further projects in these priority areas, and three further schemes in other wetlands. The following outcomes have been supported by the Wetland Vision during 2009-2011 and are being delivered through partnerships with a wide range of local stakeholders:

- Restoration of 97 ha of reedbeds, fen and grazing marsh in the Wissey "Living Landscapes" to complement adjacent restoration efforts and provide habitat connectivity with existing wetlands.
- Restoration of wetland habitat around Thorne and Hatfield moors in the Humberhead Levels.
- Supported projects to enhance and expand wetland habitats in the Lyth Valley
- Funded the development of a local wetland vision for the Somerset Levels.

The Wetland Vision has also supported the establishment of 635 ha of linking wetlands in the West Midlands, funded the creation of grazing marsh and exploration of improved catchment management in the River Till floodplains in Northumberland, and helped to develop approaches to ecosystem services, based around the River Fal in Cornwall.

3.2 The Study Areas

In collaboration with Natural England, four regional case study areas were selected for analysis. The criteria for selection were:

- Part of the wetland vision
- Regionally representative of peatland resources
- Identified as priority Target Areas for restoration

The regional areas (**Figure 3.1**) include the peatlands contained in:

- The East Anglian Fens
- The Humberhead Levels
- The Somerset Moors and Levels
- The Lyth Valley

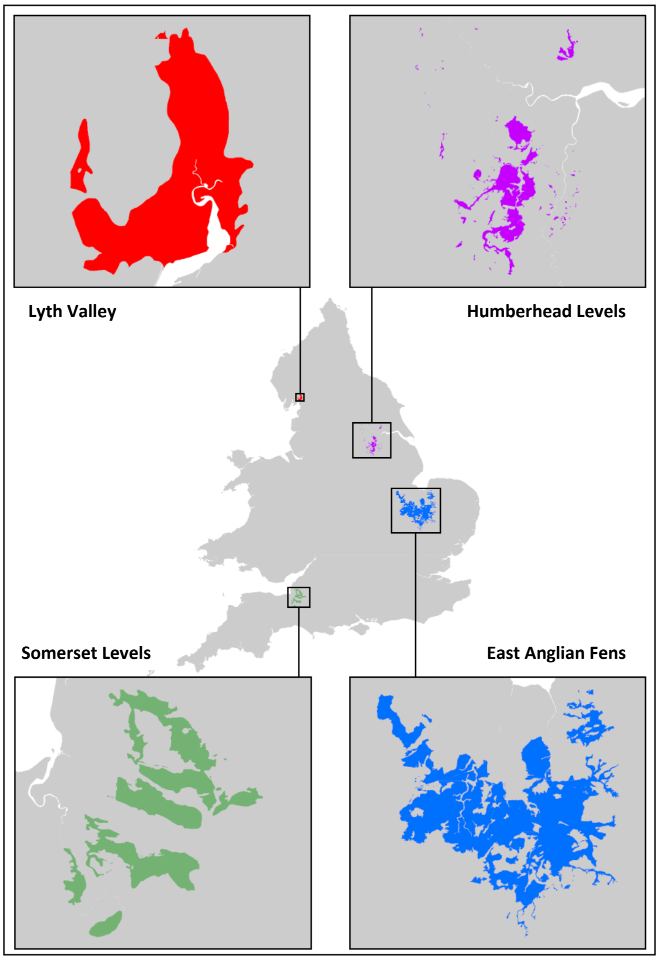
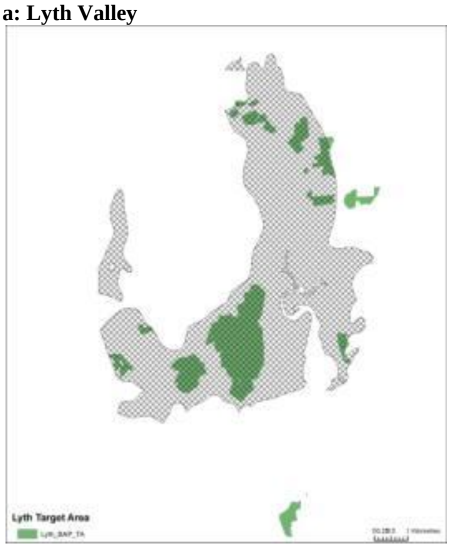


Figure 3.1: The location of the Lyth Valley, Humberhead Levels, Somerset Levels, and East Anglian Fen peatland regional study areas in England

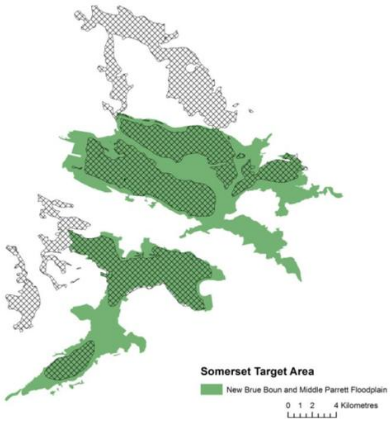
Each of these regional study areas contain a number of subsidiary 'Target Areas' for peatland restoration, as shown in Figure 3.2, selected because they were considered to be areas where land might be managed in the future to improve the delivery of non-market ecosystem services. It is noted that in all regional areas peatland extends beyond the boundaries of the Target Areas and in some cases, notably Somerset, the Target Areas contain peat and non peat areas. For the purpose here, the focus is on the potential restoration of peatland within the Target Areas (Table 3.1). The potential impact of restoration of peatland on agriculture at a larger scale beyond the Target Areas within the regional areas is also considered.

a: Lyth Valley



b: Humberhead Levels

d: Somerset Levels



c: East Anglian Fens

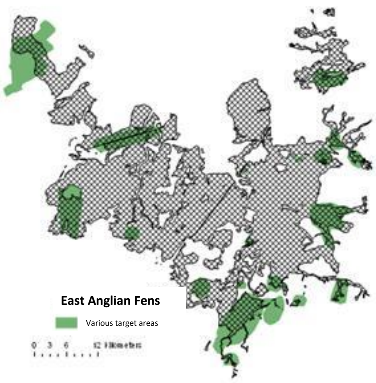


Figure 3.2: The Target Areas (shaded) for peatland restoration within each of the regional study areas (hatched)

Table 3.1: Selected case study sites and there characteristics

Site	Area of peat in region (as Figure 3.2)	Area of peat in 'target' areas	Description
East Anglian Fens	34,889 (133,000)	20,564	Currently in arable and horticultural production, restoration to fen/grazing marsh/reedbed with little or no production
Humberhead Levels	6,300	364	Currently mainly arable in production (varied), restoration of areas to floodplain and fen lagg, with some wet grassland, including flood storage
Somerset Levels	13,548	7425	Currently predominantly grassland, including restoration mainly through HLS, with some continued agricultural production
Lyth Valley	1,284	612	Currently mainly grassland , restoration to floodplain grazing marsh, reedbed and fen with little or limited continued grazing production

3.3 Existing and Future Land Use and Farming Systems

Land use information in the Regional case study areas and Target Areas was obtained from two main sources, the Land Cover Map 2000 (CEH, 2000) and Defra Agricultural June Census statistics 2004, the latest year for which full survey details are available. The latter were corroborated against Defra 2008 June Census data information which is based on a sample rather than full survey. The results indicate that the 2004 land use estimates provide a reasonable estimate of crop areas and livestock numbers[62]. Information on the productivity and financial performance of farming systems in peatland areas was obtained from secondary sources, notably Defra statistics, the regional farm business surveys [63], and farm management

[62] Two major types of change have occurred for which adjustments have been made, namely discontinuation of set aside has been associated with an increase in crops harvested by combine harvester, especially cereals : some further reduction in and consolidation of the national dairy herd. It appears that more recently, however, the rate of structural change in agriculture has slowed, partly in response to strengthening commodity prices and generally improved prospects for farming (RBR, 2010 various). The change from crop area and headage payments to single farm payments does not appear to have had a major effect on farm production in lowland England , although there was some initial reduction in beef and sheep numbers and stocking rates

[63] Crane, R. and Vaughan, R. (2010). *Farm business survey 2008/09: Horticulture in England*. Rural Business Research at the University of Reading.

Lang, B. (2010). *Farm business survey 2008/2009: crop production in England*. Rural Business Research at Cambridge, University of Cambridge.

Lang, B. (2004). Report on farming in the Eastern counties of England 2003/04. Rural Business Research at Cambridge, University of Cambridge.

pocket books[64] supplemented by personal contact with farmers and their representatives in the study areas.

The regional study sites vary markedly in land use and farming systems (Table 3.2): arable in the east and grassland in the west. Farm sizes are associated with farm type and for this reason there are regional differences; ranked in order of size as follows - general cropping, cereals, dairy grazing and horticulture.

The eastern peatland regions of the Fens and the Humberhead Levels are characterised by relatively intensive, larger scale arable farming systems, mainly cereals and general cropping farms, and some small scale specialist horticultural and fruit farms. Farms are significantly larger in the arable systems of the eastern regions, especially for general cropping farms in the Humber region. Arable farms in the Humberhead levels for example account for 35% of farms by number and 90% of the farmed area. In the Fens these figures are 60% and 90% respectively. Farm sizes have increased over the last 20 years in pursuit of economies of scale and specialisation.

These eastern peatland arable areas contain regionally high levels of root crops production (potatoes and sugar beet), 'vegetables grown in the open' (notably carrots, onions and beetroots) and salad crops (lettuce, celery, leeks, calabrese) as well as other high value crops on specialist horticultural and fruit farms. Much of this high value cropping is irrigated and served by pumped drainage.

Wilson, P. and Cherry, K. (2010). Analysis of gross and net margin data collected from the farm business survey in 2006/07 and 2007/08. Rural Business Research, University of Nottingham.
[64] Nix, J. (2009). The John Nix farm management pocketbook: 40th edition. The Anderson Centre, Leicestershire.
Robertson, P. and Wilson, P. (2010). *Farm business survey 2008/09*: dairy farming in England. Rural Business Research, University of Nottingham.
ABC (2009) The Agricultural Budgeting and Costing Book, Agro-Business Consultants: Nov 2009. Melton Mowbray

Table 3.2: Farming in the Regional Peatland Study Areas (within which the Target Areas are located)

	The Fens Peat Lands					Humber Peat Lands				
Robust Farm Type	**Number of Holdings**	**Total Area (ha)**	**% of holdings**	**% of area**	**Av farm size ha**	**Number of Holdings**	**Total Area (ha)**	**% of holdings**	**% of area**	**Av farm size ha**
Cereals	290	25,532	21%	24%	88	23	2,351	25%	37%	102
General Cropping	512	74,384	37%	69%	145	9	3,013	10%	48%	335
Horticulture	38	816	3%	1%	21	5	85	5%	1%	17
Dairy	5	195	0%	0%		#	#			
Grazing Livestock (Lowland)	93	2,096	7%	2%	23	9	211	10%	3%	23
Mixed	32	2,129	2%	2%		#	#			
Other Types	420	2,618	30%	2%	6	34	241	37%	4%	7
Others (suppressed identity)	0	0	0%	0%	0	11	407	12%	6%	37
Total	1,390	107,770	100%	100%	78	91	6,308	100%	100%	69

	Somerset Peat Lands					Lyth Peat Lands				
Robust Farm Type	**Number of Holdings**	**Total Area (ha)**	**% of holdings**	**% of area**	**Av farm size ha**	**Number of Holdings**	**Total Area (ha)**	**% of holdings**	**% of area**	**Av farm size ha**
Cereals	6	433	2%	4%	72					
General Cropping	#	#				#	#			
Horticulture	13	148	3%	1%	11					
Dairy	38	3,585	10%	35%		8	959	16%	41%	
Grazing Livestock (Lowland)	95	4,254	25%	42%	45	12	687	24%	29%	57
Mixed	#	#				#	#			
Other Types	211	1,401	56%	14%	7	19	190	38%	8%	10
Others (suppressed identity)	16	421	4%	4%	27	11	528	22%	22%	47
Total	379	10,241	100%	100%	27	50	2,364	100%	100%	47

Source Defra, 2010, June Census , 2009

excl specialist pigs and poultry # denotes a value suppressed to prevent disclosure of information about individual holdings.

In contrast the western peatland regions of Somerset and the Lyth valley are predominantly livestock agricultural economies. Here grassland, accounts for at least 75% of the farmed area. Specialist dairy farms account for 10-15% of holdings on about 35-40% of the farmed area, and are thus typically amongst the largest farms by size in the locality. Grazing livestock is the dominant farm type in terms of numbers of holdings, accounting for about 25% of all holdings. There are, however, small but locally important areas of arable farming in both regions, including potatoes and vegetables, and some specialist horticultural producers, including fruit production in the Somerset case.

3.4 Financial Performance of Farming Systems

UK farm incomes, which maintain the presence of farming in the landscape, have shown volatility around a general decline over time, even allowing for some recent strengthening due to stronger commodity prices. In 2008, total income from farming was 60% lower in real terms than in 1975.

The profitability (measured in terms of Management and Investment Income (MMI) /ha) of farm businesses vary according to type and size. By way of example, Table 3.3 shows financial returns for cereal and general cropping farms in the Fens, and for specialist horticultural and dairy farms in England during the period 2007-9 inclusive, derived from

Farm Business Survey results[65]. Profits (M&II) here include charges for family labour and land based on typical rents (even though farms may be owner occupied). They exclude subsidies such as annual receipts under the Single Payment Scheme which, depending on historical entitlements, can range, between £180 and £220/ha on eligible land.

Table 3.3: Different financial performance indicators of different farm types[66]

Representative Financial Performance (£/ha) by Farm Type , 2007-2009*						
	The Fens				All England	
	Cereals	General cropping			Hortic	Dairy
	All farms	All farms	Bottom quartile	Top quartile	Mainly outdoor veg**	all lowland farms
Av size ha	190	250	220	180	95	120
Gross Output	920	1459	1263	1944	12003	2748
Variable Costs	290	457	541	492	5097	1088
Gross Margin	630	1001	722	1452	6906	1660
Fixed Costs	463	789	875	870	6472	1176
Net margin	167	214	-153	582	434	484
Source : FBS - Lang, 2010; Crane and Vaughan, 2010; Robertson and Wilson, 2010						
*averaged over 2007/8 and 2008/9 years at current prices , ** 2009						
including rents/land charges						

The detailed distribution of land use in the Study Areas reflects dominant farming systems (Table 3.4). In the mainly arable areas of the Fens and Humberhead, cropping accounts for about 90% of the farmed area. In the most intensive areas, especially on remaining deep peats, cereals act as a 'break' crop, facilitating rotations of potatoes, vegetables and salads. Here, cereals may account for only 30% of the cropped area. Cereals tend to increase in importance as peat soils have degraded over time and the land loses its advantage for high value cropping. Some of this high value cropping has switched to sand and silty soils, with irrigation. Much of the production of field-scale vegetables is now large scale, benefiting

[65] Crane, R. and Vaughan, R. (2010). *Farm business survey 2008/09: Horticulture in England*. Rural Business Research at the University of Reading.

Lang, B. (2010). *Farm business survey 2008/2009: crop production in England*. Rural Business Research at Cambridge, University of Cambridge.

Lang, B. (2004). Report on farming in the Eastern counties of England 2003/04. Rural Business Research at Cambridge, University of Cambridge.

[66] Nix, J. (2009). The John Nix farm management pocketbook: 40th edition. The Anderson Centre, Leicestershire.
Lang, B. (2010). *Farm business survey 2008/2009: crop production in England*. Rural Business Research at Cambridge, University of Cambridge.

Robertson, P. and Wilson, P. (2010). *Farm business survey 2008/09*: dairy farming in England. Rural Business Research, University of Nottingham.

Wilson, P. and Cherry, K. (2010). Analysis of gross and net margin data collected from the farm business survey in 2006/07 and 2007/08. Rural Business Research, University of Nottingham.

ABC (2009) The Agricultural Budgeting and Costing Book, Agro-Business Consultants: Nov 2009. Melton Mowbray from specialisation in crop production and marketing. Farmers overcome constraints imposed by rotation requirements on vegetable crops, notably potatoes and carrrots, by seasonal 'renting' from other farmers. There is much contracting of specialist services such as cultivations and harvesting , and in some cases complete production.

Table 3.4: Agricultural Land Use (including woodland) for the Study Areas (source Defra Ag Census, 2004)

	East Anglian Fens		Lyth Valley		Somerset Levels		Humberhead Levels	
	whole	target	whole	target	whole	target	whole	target
Farmed areas (ha)	34889	20500	1284	612	23996	7425	6300	364
wheat	38.5%	35.8%	3.3%	4.6%	5.2%	10.0%	38.5%	no data*
barley and other cereals	3.5%	5.6%	0.2%	0.2%	1.3%	2.5%	3.5%	
peas and beans (comb)	6.4%	5.1%	0.0%	0.2%	0.4%	1.2%	6.4%	
oil seed rape	2.9%	3.2%	0.0%	0.0%	0.4%	0.7%	2.9%	
sugar beet	11.7%	9.3%	0.0%	0.0%	0.0%	0.0%	11.7%	
potatoes	8.3%	7.1%	0.1%	0.1%	0.1%	0.1%	8.3%	
other veg in open	5.3%	4.7%	0.0%	0.0%	0.1%	0.1%	5.3%	
linseed and oth arable	1.0%	1.3%	0.0%	0.1%	0.2%	0.8%	1.0%	
maize	0.0%	0.0%	0.5%	0.7%	3.5%	5.9%	0.0%	
fallow and SAS	7.4%	9.4%	0.0%	0.0%	1.5%	3.0%	7.4%	
horticulture	6.3%	5.9%	0.3%	0.3%	0.5%	0.6%	6.3%	
fruit	0.2%	0.2%	0.0%	0.0%	0.4%	0.4%	0.2%	
nursery stock/flowers	0.3%	0.4%	0.1%	0.1%	0.0%	0.0%	0.3%	
Total crops	91.8%	88.1%	4.5%	6.3%	13.7%	25.4%	91.8%	
forage crops	0.2%	0.3%	0.2%	0.2%	0.2%	0.0%	0.2%	
grassland pp	4.4%	5.8%	71.2%	70.2%	73.8%	61.6%	4.4%	
grassland temp	1.1%	1.9%	7.2%	6.6%	9.1%	7.7%	1.1%	
rough grazing (pr)	1.4%	1.4%	15.3%	15.1%	2.4%	3.3%	1.4%	
Total grass	7.1%	9.4%	94.0%	92.1%	85.5%	72.6%	7.1%	
woodland	1.0%	2.3%	1.5%	1.4%	0.7%	1.4%	1.0%	
total %	100.0%	99.8%	100.0%	99.8%	100.0%	99.4%	100.0%	

*The Humberhead target area is too small to enable non attributable small area statistics

Livestock production varies between the regions (Table 3.5). In the predominantly grassland peat areas of Somerset and Lyth, dairying accounts for over 40% of livestock units (where 1 livestock unit = 1 dairy cow equivalent based on feed energy requirements). In the Fens, where grassland is less than 10% of the farmed area, there is little dairying: most livestock comprise suckler cows producing beef calves and the fattening at grass of 'store' cattle of different ages, some of them by itinerant graziers.

Average livestock units (Lu) per ha, a measure of grassland intensity, also varies amongst the regions. In Somerset, Lyth and Humberhead, stocking rates average 1.6-1.8 Lu/ha, indicative of the moderately intensive management of 'improved' grassland. In the Fens, this is about 0.7-0.9 Lu/ha, typical of extensive grassland farming under conditions of poor agricultural drainage or grasslands purposely managed for conservation.

Table 3.5 Distribution of Livestock Units by Livestock type in the Regional Peatland Areas

	East Anglian Fens	Lyth Valley	Somerset Levels	Humberhead Levels
Dairy and dairy replacements*	3%	50%	47%	32%
Suckler beef cows	34%	10%	8%	16%
Cattle of various ages	53%	20%	40%	39%
Sheep: ewes and lambs	10%	20%	5%	13%
	100%	100%	100%	100%

Average stocking rates Lu/ha	0.9	1.8	1.8	1.7

*usually ratio of 4:1 Lu for dairy cows to replacement young milk cows, although higher where replacements are produced for sale, as they are in Somerset.

The aforementioned information on farming systems and land use has been used to inform the assessment options on peatlands.

3.5 Agri-environment options for peatlands

The Restoration of Target Biodiversity Action Plan priority habitats in the four case study areas probably can be achieved through implementation of current management options of the Higher Level Stewardship (HLS) Agri-environment Scheme. The extent to which these options generate peat formation depends on the management of drainage and vegetation associated with agricultural use.

The payments under HLS are mainly a reflection of the opportunity cost to farmers of taking land out of production and the extra costs involved in meeting the requirements of the scheme. While they reflect a revealed willingness to pay by society for environmental benefits for wetland (and peatland) restoration, they are not a complete estimate of the benefit obtained. Annual payments for range between £150 and almost £400 /ha, depending on intended outcomes (Table 3.6)

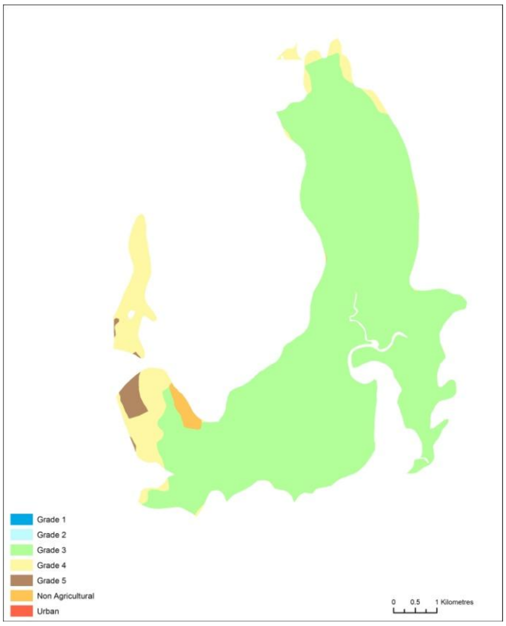
Table 3.6: Selected HLS Options and Payments

Code	Option	Payment	Unit
	Options for boundary features		
HB14	Management of ditches of very high environmental value	£36	100
	Option for grassland		
	Management of grassland for waders and wildfowl		
HK9	Maintenance of wet-grassland for breeding waders	£335	ha
HK10	Maintenance of wet-grassland for wintering waders and wildfowl	£225	ha
HK11	Restoration of wet-grassland for breeding waders	£335	ha
HK12	Restoration of wet-grassland for wintering waders and wildfowl	£255	ha
HK13	Creation of wet-grassland for breeding waders	£355	ha
HK14	Creation of wet-grassland for wintering waders and wildfowl	£285	ha
	Options for wetland		
	Reedbeds		
HQ3	Maintenance of reedbeds	£60	ha
HQ4	Restoration of reedbeds	£60	ha
HQ5	Creation of reedbeds	£380	ha
	Fens		
HQ6	Maintenance of fen	£60	ha
HQ7	Restoration of fen	£60	ha
HQ8	Creation of fen	£380	ha
	Lowland raised bogs		
HQ9	Maintenance of lowland raised bog	£150	ha
HQ10	Restoration of lowland raised bog	£150	ha
	Options for orchards		
HC18	Maintenance of high-value traditional orchards	£250	ha
HC20	Restoration of traditional orchards	£250	ha
HC21	Creation of traditional orchards	£190	ha

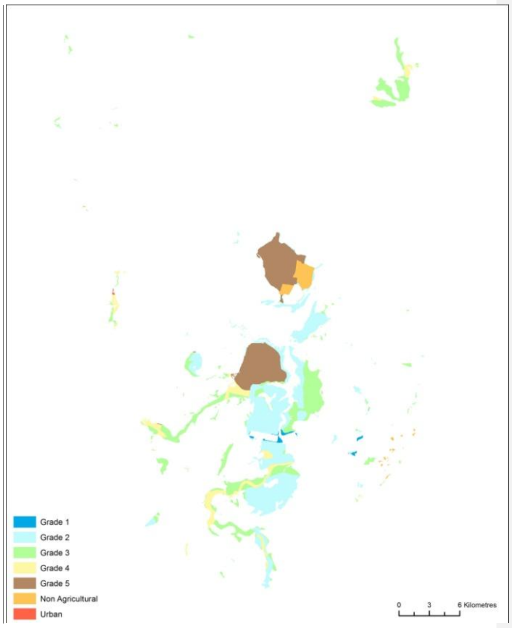
3.6 Agricultural Land Class in the Target Area Peatlands

The distribution of Agricultural Land Grades for each of the Study Areas is shown in

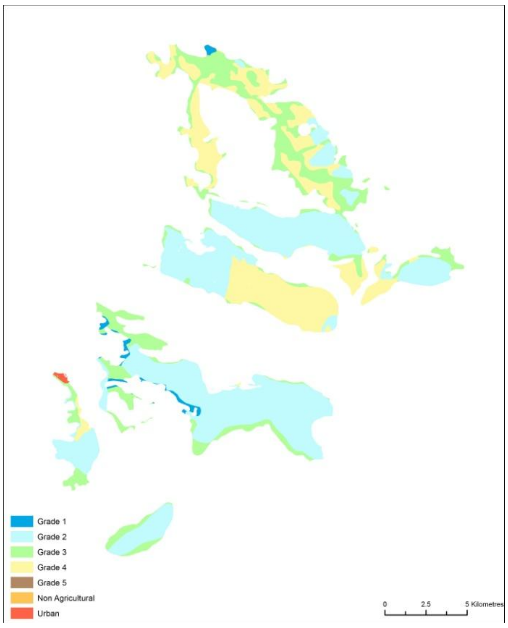
a: Lyth Valley peat type



b: Humberhead Levels peat type



d: Somerset Levels peat type



c: Great Fen peat type

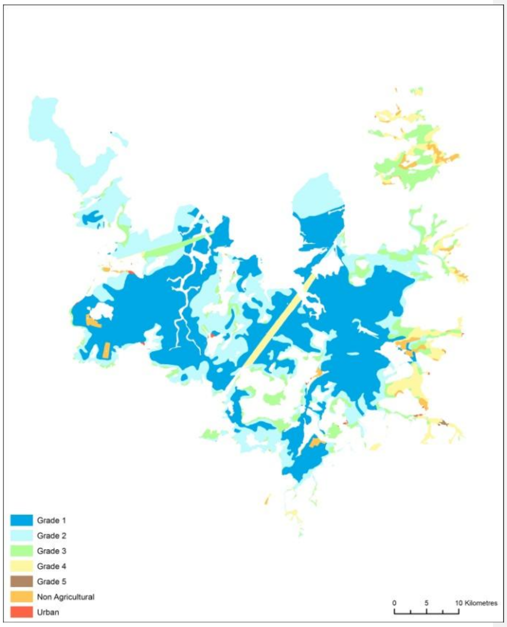
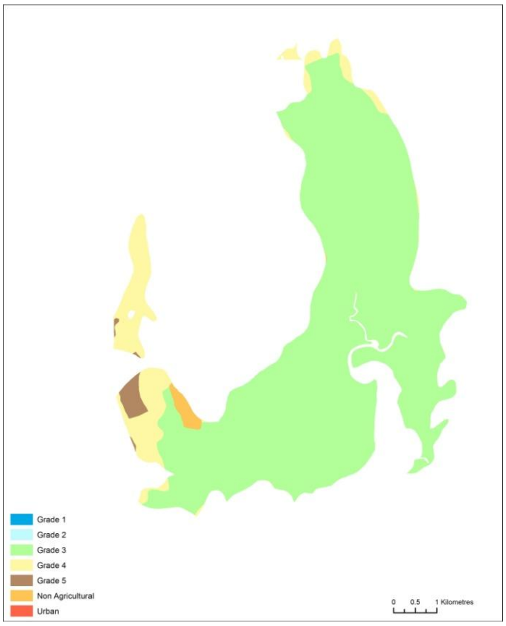


Figure 3.3. Under controlled drainage, as in the Fens and Humberhead, large areas of peatlands are classed as Grade 1 (Table 3.7), supporting intensive arable production, often with ground-fed summer irrigation. The classification of Grade 1 and 2 in the Fens and Humberhead is critically dependent on pumped drainage. Where agricultural drainage is limited, as in parts of Lyth and Somerset, peats are classed as Grade 4 and put down to grass. However, controlled drainage can support improved grassland, as on the Somerset Moors, as well as enabling conversion to arable farming: hence a Grade 2 classification for peatlands in some grassland areas. It is important to note that ALC grade reflects a capability under a prevailing land management regime that may change, such as land drainage. The classification of land could also be affected by environmental conditions, such as climate change.

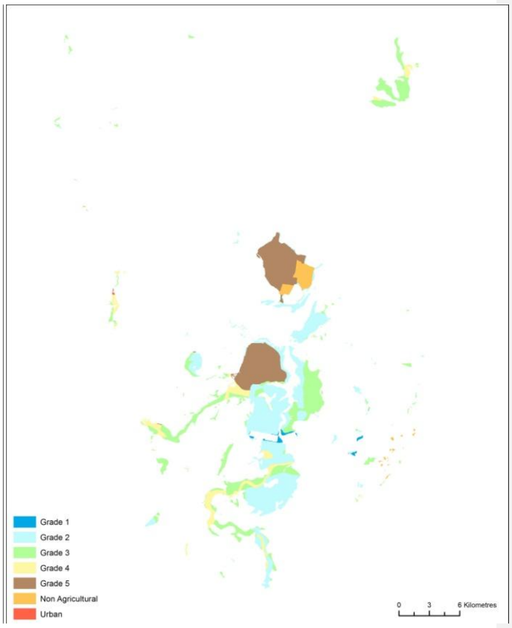
Table 3.7: Percentage of total peatland in different Agricultural Land Classification Grades for each Study Area

	East Anglian Fens	Humberhead Levels	Somerset Levels	Lyth Valley
Total areas ha surveyed	132131	14234	16126	3561
Grade 1	49%	1%	1%	0%
Grade 2	34%	39%	52%	0%
Grade 3	8%	27%	22%	87%
Grade 4	6%	8%	25%	11%
Other	3%	25%	0%	2%
Total	100%	100%	100%	100%

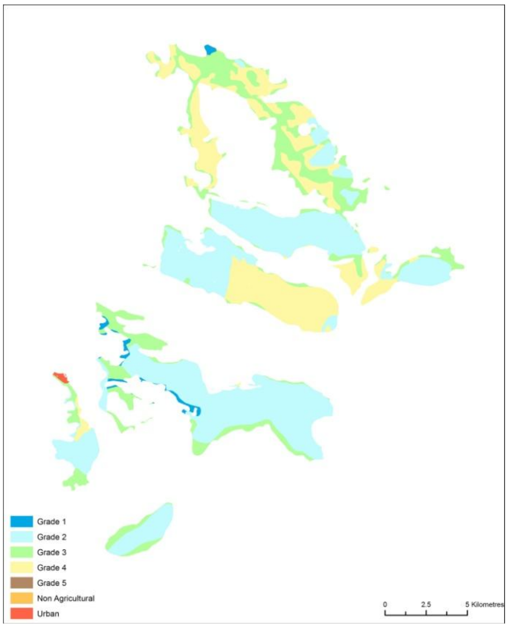
a: Lyth Valley peat type



b: Humberhead Levels peat type



d: Somerset Levels peat type



c: Great Fen peat type

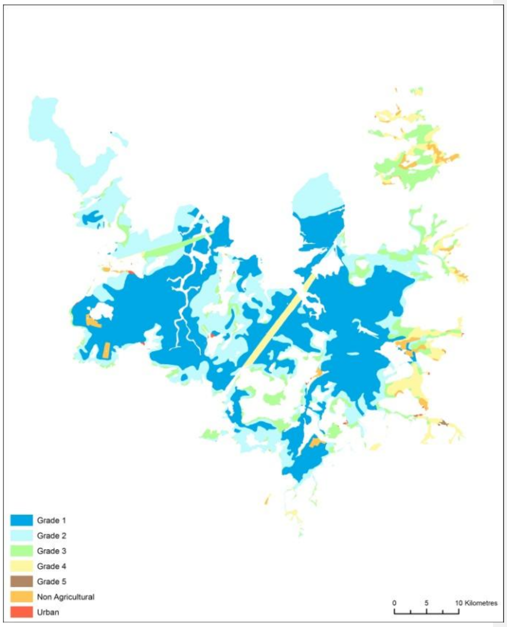


Figure 3.3: Location of different land grades on the case study sites (Source: Natural England)

3.7 Market Prices for Agricultural Land

In theory, the market price of land should represent the present capital value of commercial profits from farming over a reasonable time frame, say an investment period of 30 years from a farmer perspective. Table 3.8 shows the market prices of agricultural arable and pasture land in the study regions. Land prices have risen rapidly in the last 4 years, partly as a result of more buoyant agricultural commodity prices.

Table 3.8: Representative Market Prices for Agricultural Land (£/ha, 2009)

	East Midlands	Yorks and Humberside	South West	North West
Pasture Land	11,700	11,100	12,400	14,800
Arable Land	14,200	14,500	14,800	16,000

Sources : RICS, VOA, 2010[67]

Discussions with land agents in the study areas suggested current land prices of around £15,000 per ha for Grade 1 and 2 land, with little distinction made between the two grades. Grassland values appear to be about £10,000 - £12,000 per ha, but much depends on location, access and drainage condition. Arable land that comes with abstraction licences can command higher prices, sometimes by as much as an extra 20% -25%.

Land prices are not necessarily a reliable indicator of agricultural potential, and are not always closely attuned to ALC grade. Relatively little land is sold in any year (less than 1 % of total stock), and prices are often influenced by 'local' factors. Of relevance here, Defra advises that the loss of agricultural land in terms of its potential value to the nation can be estimated using the market value of land, adjusted to remove a subsidy element. This is further discussed below.

3.8 Land use and peats: the effects of agricultural degradation

As referred to earlier, the agricultural use of peatlands results in its degradation over time, mainly due to drainage and cultivation for crop production. Usage for permanent grassland can conserve peatlands providing wetness is maintained. However, the removal of vegetation through grazing and hay/silage cutting, and the extraction of materials for thatching and fuel, limits the further formation of peat soil. Conditions conducive to peat formation are likely to limit land use to extensive summer grazing.

Natural England classify lowland peatlands into two main types: raised bogs, and fen/reedbeeds. The latter much larger category by area is further classified according to condition, whether deep or degraded. As noted previously, the degradation of agricultural peatlands is strongly associated with its use for arable farming (see Table 2.2).

[67] RICS (2010). Rural Market Survey. http://www.rics.org/ruralmarketsurvey

Evidence suggests that peat wastage in arable farming ranges between 10 and 30 mm per year, highest where ploughing and power harrowing (to achieve fine seedbeds and bury crop residues) and intensive drainage (to control water levels and facilitate machinery travel) are practiced in support of large scale field vegetable production. In their assessment of recent peat wastage in the Fens and Humberhead peatlands, Holman (2009) and Holman and Kechevarzi (2010) used values of 10 mm to 21 mm/year, depending on peat thickness and land use[68]. Among agricultural land uses, peat wastage is likely to be least under extensively managed, mainly summer grazing of permanent pasture, where water levels are maintained at a relatively high level for most of the year.

In the East Anglian fens, where about 60% of remaining peats are less than 1 m thick[69] with an average depth of 70 mm, this suggests a remaining life under the plough of between 25 to 50 years, and considerably less on thinner peats. The conclusion is not contested in principle by farmers, although there may be debate on the actual longevity of remaining arable peatlands. The view is widely held by those who earn their livelihoods through peatland farming is that the peat soils are a resource whose use offers comparative advantage in specialist arable farming, even though eventually this capability will be exhausted.

[68] Holman IP and Kechevarzi C (2010). An estimate of peat reserves and mineralisation in the Humberhead peatlands. Unpublished report for the Royal Society for the Protection of Birds.

[69] Holman IP (2009). An estimate of peat reserves and loss in the East Anglian Fens. Unpublished report for the Royal Society for the Protection of Birds

4 Impact of Peatland Restoration on Agriculture, Food and Ecosystem Services

This chapter explores the implications of alternative uses of lowland peatland for agricultural production, national food security, potential environmental burdens and a range of ecosystem services.

This section considers alternative land use scenarios in the peatland Target Areas and the implications for agriculture, food security and a range of ecosystem services.

The approach involved a number of steps:

- Existing cropped areas and livestock numbers in the Target Areas were determined using a combination of Defra Agricultural Census Data (2004 and 2009) and LCM Data (2000).
- Estimates of Yields, Prices, Gross Output, Gross Margins, Fixed Costs and Net Margins were derived drawing on a range of secondary sources supported by discussions with key informants. Prices were based on averages over the period 2008 to 2010, expressed in 2010 values.
- Estimates of Environmental emissions by crop and livestock type were drawn from lifecycle analysis.[70]
- Different peatland restoration and agricultural management scenarios (see section 4.1) were considered in terms of their impact on the type, quantities and relative proportions of crop and livestock produced, crop yields and grassland stocking rates, costs such as drainage, and environmental costs. A spreadsheet model was constructed for this purpose.
- The effect on national food supplies and security of taking land out of agricultural production was assessed.
- Estimates of the value selected ecosystem services were derived, including changes in carbon emissions. A benefit transfer model was applied to the four Target Areas.

[70] Williams A G, Audsley E, Sandars D L. (2006). Determining the Environmental Burdens and Resource Use in the Production of Agricultural and Horticultural Commodities. Final Report to Defra, Project IS0205Cranfield University and Defra (accessible via www.agrilca.org)

4.1 Land use Scenarios

Although peatland soils can offer considerable comparative advantage for intensive high value cropping, they are liable to continued degradation with consequences for long term yields and the sustainability of farming systems, especially under conditions of climate change. Their degradation is also associated with release of soil carbon, further contributing to global warming and climate change. Thus, while their agricultural usage makes an important contribution to national food supply, this capability and the viability of intensive farming systems on peats are potentially at risk in the longer term.

In this context, a number of future land use scenarios are considered for peatlands in the study areas.

For the Target Areas the scenarios are:

(i) *Baseline - Continued Agricultural Production* – Current agricultural land use with degradation over time and associated changes in farming systems and performance. This requires no surface inundation and water levels managed at mean depths of at least 0.5m throughout the year,.

(ii) *Degraded Arable Peatland* –wasted peats exposing underlying mineral soils not suitable for intensive arable farming. Soils liable to seasonal water logging, requiring field (and pumped) drainage to control water levels to 0.5m

(iii) *Peatland Restoration* - No agriculture – peat forming vegetation. This may involve frequent, possibly long duration flooding and standing water, with near surface water table levels throughout most of the year.

(iv) *Peatland Conservation I* –(mainly) extensive grazing in accordance with BAP priorities, may also include wet woodlands. This involves surface flooding and standing water in winter and high water tables during winter spring and autumn, managed to about 0.2m from the surface, to allow summer grazing and some hay making from May through to early September

(v) *Peatland Conservation II* – semi-intensive grazing - a moderately intensive grassland system to reconcile farming and peatland conservation objectives. This involves high winter water tables and short duration winter flooding, with water tables managed to about 0.4m from the surface to allow grazing and silage making from April through to October.

(vi) *Large scale Conservation* - the extension of restoration/conservation beyond the Target Areas to the larger scale – as for (ii) above. This is identified as a 'multiplier' of impacts assessed for the Target Areas.

The assessment of Continued Agricultural Production provides the counterfactual against which other land use scenarios are assessed. The options of bio-fuel cropping of willow or miscanthus are not considered here, although as heavily mechanised processes incompatible with high water tables, it is considered they are unlikely to represent a conservation option.

Particular focus is placed here on the incremental effect of these scenarios on:

(i) national food production and national food security
(ii) the broad range of ecosystems goods and services provided by peatlands
(iii) the rewards and incentives to land managers

Budgets were constructed using a spreadsheet facility for each of these scenarios, allowing for changes in cropping patterns and grassland management options (land use cover), crop yields, livestock type and stocking rates. The methods used follow those reported elsewhere for the appraisal of wetlands options[71]. Net margins were derived for major types of agricultural land use. These include charges for all labour including unpaid family labour. They exclude any charges for land, whether rent or mortgage payments , because the purpose is to determine the value-added per ha, before rents. They also exclude annual single farm payments (currently about £200/ha for eligible land), that is land previously used for crops and livestock that received direct subsidies.

4.1 Scenario Analysis for Target Areas

4.1.1 Peatlands in the Fens

The peatland Target Areas for The Fens comprises about 20,000 ha, of which about 30 % are deep peats (thicker than 1 m) and the rest are degraded. A total extended area of 34,900 ha has been identified for restoration.

Table 4.1 contains the results of scenario analysis for the Fen peatlands. Under the *Baseline Continued Agricultural Production Scenario*, under present circumstances, the overall aggregate annual value of agricultural output in the Fen Target Areas is estimated at £48 million, with a net margin of £7.2 million, equivalent to £2,400 gross output and £360 net margin per ha (excluding rent, and payments and other income). (It is noted that farmers are in receipt of single farm payments of about £250 per ha on land previous in receipt of production subsidies). Land use and the profitability of farming vary considerably reflecting the condition of peat soils and the texture of underlying soils where peats are degraded. The Target Areas contain a greater proportion of conservation areas and extensively farmed degraded peats than other parts of the Fen peatland. (The average net margin for the larger area is about £400/ha).

[71] Posthumus H., Rouquette, J.R., Morris, J., Gowing, D.J.G., Hess T.M.. (2010) A framework for the assessment of ecosystem goods and services; a case study on lowland floodplains in England. Ecological Economics, 65, 151-1523
Rouquette, J.R., Posthumus, H.,Gowing, D.J.G., Tucker, G., Dawson, Hess, T.M and Morris, J. (2009) Valuing nature conservation interests on agricultural floodplains. J. Applied Ecology. 46, 2, 289-296
Morris, J., Bailey, A.P., Lawson, C.S., Leeds-Harrison, P.B., Alsop, D., and Vivash, R. (2007). The economic dimensions of integrating flood management and agri-environment through washland creation: a case from Somerset, England. *Journal of Environmental Management* 88: 372-381, (2008)
Morris, J., Gowing, D., Mills, J. And Dunderdale, J. (2000). Reconciling agricultural economic and environmental objectives: the case of recreating wetlands in the fenland area of eastern England. *Agriculture, Ecosystems and Environment*, **79**, 245-257.

Table 4.1: Agricultural Gross Output and Net Margins by Scenario for Fen Peatlands

		Gross Output	Net Margin	Gross Output	Net Margin	Range
		£'000	£'000	£/ha	£/ha	+/- £/ha
East Anglia Fens						
Target Areas	20029	ha				
Baseline continuation		48,000	7,200	2399	360	200-1200
Degraded arable peats		18,200	-400	930	5	-160 to 50
Peat restore		1,001	-501	50	-25	0 to -50
Peat conserve I -wet grass		6,200	-300	307	-15	-50 to 50
Peat conserve II - grass		21,900	148	1055	10	-50 to 50
Extended Area						
total	34889	ha				
multiplier	1.74					

In the most intensively farmed deep peat areas, high value cropping of potatoes, vegetables and salad crops can account for over 60% of the total farmed area. These crops can achieve annual net margins of £1,800 to £2,200 per ha. For an average year in rotation with cereals, this generates a net margin about £850 - £1200 per ha, given that other crops such as cereals, which do not do particularly well on peat soils, have low or negative net margins. There is much sub-contacting of land and production to avoid the restrictions imposed by rotations on any one farm.

Where peats have wasted to leave heavy clay marl or 'skirt soils, cropping is limited to cereals and oil seeds, possibly with sugar beet. Here soils are difficult to work and typically subject to poor drainage. Average gross output is about £950/ha, gross margins are £550/ha, and net margins are probably -£50 to -£80/ha, just about breaking even at best (excluding land rents).

Thus, overall, the average loss associated with taking land out of production under current conditions would be about £360- £400/ha, ranging between 200 to £1200/ha according to the quality of remaining peat and its current use. Losses would be highest where deep peat supports intensive field vegetable and salad crops .

Continued arable production will degrade the remaining peat soils, at the annual rate of about 10mm to 30mm. Drier summer conditions under climate change will exacerbate this process. At current rates, the bulk of the remaining peats will become 'wasted' over the next 30 to 100 years, depending on current status and usage. The rate of deterioration can be arrested by soil conservation measures such as minimum tillage and retained water levels to avoid drying and wind generated 'blow-outs'. But peatland vegetable farming is characterised by intensive ploughing to bury trash, power harrowing to give a fine seedbed, and lowered water levels to support machinery travel. Measures such as laser levelling of fields to remove hollows and aid soil water management, controlled water levels and soil moisture, and machinery 'tramlines' to reduce machine trafficking can reduce the rate of soil loss but not eradicate it. The potential of the land once peat is wasted depends on (i) the cropping potential of the underlying mineral soils and (ii) the need for additional investment, especially land drainage.

Under the *Degraded Arable Peatland* scenario it is assumed that peats have wasted to leave heavy clay marl or 'skirt soils and cropping is limited to cereals and oil seeds, possibly with sugar beet. Here soils are difficult to work and typically subject to poor drainage. The Gross Output from the Fen Target Areas fall by over 60% from its present level, to about £930/ha with net margins just about breaking even, within a range of £-150 to £150/ha. Under this scenario, the comparative advantage of the peats is lost, but more than this, in some areas, farming will be relatively disadvantaged by poor soil and drainage conditions. Investments in land drainage, at about £2,500/ha (about £200/ha/year at 5% real interest rates over 20 years) will probably not be financially attractive, especially to the large institutional land owners in the Fens that let land to tenant farmers. Thus, much will depend on the type of underlying soils and the need for additional drainage investments. On peats over sands or silts, continued high value cropping may be feasible, supported by irrigation

In the longer term, the net cost of withdrawing arable land from production is likely to decline. This 'degraded' future for arable farming, in which much of peatland farming is rendered commercially marginal, is the counterfactual against which other options can be assessed. The implications of the rate of degradation of peats for the viability of alternative land use are considered later.

Under the *Peatland Restoration Scenario*, the entire Target Areas are converted to wet fen and peat forming vegetation. Farming is not commercially viable in the absence of other income streams such as single farm payments or agri-environment receipts. Some stock may be grazed to assist in habitat management biodiversity, as currently at the National Trust Wicken Fen, at a reported net cost of about £50/ha[72]. It is assumed here that about half the area is extensively grazed for this purpose, at an average cost of £25/ha

Thus, under this *Peatland Restoration* Scenario, the net cost is the loss of annual net margin from continued farming, which could either be an average of £385/ha or £30/ha, depending on whether the current land use or a degraded counterfactual is used. For the currently most productive areas, the net cost would probably be about £1000/ha.

The *Peatland Conservation I Scenario* involves the universal adoption of wet grassland in accordance with local BAP priorities. An equal mix of extensive grazing (zero fertiliser) with hay cutting in some cases, raised water levels and species rich pastures are assumed, with stocking rates typically 0.5 grazing livestock units per ha or less. In the Fens, this will mainly involve suckler cows and fat cattle. Gross output declines to about 10% of its current level for the Target Areas, at about £300/ha and a net margin of £-15/ha, ranging from about £-50 to £30. This option would deliver regional BAP targets and retain a farming presence in the landscape. It would require agri-environment or other payments for environmental services to make it commercially attractive to farmers. There could be opportunities to increase farm income by marketing 'environmentally assured' livestock products.

The *Peatland Conservation II* scenario involves the conservation of remaining peats under a moderately intensive, mainly beef grassland regime. This assumes a mix of grassland regimes with chemical fertiliser ranging from about 25 kgN /ha through to 150 kgN/ha for grazing and silage making systems respectively. It assumes that sufficient livestock and livestock management skills are available in the region, something that would need to be built

[72] Personal communication: Wicken Fen Estates Manager

up. Gross output is about 40% of current 2010 levels at around £1000/ha gross output, with net margins just above breakeven at £10/ha. It is perceived that this system could deliver a range of environmental benefits, although it is also noted that livestock systems can generate relatively high environmental burdens, especially regarding GHG emissions[73].

Over all, the net cost to farming of taking land out of production in the Fens at present appears to be about £360/ha per year on average over the whole area, and over £1000/ha on the currently most productive land. In time, however, continued arable production will degrade the advantage of these areas, possibly to the point where arable farming becomes commercially non-viable due to the poor agricultural quality of remaining soils, and the need for remedial investments in land drainage.

Other options for agricultural land use include the introduction of bio-energy crops such as willow and miscanthus. These options, because they involve cultivations, removal of vegetation, use of heavy machinery and lowered water levels especially for harvest periods, are unlikely to lead to peat formation but could, with appropriate soil management, deliver similar peat conservation outcomes to those of the semi –intensive grassland options. The potential for conservation oriented bio-energy cropping on peat soils is worthy of further study.

4.1.2 Peatlands in the Humberhead Levels

The analysis of peatland options on the Target Areas of the Humberhead levels reveals similar outcomes to that of the Fens (Table 4.2). It is noted that the current Target Areas are small at 630ha, containing about 360 ha of peat. The extended area for possible peatland restoration covers 6,300 ha. The comments below are best made with respect to the larger area, rather than the specific circumstances of the 360 ha.

Cropping patterns in The Humberhead Levels are similar to those observed in the Fens, with a relatively high presence of potatoes, field vegetables and salads. As noted earlier, general cropping farms are the biggest single farm type by number and area. The comments made above regarding arable systems on the Fens apply in the Humberhead case.

With respect to the *Baseline Continued Agriculture Scenario*, the current average gross output is about £2,500 /ha with net margins averaging £418/ha, higher than the Fens reflecting the higher incidence of dairying. As in the Fens, arable margins for vegetables and salads in rotation on deep peats are between £800 and £1300/ha. There is much sub contracting of vegetable production between farms. In the event of the degradation of arable peats such that only cereal, oil seed and sugar beet production is possible, gross output falls by 60% and net margins just about breakeven (excluding rents and single farm payments).

Under the *Peatland Restoration Scenario*, the entire Target Areas are converted to wet fen and peat forming vegetation. Farming is not commercially viable. Some stock may be grazed to assist in habitat management biodiversity, probably at a net cost of about £25/ha. Thus, under this *Peatland Restoration* Scenario, the net cost is the loss of annual net margin from continued farming, which could either be about £440/ha or £30/ha, depending on

[73] Williams et al, 2006, opcit

whether the current land use or further degraded peat is taken as the counterfactual. For the most productive areas, the net cost would probably be around £1000/ha.

Table 4.2: Agricultural Gross Output and Net Margins by Scenario for the Humberhead Peatlands

		Gross Output	Net Margin	Gross Output	Net Margin	Range
Humberhead Levels		£'000	£'000	£/ha	£/ha	+/- £/ha
Target Areas	360	ha				
Baseline continuation		936	150	2597	418	220-1300
Degraded arable peats		339	30	942	7	-160 to 50
Peat restore		18	-9	50	-25	0 to -50
Peat conserve I -wet grass		109	1	302	4	-50 to 50
Peat conserve II - grass		427	23	1186	63	0 to 100
Extended Area						
total	6300	ha				
multiplier	17.50					

The *Peatland Conservation I Scenario* involves the universal adoption of wet grassland in accordance with local BAP priorities. Stocking rates assume about 0.5 grazing livestock units per ha or less mainly for suckler cows and fat cattle, and some sheep. Gross output declines to about 10% of its current level for the Target Areas, at about £300/ha and a net margin of £4/ha, ranging from about £-50 to £50/ha depending on type of stock and stocking rates. This option would deliver regional BAP targets and retain a farming presence in the landscape. It would require agri-environment payments to make it commercially attractive to farmers.

The *Peatland Conservation II* scenario involves the conservation of remaining peats under a moderately intensive grassland regime supporting dairy, beef and sheep regime, with similar management to that described for the Fens. Gross output under this scenario is about 60% of current 2010 levels. At about £1200/ha gross output, with net margins of about £63 /ha, assuming that dairy account for about 10% of total livestock units, falling to about £10/ha in their absence. It is perceived that this system could deliver a range of environmental benefits, although measures would be required to control the potential environmental burdens associated with livestock production.

Over all, the net cost to farming of taking land out of production in the Humberhead levels is similar to that of the Fens at about £418/ha per year on average over the whole area, and over £1000/ha on land with intensive vegetable cropping. As with the Fens however, the arable peat soils in the Humberhead are vulnerable to further degradation, with reduced suitability for high value cropping and need of additional drainage investment.

4.1.3 Peatlands in the Somerset Moors

The analysis of peatland options on the Target Areas of 7,321 ha in the Somerset Moors reflects conditions in a mainly livestock area, supporting dairy production, suckler beef cows, fat cattle and sheep (Table 4.3). With respect to the *Baseline Continued Agriculture Scenario*, average net margins are currently about £164/ha. Complete degradation of arable peat soils, currently about 26% of the area (including forage maize), would reduce average net margins to about £140/ha.

Table 4.3: Agricultural Gross Output and Net Margins by Scenario for the Somerset Moors

		Gross Output	Net Margin	Gross Output	Net Margin	Range
		£'000	£'000	£/ha	£/ha	+/- £/ha
Somerset						
Target Areas	7,321	ha				
Baseline continuation		10,389	1200	1419	164	100 to 200
Degraded arable peats		9320	1035	1271	141	100 to 200
Peat restore		366	-183	50	-25	0 to -50
Peat conserve I -wet grass		2231	38	305	5	-50 to 50
Peat conserve II - grass		8885	1328	1214	181	140 to 220
Extended Area						
total	23,996	ha				
multiplier	3.28					

Under the *Peatland Restoration Scenario*, the entire Target Areas are converted to wet fen and peat forming vegetation. Farming is not commercially viable. Some stock may be grazed to assist in habitat management biodiversity, probably at a net cost of about £50/ha. Thus, under this *Peatland Restoration* Scenario, the net cost is the loss of annual net margin from continued farming, which could either be about £190/ha or £165/ha, depending on whether the current land use or further degraded peat is taken as the counterfactual. For the most productive areas, that include potato and horticultural production net margin losses may be £800 - £1000 /ha.

The *Peatland Conservation I Scenario* involves the universal adoption of wet grassland in accordance with local BAP priorities. This would extend the areas covered by high level stewardship arrangements and other management agreements that are common in the Somerset Levels and Moors. Stocking rates assume about 0.5 grazing livestock units per ha or less mainly for suckler cows and fat cattle, and some sheep. Gross output declines to about 20% of its current level for the Target Areas, generating about £300/ha and a breakeven net margin, ranging from about £-50 to £50 depending on type of stock and stocking rates. This option would deliver regional BAP targets and retain a farming presence in the landscape. It would require agri-environment payments to make it commercially attractive to farmers.

The Peatland Conservation II two scenario involves the conservation of remaining peats under a moderately intensive grassland regime, converting arable to grassland and limiting nitrogen applications as part of management agreements (to range between 25 and 150kgN), and involving adoption of peatland conservation practices. This would support a dairy, beef and sheep regime, and potentially develop a market for regionally branded products. Targeted environmental payments would reward farmers for specific environmental outcomes such as the management of water course habitats. Under this scenario, gross output is about 90% of current 2010 levels. At about £1200/ha gross output, with net margins of about £181 /ha, assuming that dairy account for about 30% of total livestock units, falling to about £20/ha in their absence. It is perceived that this system could deliver a range of environmental benefits, although measures would be required to control the potential environmental burdens associated with livestock production.

Overall, the net cost to farming of taking land out of production in the Somerset Moors levels is about £160/ha per year on average over the whole area, and about £800-£1000/ha on land with intensive vegetable cropping. As with other peat areas, however, the arable peat soils in the Somerset are vulnerable to further degradation, with reduced suitability for high value cropping and need of additional drainage investment, particularly where they overlay heavy clays.

4.1.4 Peatlands in the Lyth Valley

The analysis of peatland options on the Target Areas of the Lyth Valley (Table 4.4) reflects its predominantly grassland landscape, with over 90% of the area supporting dairy, beef and sheep production. The Target Areas contain 603 ha of peatland, but potentially extend to a total of 1,284 ha. With respect to the *Baseline Continued Agriculture Scenario*, average net margins are currently about £230/ha. Complete degradation of arable peat soils, currently about 7% of the area (mainly comprising cereals and forage maize), would probably reduce net margins by about £50-60/ha on those areas affected.

Table 4.4: Agricultural Gross Output and Net Margins by Scenario for the Lyth Valley

		Gross Output	Net Margin	Gross Output	Net Margin	Range
		£'000	£'000	£/ha	£/ha	+/- £/ha
Lyth						
Target Areas	603	ha				
Baseline continuation		1,084	138	1797	229	150 to 300
Degraded arable peats		1057	136	1715	226	150 to 300
Peat restore		30	-15	50	-25	0 to -50
Peat conserve I -wet grass		181	1	300	2	-50 to 50
Peat conserve II - grass		892	127	1478	211	140 to 220
Extended Area						
total	1284	ha				
multiplier	2.13					

Under the *Peatland Restoration Scenario*, the entire Target Areas are converted to wet fen and peat forming vegetation. Farming is not commercially viable. Some stock may be grazed to assist in habitat management biodiversity, probably at a net cost of about £25/ha. Thus, under this *Peatland Restoration* Scenario, the net cost is the loss of annual net margin from continued farming, which could be about £250/ha.

The *Peatland Conservation I Scenario* would extend the areas covered by Higher Level Environmental Stewardship arrangements and other management agreements, some of which are evident in the area. Stocking rates assume about 0.5 grazing livestock units per ha or less. It is assumed that milk cows would not occupy these wet grasslands. Gross output declines to about 20% of its current level for the Target Areas, generating about £300/ha and a breakeven net margin, ranging from about £-50 to £50/ha. This option would achieve regional BAP targets and retain a farming presence in the landscape. It would require agri-environment payments to make it commercially attractive to farmers.

The *Peatland Conservation II* two scenario involves the conservation of remaining peats under a moderately intensive grassland regime, converting arable areas to grassland, limiting nitrogen applications as part of management agreements (to range between 25 and 150kgN) and requiring the adoption of peatland conservation practices, including seasonal water level management. This would continue to support a support a dairy, beef and sheep regime, and, as for Somerset, has potential develop regionally branded products. Targeted environmental payments would reward farmers for specific environmental outcomes such as the management of water course habitats. Under this scenario, gross output is about 90% of current 2010 levels, with net margins of about £210/ha, assuming that dairy accounts for about 30% of total livestock units, falling to about £80/ha in their absence. As for the Somerset case, this system could deliver a range of environmental benefits, although specific measures and expenditure would be needed to control the potential environmental burdens associated with dairy and livestock production.

Over all, the net cost to farming of taking land out of production in the Lyth Valley levels is about £230/ha per year on average. Adopting semi-intensive grassland management could achieve a balance of farming and environmental objectives, including the conservation of peats soil.

4.2 Summary of the Financial Implications of Land Use Change in Peatlands

The foregoing analysis suggests that taking arable land out of production involves a loss of net margin, that is value-added, of about £380 - £440/ha year given typical cropping patterns at the landscape scale. There would be a net loss of about £1000-£1300/ha on the most intensively farmed areas where vegetable and salad cropping approach 60% of the area. (All these estimates exclude land charges (rents and mortgages) and exclude receipts under the Single Payment Scheme which can be about £200/ha on eligible land).

In predominantly grassland areas, the restoration of peatland to wet fen or other peat forming habitats would result in loss of net margin of around between £170 -220/ha, higher where there is a greater incidence of dairying. There is generally a high degree of uncertainty about these estimates because (i) there is much variation between years and between individual farms and (ii) they are broad estimates based on high level sample survey data. A plus/minus 25%-30% range can be expected in these estimates.

Degradation of arable peats removes their comparative advantage for potatoes and vegetable cropping, and depending on the underlying soil conditions, continued arable cropping will probably just about breakeven at current commodity prices. Investments in field and possible arterial drainage would be needed to retain their potential for arable, mainly cereal and sugar beet, production.

The restoration of peatlands to wet grasslands, with very low stocking rates, would probably fail to breakeven and would require continued supplementary payments to retain farmer interest. Semi intensive grassland farming, with moderate levels of chemical and organic fertiliser, could offer a commercially feasible peatland 'conservation and carbon storage' option, especially in dairy areas, with modest returns of £50- £200/ha. This would require high standards of management in order to meet environmental objectives.

4.3 Economic Implications of Land Use Change in Peatlands

While the foregoing analysis considers impact of land use change on the financial value of output value–added from a financial perspective, viewed through the eyes of farmers, the implications for the national economy could be different. Defra advises two possible approaches to economic assessment for assessing changes in land use associated with flood defence investments that have relevance here. One involves displacements, the other complete land loss.

4.3.1 Displacement effects

Regarding displacement, it is likely, in the event of curtailing arable production on peats, that high value crops such as potatoes, vegetables and salad crops would relocate to other areas and soils. Indeed this has been happening for some time as peatlands, especially in the Fens, have deteriorated. These crops have moved onto lighter more manageable soils, usually requiring overhead irrigation. The same farm businesses are often involved, through either land purchase or contract farming, using established production and marketing capabilities. This relocation of high value crops usually involves the displacement of wheat. Similarly, subject to changing market conditions, a reduction in milk output would also be made up by production elsewhere

Thus from an economic perspective the net loss could be expressed in terms of loss of value added from wheat production, plus any additional costs of relocation, such as investments in production or marketing infrastructure, such as drainage, irrigation and storage. At current average yields (8.8t/ha and prices at £110/t), net margins on winter wheat are about £20/ha, rising to £100/ha if prices strengthen to £120/t. Therefore, a very approximate estimate of economic cost associated with displacement of crops from peatlands is £50-£100/ha, plus additional costs of production infrastructure (such as irrigation installations and crop storage) at about £100/ha/year. Thus, an 'economic' assessment of displacement gives about £200/ha/year [74].

4.3.2. Land Lost from Agriculture

Where land is completely lost from agriculture, the prevailing market prices for agricultural land can in theory reflect the present value of future value-added from farming that are foregone. Based on Defra guidance, representative prices for land grade, adjusted to remove the effect of farm payment subsidies, suggest an equivalent annual value of between £520

[74] This approach is used by Defra in the appraisal of flood risk management investments

and £590/ha (at 3.5% discount rate over 50 years) (Table 4.5). This probably overestimates the current profitability of all but the most intensively farmed land. It may however reflect the value of farm land at the margin to farms that can achieve economies of scale by increasing farm size through land acquisition. Thus, using this method, the lost of value-added from agricultural land used for peat restoration is equivalent to about £550/ha /year.

Table 4.5: Estimated Value of Land Loss from Agriculture based on ALC Grade and Market Prices

ALC Grade	Value £/ha	Less SP adjust-ment	Net £/ha	Fens	Humber head	Somerset	Lyth
1	15,000	600	14,400	49%	1%	1%	0%
2	15,000	600	14,400	34%	39%	52%	0%
3	13,500	600	12,900	8%	27%	22%	87%
4	12,000	500	11,500	6%	8%	25%	11%
5	8,250	300	7,950	3%	25%	0%	2%
Average £/ha				13900	12200	13400	12700
Equivalent Average Annual Value: £/ha at 3.5 % over 50 Years				594	521	573	543

Based on Defra/Valuation Office/RICS Sources

4.4 The contribution of the Peatland Target Areas to food production and food security

Peat soils make an important contribution to agricultural production, especially regarding to high value crops (Table 4.6). The Target Areas identified here of 66,500 ha account for about for about 0.5% of the mainly lowland crop and grassland areas (12.1 million ha, excluding rough grazing) and about 0.9% the value of total production. They account for around 3% of each of the total national areas of sugar beet area, potatoes and vegetables grown in the open, and about 0.7% of the national fruit growing area. The Fens Target Area alone accounts for about 80% of these contributions. These estimates are not to be confused with the larger peatland study areas of which the Target Areas are part. The total Fenland peat area for example, including now degraded peatlands of over 133,000 ha, probably accounts for about 10% of the national areas given to potatoes, sugar beet and vegetables[75].

As discussed earlier, it is probable that the withdrawal of peat land from agricultural production would involve some relocation of high value crops elsewhere, displacing wheat in the process. The Target Areas comprise about 65 % arable land and about 15% dairy grassland, about 53,200 ha, equivalent to about 3% of the UK wheat area. Hence a similar proportion of wheat output could be lost or displaced, equivalent to about 460,000 tonnes per year, about £50 million at replacement cost per year.

[75] According to NFU (2008), using Defra Statistics, the total East Anglian Fenland area of over 500,000 ha (including all soils), produces about 37%, 24% and 17% respectively of England's area of vegetables grown in the open, potatoes and bulbs and flowers.

Table 4.6: Agricultural Production for the UK (2007-9) and Peatland Target Areas

Proportion of national production: UK - Peatlands in Target Areas average values for 2007-09: Target Areas

	UK National			**Percentages of national output by Target Areas**												**Totals for Target Areas**		
	area	prod	value	**Fens**			**Humberhead**			**Lyth**			**Somerset**			All		
Ouputs	ha	tonnes 000	000£	area	prod	value	area	prod	value	area	prod	value	area	prod	value	area	prod	value
Wheat	1,908,000	14,942	1,719,707	0.80%	0.85%	0.88%	0.15%	0.16%	0.16%	0.00%	0.00%	0.00%	0.16%	0.15%	0.16%	1.1%	1.2%	1.2%
Barley	1,030,000	5,997	686,410	0.20%	0.20%	0.17%	0.03%	0.03%	0.02%	0.00%	0.00%	0.00%	0.06%	0.06%	0.05%	0.3%	0.3%	0.2%
Oil Seed Rape	620,341	2,011	506,081	0.42%	0.46%	0.43%	0.04%	0.05%	0.04%	0.00%	0.00%	0.00%	0.08%	0.08%	0.08%	0.5%	0.6%	0.6%
Peas for harvesting dry	25,000	102	14,000	3.66%	3.50%	3.82%	0.70%	0.67%	0.73%	0.00%	0.00%	0.00%	0.72%	0.66%	0.72%	5.1%	4.8%	5.3%
Field beans	144,000	541	75,000	0.64%	0.68%	0.68%	0.21%	0.22%	0.23%	0.00%	0.00%	0.00%	0.13%	0.13%	0.13%	1.0%	1.0%	1.0%
Sugar Beet	121,000	7,568	204,000	2.76%	2.56%	2.76%	0.61%	0.57%	0.61%	0.01%	0.00%	0.00%	1.18%	0.68%	0.63%	4.6%	3.8%	4.0%
Potatoes	144,211	6,044	698,568	1.77%	2.20%	2.66%	0.36%	0.45%	0.55%	0.00%	0.00%	0.00%	0.03%	0.03%	0.03%	2.2%	2.7%	3.2%
Fresh veg grown in open	120,000	2,551	1,075,000	1.39%	2.62%	1.75%	0.28%	0.53%	0.28%	0.00%	0.00%	0.00%	0.03%	0.05%	0.02%	1.7%	3.2%	2.1%
Hortic	170,000		2,441,000	1.24%		1.62%	0.24%		0.31%	0.00%		0.00%	0.08%		0.09%	1.6%	0.0%	2.0%
Fresh fruit	28,000	410	528,000	0.23%	0.46%	0.21%	0.04%	0.09%	0.04%	0.00%	0.00%	0.00%	0.33%	0.62%	0.29%	0.6%	1.2%	0.5%
Other non food	85,711		1,108,000	0.15%			0.03%			0.00%			0.01%			0.2%	0.0%	0.0%
Total crops	4,623,000		6,781,800	0.68%		1.19%	0.13%		0.23%	0.00%		0.00%	0.13%		0.12%	0.9%	0.0%	1.5%
Total Grass	11,506,000			0.03%			0.00%			0.01%			0.15%			0.2%	0.0%	0.0%
milk production			3,128,000			0.01%			0.01%			0.04%			0.41%			0.5%
meat production			5,138,000			0.05%			0.01%			0.02%			0.26%			0.3%
Total dairy and livestock			8,266,000			0.03%			0.01%			0.03%			0.32%			0.4%
Total Agriculture	12,100,000		14,996,700	0.29%		0.56%	0.05%		0.11%	0.01%		0.02%	0.20%		0.23%	0.5%		0.9%

hortic and fruit value lifted by 1.5 to allow for wholesale market: farm gate prices for national valuation

field veg adjusted by same uplift factor, area: value, as potatoes

Notes:

1 The areas, yields and values for the UK are an average taken from years 2007; 2008; 2009

2 Wheat and barley are figures for both winter and spring varieties

3 value of production is at market prices basis, as quoted in Agriculture in the UK, hortic and veg prices adjusted for market - farm gate price differences

4 Peas for harvesting dry and field beans are for stockfeeding

5 Field vegetables use the classification in Agric UK. It includes, cabbages, cauliflowers, carrots, lettuces, mushrooms, peas and tomatoes

6 Potatoes includes early and maincrop

7 Horticulture includes other field vegetables (seee note 5), plants and flowers, orchard fruit & soft fruit

8 Non-food crops include bulbs and nursery items

9 Fruit includes Orchard fruits (including non-commercial orchards) and soft fruit

10 Meat production includes cattle and calves, pig meat, sheep meat, poultry meat

11 Total crops includes all arable crops and also includes oats, rye, fibre crops, linseed and hops

12 Total grass includes temporary grass, permanent grass and rough grazing

The withdrawal of the Target Areas in the four study areas would probably not have a major impact on UK national food supply and food security. It is likely that the production of high value cropping would be for the most part made good by substitution of cropping elsewhere. Furthermore, the comparative advantage of peat soils for high value cropping is being lost over time as they are degraded. In response, the production of vegetable and salad crops has, according to farmers, moved to mineral soils supported by irrigation. Although the area of production of these crops has declined in total, the relocation of cropping is evident in the significant increase in abstraction licences for sprinkler irrigation on mineral soils[76].

Although the scale of the peatland restoration considered here would probably not make a major impact on total food production now, projections for global food demand and supply suggest that that food security might become more critical in 30 to 50 years time. In this respect, peatland strategies could give more priority to maintaining capacity for future food production and less to meeting current food needs (because they can be met by other means).

Thus, future food security could be enhanced by conserving agricultural peatlands, taking them out of agricultural production now, or farming them extensively, so that they can be returned to agricultural production should the need arise. Thus a conservation strategy would include an option (and an option value) for future ‘agricultural reclamation’. The peatland scenarios identified above have potential to do this to varying degrees.

Maintaining the reclamation option will however require that (i) reclamation potential is ‘engineered’ into restoration projects, (ii) critical drainage and flood defence infrastructure is maintained, (iii) knowledge and skills in the agricultural management of peatlands are maintained and (iv) restoration projects of any significant scale include a ‘food security’ response strategy. Building in an option value for retaining the agricultural potential peatlands could increase the cost of peatland restoration, but it should help to balance some of the arguments round the ecological restoration - food security debate. It is also likely encourage the development of the sustainable management of peatland farming.

4.5 Ecosystems Services from Peatlands under different Scenarios

Peatlands provide a range of environmental benefits, often referred to as ‘ecosystem services’, in addition to agricultural outputs. These vary in accordance with the use of peatlands. Generally, there is a trade off between their use for agricultural production and the generation of other beneficial services or environmental costs.

Two approaches were used to derive estimates of the environmental effects and outcomes of the scenarios. One worked from first principles using unit rates for estimating selected emissions, valued at standard rates. The second used a benefit transfer model using data on characteristics of the Target Areas. These approaches and their results are discussed in turn.

[76] Personal communication, Dr Keith Weatherhead, Cranfield University

4.5.1 Environmental Emissions of Peatland Scenarios

Data on environmental emissions associated with different crops and livestock systems were derived from lifecycle analysis[77]. Emission values per unit output (tonnes of crop and livestock products) were produced and expressed per ha according to crop yields and stocking rates. The rates of emission of soil carbon and other greenhouse gases from peatlands according to their condition and use was taken from Natural England[78]. Emission outputs were derived for each of the peatland scenarios in the Target Areas.

Emission quantities eg GHG (CO_2te) and acidification potential, were produced and then multiplied by unit values from published sources (Table 4.7). Carbon was valued as at 2010 price of £52/t CO_2e for non-traded carbon in accordance with DECC guidance 2010[79]. Research literature was used to value the non-market cultural services of peatlands under different land uses, as reviewed in Appendix 4, namely general farm land £90/ha/year, forest woodland £145/ha/year and SSSI wetland £770/ha /year. These proportions were applied to land under different categories of use under each of the scenarios.

Table 4.7. Valuation data used for analysis of selected non-market ecosystem costs and benefits *

Economic data:		
GHG value	£52	£/t CO_2
Ammonia	£1,840	£/t
Nox	£837	£/t
VOCs	£1,564	£/t
Sulphur Dioxide	£1,452	£/t
Cultural value: non SSSI	£90	£/ha
Cultural value: forest/woodland	£145	£/ha
Cultural value: SSSI	£773	£/ha

*emissions values based on Williams et al, 2008; cultural values from various sources reported in Jacobs et al, 2008[80])

The annual per hectare GHG flux (t CO_2e) from different types of peatland under different types of land use were taken from data reviewed by Natural England[81]. These values are shown in Table 4.8.

[77] Williams et al, 2006. opcit

[78] Natural England, 2010, opcit

[79] Department for Energy and Climate Change (DECC). (2010) Department of Energy and Climate Change. Carbon Valuation. http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/valuation/valuation.aspx (Accessed 10/08/2010)

[80] See Table 3 Appendix 4

[81] Natural England, 2010, opcit

Table 4.8. The GHG emission (t CO_2e) from different peatland types under different land uses (Source: Natural England)

	Blanket Bog/Raised bog	Fen peatland deep	Fen peatlands wasted
Cultivated & temporary grass	22.42	26.17	4.85
Improved grassland	8.68	20.58	
Afforested	2.49	2.49	
Restored	2.78	4.20	
Undamaged	-4.11	4.20	

The annual fluxes in each of the regional study areas was up-scaled from the data in Table 4.7 and Table 4.8 assuming that different proportions of land use would occur under each scenario. Allowance is also made for the different proportions of deep and wasted peat in each area. The proportional representation of each land use type on each peatland type in each regional area for each scenario is shown in Table 4.9.

Table 4.9. The proportion of land under each type of land use assumed for each scenario in each regional study area

		East Anglian Fens			Lyth Valley			Somerset Levels			Humberhead Levels		
		Blanket Bog/Raised bog	Fen peatland deep	Fen peatlands wasted	Blanket Bog/Raised bog	Fen peatland deep	Fen peatlands wasted	Blanket Bog/Raised bog	Fen peatland deep	Fen peatlands wasted	Blanket Bog/Raised bog	Fen peatland deep	Fen peatlands wasted
BAU	Cultivated & temporary grass	88%	88%	88%	6%	6%	6%	25%	25%	25%	92%	92%	92%
	Improved grassland	5%	5%	5%	84%	84%	84%	50%	50%	50%	5%	5%	5%
	Afforested	2%	2%	2%	0%	0%	0%	0%	0%	0%	1%	1%	1%
	Restored	5%	5%	5%	10%	10%	10%	25%	25%	25%	2%	2%	2%
	Undamaged	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Arable degradation	Cultivated & temporary grass	88%	88%	88%	6%	6%	6%	25%	25%	25%	92%	92%	92%
	Improved grassland	5%	5%	5%	84%	84%	84%	50%	50%	50%	5%	5%	5%
	Afforested	2%	2%	2%	0%	0%	0%	0%	0%	0%	1%	1%	1%
	Restored	5%	5%	5%	10%	10%	10%	25%	25%	25%	2%	2%	2%
	Undamaged	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Improved grassland	Cultivated & temporary grass	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Improved grassland	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
	Afforested	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Restored	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
	Undamaged	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Wet grassland	Cultivated & temporary grass	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Improved grassland	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Afforested	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Restored	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Undamaged	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Peat restoration	Cultivated & temporary grass	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Improved grassland	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Afforested	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Restored	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Undamaged	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

The resulting £/hectare/year values of selected environmental effects are given in Table 4.10. They are associated with loss of soil carbon, 'land system' emissions of GHG and acidification effects (ammonia and sulphur) and the provision of cultural services, vary according to peatland scenario (). It is noted that these are indicative per hectare values for the target areas for assumptions made. They cannot be generally applied to a specific restoration proposal unless the assumptions can be shown to be valid.

The *Baseline scenario*, with ongoing peatland degradation, produces a net negative value for selected ecosystem services of -£569/ha/year, an overall environmental cost (Table 4.10). Here, the costs of loss of soil carbon (-£441) and costs of emissions from farming (-£250) exceed the cultural benefits of existing land use (+£122).

Degraded arable peatland generates a net annual cost of -£289/ha assuming carbon losses are low once peats are fully degraded. Improved grassland generates an overall net ecosystem cost of -£354/ha. Restoration of peatland generates a net benefit of £994/ha attributable mainly to net carbon sequestration and cultural benefits. It is assumed here that 'restored' peat forming soils under 'no agriculture' land use exhibit similar net carbon absorption rates as undamaged blanket/raised bogs[82], although this may be optimistic. Conservation of peatlands using extensive grassland systems is estimated to generate a positive ecosystem benefit of +£614/ha in the Fens, mainly due to the assumption that cultural services, relating to biodiversity, landscape and access to the countryside, generate about £770/ha/year

The lower part of Table 4.8 shows the incremental effects of land use change from the current situation. The restoration of peatlands to peat forming vegetation could generate selected ecosystem benefits of around £1500/ to £1900 ha/year compared to the Baseline of continued agricultural production. A switch to extensive grassland systems under restored peatlands appears to produce net environmental gains of about £1,000/ha compared to the Baseline case for the assumptions made, excluding, for the moment, the value of agricultural production.

These estimates are indicative and must be treated cautiously. They could range by over +/- 50%-75% according to assumptions regarding carbon emissions rates and values, and local variation in the value of cultural services.

[82] For the purpose here, this is assumed to be -4.11tCO_2e/ha x £52/tCO_2e ,(Table 4.8) for fully restored peat forming vegetation not used for agriculture. This represents an ultimate scenario for full peat restoration and peat forming vegetation It is noted that restored fenland peats may not be suitable for achieving this degree of peat formation and continue to exhibit positive net carbon emissions.
The study areas currently contain varying amounts of blanket/ raised bogs as a proportion of the total peatland areas (Appendix Tables A6.9 to A6.13) as follows: Humberhead 25%, Lyth 21%, Somerset 13%, Fens 3%.

Table 4.10: Per hectare non-market value of selected ecosystem costs and benefits associated with changing land use in the Study Areas

	Fenland	Fenland	Lyth	Somerset	Humberhead
Baseline					
	GHG fluxes (£ /ha)	-441	-110	-592	-803
	Agric. emissions (£/ ha)	-250	-509	-416	-259
	Cultural services benefits (£/ ha)	122	158	261	103
	Net value (£/ha)	-569	-461	-748	-959
Degraded arable peats	GHG cost (£ /ha)	-222	-15	-63	-232
	Agric. emissions (£/ ha)	-205	-508	-414	-218
	Cultural services benefits (£/ ha)	138	158	261	110
	Net value (£/ha)	-289	-365	-216	-339
Peat restore	GHG cost (£ /ha)	214	214	214	214
	Agric. emissions (£/ ha)	-7	-7	-7	-7
	Cultural services benefits (£/ ha)	773	773	773	773
	Net value (£/ha)	980	980	980	980
Peat Conserve I Wet Grass	GHG cost (£ /ha)	-45	-30	-137	-108
	Agric. emissions (£/ ha)	-115	-113	-562	-113
	Cultural services benefits (£/ ha)	773	773	773	773
	Net value (£/ha)	613	630	74	552
Peat Conserve II Improved grass	GHG cost (£ /ha)	-185	-82	-531	-391
	Agric. emissions (£/ ha)	-396	-427	-377	-409
	Cultural services benefits (£/ ha)	227	227	227	227
	Net value (£/ha)	-354	-283	-681	-574
Relative differences					
Baseline-Degrad arable	Net value (£/ha)	279	95	532	620
Baseline – Peat restore	Net value (£/ha)	1,549	1,441	1,728	1,939
Baseline-Wet grass	Net value (£/ha)	1,181	1,091	822	1,511
Baseline-Improved grass	Net value (£/ha)	215	178	67	385

4.5.2 Values for combined agricultural and (selected) environmental outcomes for Scenarios.

The values from the assessment of agricultural production and environmental emissions can be combined to show the net effect of the land use scenarios (Table 4.11). For the assumptions made, continuing agricultural production results in a net cost (-£200 to -£500/ha), mainly due the impact of GHG related emissions associated with loss of soil carbon. Once degraded, carbon emissions are lower, but so is agricultural productivity:

arable net costs are about -£250/ha compared to (mainly) grassland net costs at -£100/ha. Peat restoration to peat forming vegetation generates a net benefit of about £950/ha/year, due to a combination of carbon sequestration and cultural benefits. Wet grassland has potential to deliver substantial environmental benefits , for the assumptions made, but net margins from agriculture are small and probably negative, requiring (and justifying) agri-environment payments to deliver some of habitat and landscape outcomes. Combined net margins are about +£500/ha. Here farming is mainly providing environmental benefits, including carbon storage. Semi intensive grassland farming has potential to achieve modest to moderate farm incomes, but environmental emissions associated with livestock farming are relatively high, and net cost is about -£500/ha

Table 4.11. Summary of Agricultural and Selected Environmental Outcomes by Scenario and Target Areas

	Fens	Humberhead	Somerset	Lyth
	£/ha	£/ha	£/ha	£/ha
Baseline -Continued Agric Production				
Agricultural Net margin*	360	418	164	229
Environmental Net margin**	-569	-959	-748	-461
Combined net margin	-209	-541	-584	-232
Degraded Arable Peats				
Agricultural Net margin*	5	7	141	226
Environmental Net margin**	-289	-218	-216	-365
Combined net margin	-284	-211	-75	-139
Peat Restoration – fen/bog				
Agricultural Net margin*	-25	-25	-25	-25
Environmental Net margin**	980	980	980	980
Combined net margin	+955	+955	+955	+955
Peat conservation I- Wet grass				
Agricultural Net margin*	-15	4	5	2
Environmental Net margin**	613	552	174	630
Combined net margin	598	556	179	632
Peat conservation II- Semi intensive grass				
Agricultural Net margin*	10	63	181	211
Environmental Net margin**	-354	-574	-681	-283
Combined net margin	-344	-511	-500	-72

- Net margins from financial analysis, Tables 4.1 to 4.4. ** from Table 4.8

There is considerable uncertainty in these estimates such that they must be treated cautiously as indicative values about which there is considerable variation, at least of the order of 25% -

100%. There is uncertainty, for example, about the net carbon sequestration potential of fully restored peatlands, especially in fenland areas. The estimates are also not complete. They exclude other environmental costs and benefits associated with diffuse pollution to water and contribution to flood control respectively. The magnitude of these environmental effects, both positive and negative, are likely to vary considerably according to local conditions, such that generalised estimates are difficult and potentially misleading without more detailed assessment, for example of potential flood damage costs. The estimates also do not include costs at the landscape scale, such as the capital and operating costs of land drainage and flood protection, nor of the effects of options on related industries and the local economy. These are likely to vary between scenarios.

The analysis here presents indicative per hectare values of agricultural and environmental benefits and costs for peatland management scenarios in their steady state, that is for a representative year at full development. It does not consider aggregate values over the period of transition from the present to a possible future scenario. This would require data on likely rates of change for given peatland conditions (including current peat depths) that are currently not available. It would be appropriate, however, to build on the estimates here to explore the effect of rates of degradation over time on the annual flows of agricultural and environmental benefits and costs, thereby deriving estimates of the relative net present values of alternative peatland scenarios.

The estimates derived here do however indicate the potential scope for reconciling agricultural and environmental objectives in peatlands. It is noted that conventional agricultural production systems generally results in an overall negative environmental burden[83]. Conserving remaining peatlands could prove economically more efficient given that continued use generates relatively high environmental burdens compared to other farmed areas.

4.5.3 Benefit Transfer Estimates of the Economic Value of Restored Wet Peatlands

Because of the expense of carrying out site specific valuation studies, the 'Meta-analyses' of previously developed data sets has been developed to provide generic estimates of benefits that can be 'transferred' to previously un-surveyed sites[84].

The approach developed by Brander et al. (2008)[85] has been used here to estimate the value of the restoration of peatlands for Target Areas in the Target Areas The methods uses a statistical regression function that is based on 294 studies of European wetland sites, including inland marshes and peat bogs.

[83] Jacobs et al, 2008. Environmental Accounts for Agriculture.

[84] Eftec, 2010. Valuing Environmental Impacts: Practical Guidelines for the Use of Value Transfer in Policy and Project Appraisal. Case Study 3 – Valuing Environmental Benefits of a Flood Risk Management Scheme for Department for Environment, Food and Rural Affairs February 2010. Eftec , London

[85] Brander, L.M., Ghermandi, A., Kuik, O., Markandya, A., Nunes, P.A.L.D., Schaafsma and M., Wagtendonk, A. (2008) „Scaling up ecosystem services values: methodology, applicability and a case study. Final Report, EEA May 2008.

Data are fed into the function regarding the type of wetland site and its size, as well as the presence, yes or no, of particular user and non-user services delivered by the wet site, such as contribution to water quality and supply, flood control, recreational activities, materials supply, biodiversity and landscape. The estimates are weighted by the size and relative prosperity of the population within a 50km radius of the site. Allowance is also made for the presence of substitute sites within a 50km radius – the more substitutes there are, the less is the likely value of any one site. The methods and results are given in Appendix 5.

Table 4.12 summarises the estimates of average value per ha for restored wet peatlands in the Target Areas. The values are much higher for inland marshes compared to peat bogs that tend to be more isolated and less diverse in their services, at least in a broader European context.

It is clear from the analysis that values are highest where large populations of 'users' can benefit from the site, especially associated with recreation and amenity (Table 4.10). Furthermore, flood control, water quality and biodiversity are major sources of potential benefit. On these designated sites, it is assumed that there is limited extraction of materials (including energy cropping of peats) and limited gaming of wildlife that would tend to compromise conservation objectives, other services and depress overall values.

Table 4.10: Estimates of the values of services from restored peatlands in selected Target Areas using the Brander et al, 2008 Benefit Transfer model.

	Area of TA (ha)	Average value £/ha/year	Aggregate average value £million/year
The Great Fen	3,594	502-2,184	1.8-7.8
Humberhead	673	1,203-5,233	0.8-3.5
Somerset1 (Middle Parret Floodplain)	6,877	329-1,430	2.2-9.9
Lyth Valley (TA inside the peat)	610	437-1,901	0.2 -1.1

The range of estimates reflect restoration either as peat forming wetlands (indicated by the lower value), or as inland grazing marshes (indicated by the higher value). Target Areas have potential to deliver a mix of these habitats.

These estimates, with average values of about £500-£2000 /ha and about £1000- £5,000 /ha for marginal values for selected ecosystem services, must be treated with considerable caution, not least because of reservations about whether the English case can be reliably represented using data mainly from other European countries. They are however positive and substantial and support the argument that restored peatlands can add significant value. It is noted that the estimates here do not include GHG emissions, which, at an estimated cost of between £100 and £800/ha/year for the study sites, adds further benefit.

5 Conclusions and Recommendations

The study aimed to assess the implications for agricultural production, food security and selected ecosystems services of the large scale restoration of lowland peat areas in England, interpreting the findings for policy. Conclusions are drawn with respect to each of the study objectives, which to an extent are overlapping. The conclusions must be treated with caution, being based on high level assessments and many simplifying assumptions. All numerical estimates must be regarded as indicative: any single estimate implies a robustness that is not well founded. In reality, there is considerable variation and uncertainty.

Objective 1: What are the range of different farming practices and their costs and benefits particularly regarding food production and the environment?

There are two main types of peatlands in lowland England: raised bogs and fen/marsh peatlands. According to Natural England, about two thirds of the 325,000 ha of lowland peatlands in England are now classed as wasted, mainly due to agricultural activities.

The use of peatlands for agriculture inevitably leads to their degradation, most rapidly where they are cultivated for arable cropping. Grassland farming can 'conserve' existing peats because they are wetter and less disturbed than arable peats, but the removal of vegetation for animal feeding prevents the formation of new peat soils. Hence peat formation implies non-agricultural use.

Peatlands have been 'reclaimed' for agriculture over many years, often supported by public investments in arterial drainage and pumping schemes. Where drainage standards are high, peatlands are often classed as Grade 1 or 2 Agricultural Land, reflecting their potential for high value cropping.

Four study areas were identified as a basis for exploring the consequences of modifying land use for peatland conservation and restoration. These comprise areas in The East Anglian Fens, The Humberhead Levels, The Somerset Moors and Levels and The Lyth Valley. Within these broad study areas, Target Areas for restoration of wetland habitats under the Wetland Vision were identified. These Target Areas and adjacent peatland areas are occupied by intensive arable production in the case of the Fens and Humberhead, and by mainly grassland production for dairy and fatstock in the case of Somerset and the Lyth Valley.

A review of the financial performance of farms showed that profitability of farming on arable peatlands tends to be highest under intensive cropping of potatoes, vegetables and salad crops, and, on grassland peatlands, for dairy farming. There is considerable evidence in the Target Areas, not contested by farmers, that arable production inevitably results in the degradation and eventual 'wasting' of peat soils. Appropriate soil and water management can slow down but not halt this process.

Under current land use on peatlands in the Target Areas, arable net margins, that is value-added, range between about £360-£420/ha year for typical cropping patterns on remaining deep peats. This can be about £1000-£1300/ha where vegetable and salad cropping approach 60% of the cropped area. In predominantly grassland areas, net margins of around between £170 -220/ha are achieved, higher where there is a greater incidence of dairying. These estimated margins excluding charges for land and revenue from annual single farm payments on eligible land (which can be about £200/ha).

Provisional estimates of the environmental costs associated with land in the Target Areas suggest environmental costs of between £450 and £950/ha/year, depending on the amount of carbon released from arable peats and the emissions from farming systems themselves.

Current prices for agricultural land in the Target Areas of about £15,000/ha provide an indication of the perceived profitability of investment in land for farming. This is equivalent to about £550/ha/year. This provides a market-based measure of the value of land retained in farming, although it is noted that many factors influence the price of farm land other than its production potential.

Objective 2: What are the likely scenarios for change in peatland management?

A number of scenarios for peatland management were explored that differed in terms of land use and the managed of water regimes, notably flooding and ground water table levels. The analysis assumes scenarios are in their steady state at full development.

Continued Agricultural Production, involving intensive drainage and cultivation of peat soils, will in the case of arable farming, result in their eventual loss. Current rates of peat depletion are reportedly between 10 mm and 30 mm per year, suggesting a remaining life in many areas of between 25 and 50 years. In a degraded state, depending on underlying soils, cropping would be limited to mainly cereal-based arable farming with low and possibly negative returns. Remedial investments in land drainage of £2,500 to £3000/ha would probably not prove financially viable. High value cropping is likely to relocate onto nearby mineral soils supported by irrigation, utilising existing regional capacity in production and marketing expertise, networks and infrastructure. For the most part, this relocation would probably result in the displacement of wheat production.

The combined agricultural and (partial) environmental effects of continuing agricultural production in the Target Areas gives an estimated net annual cost of between -£200 and -£500/ha, mainly due the impact of GHG related emissions associated with loss of soil carbon on arable land. Once peats have been degraded, environmental impacts are subsequently reduced, but so are the benefits from agriculture.

Peatland Restoration to peat forming vegetation, with permanently high ground water levels and surface flooding would exclude agriculture (other than limited cattle grazing to help manage habitats) , with loss of net margins from agriculture. Peat restoration generates a net benefit of about £950/ha/year, due to a combination of assumed net carbon sequestration and cultural benefits. Relative to the Baseline Continued Agricultural Production case, this give a net benefit including changes in the value of ecosystem services of around £1500/ha/year in the study sites. For arable land, this 'opportunity cost' of taking land out of agricultural production is likely to reduce over time as peatlands are degraded and become less agriculturally productive. Thus the future degraded condition is the 'counterfactual' against which the restoration option can be compared). As noted above, degraded peatlands have low remaining agricultural value, depending on underlying soils and drainage conditions. In this condition, however, they also have lower environmental value and restoration is more difficult.

Two *Peatland Conservation* scenarios were explored. *Peatland Conservation I involves* extensive livestock grazing on wet grassland in the summer in accordance with BAP priorities, with winter water flooding and high ground water levels for most of the year. It is unlikely to be commercially viable in the absence of financial payments to farmers for environmental services. But the overall combined benefits of farming and peatland conservation could be about £500/ha/year once environmental benefits are taken into account, justifying agri-environment type payments.

Peatland Conservation II involves semi-intensive grazing which attempts to reconcile farming and peatland conservation objectives. Here, flooding and ground water levels are managed to allow silage making and grazing from April to October. These systems could prove commercially viable, especially under dairy farming, and peat soils can be conserved under appropriate management. However, environmental burdens associated with livestock production, such as the risk of pollution to water, and methane and ammonia to atmosphere, could be high.

A broad assessment of ecosystem benefits (including contribution to water quality, flood control, biodiversity and recreation, but excluding carbon storage) was obtained using a benefit transfer model. Average benefits of existing restored sites in the Target Areas of were estimated at between £500 and £2,000/ha/year. While these estimates must be treated cautiously, they appear to be positive, substantial and compare favourably with the financial performance of most farming systems on peatlands.

Objective 3: What impacts would the restoration of agriculturally managed peatlands have on food production and food security in the UK?

Global food shortages in 2006/7 prompted a resurgence of interest in food security and the role of UK agriculture. UK policy on food security currently aims to 'guarantee households access to affordable nutritious food', to be achieved not only by strong domestic production, but also by establishing and maintaining international supply chains. Self sufficiency in food production is not a policy aim, although the Government recognises the importance of UK agriculture's contribution to the national food basket and the need to improve the productivity of farming.

The Target Areas identified here of 66,500 ha account for about for about 0.5% of the mainly lowland crop and grassland areas in the UK (12.1 million ha, excluding rough grazing) and about 0.9% the value of total agricultural production. They account for around 3% of each of the total national areas of sugar beet area, potatoes, vegetables grown in the open and salad crops.

Future population growth in the UK, continuing economic prosperity and greater awareness of food and healthy diets are likely to encourage consumption of vegetables and salad crops currently grown on peatlands, especially those that target niche, quality differentiated markets. While the demand and willingness to pay for these crops is likely to strengthen, domestic producers must compete for markets with importers particularly from Europe. It is important in this respect that producers are required to meet similar environmental and other standards for competition to be fair. Climate change, however, particularly associated with rising temperatures and water deficits, could favour UK producers relative to competitors from the south, although water supply for sub-surface and surface irrigation could be a limitation.

It is likely that withdrawal of peatland from production would lead to the relocation of high value cropping to mineral soils, requiring overhead irrigation instead of the sub-surface irrigation provided by ditches and sluices in most peatlands. There is anecdotal evidence (also indirectly supported by reported increased irrigated cropping on mineral soils) to show that this has happened already as peats have degraded and their comparative advantage has been lost. In the main the process of relocation is likely to displace wheat which is the dominant arable crop. It is not considered that the scale of peatland restoration considered here would threaten national food security.

Proposals to withdraw land from agriculture must take account of the general availability of land. Recent reviews of the demand for and supply of land for agriculture in the UK (and in Europe as a whole) conclude that there appears to be sufficient land to meet likely future needs. Much depends however on assumptions regarding demand for land for non-agricultural purposes, including human settlements and natural habitats, and the productivity of land retained in farming.

The analysis here uses prevailing prices for agricultural commodities, for non-traded carbon (CO_2e), and environmental benefits. A future relative strengthening of agricultural prices would favour agricultural production on peatlands. However, relatively high future carbon prices, as predicted by DECC, will particularly act against land use options for peatlands that generate high levels of carbon release.

Although the scale of the peatland restoration considered here would probably not make a major impact on total food production at the moment, projections for global food demand and supply suggest that that food security might become more critical in 30 to 50 years time. Thus, future food security could be enhanced by conserving agricultural peatlands, taking them out of agricultural production now, or farming them extensively, so that they can be returned to agricultural production should the need arise. Thus a conservation strategy would include an option (and an option value) for future 'agricultural reclamation', possibly including maintenance of critical drainage infrastructure. The peatland scenarios identified above have potential to do this to varying degrees.

Objective 4: In the light of the above, what conclusions can be drawn concerning the impact of restoring agriculturally managed peatlands to peat-forming vegetation?

The conclusions from the above are that the withdrawing peatland from farming could result in a substantial loss of value added from arable cropping, of about £350- £450/ha annually, approaching £1000/ha for the most intensively cropped areas on deep peats (excluding land costs and single farm payments). The cost of withdrawal of peat grasslands would be less, about £150- £250/ha for moderately intensive systems.

The current environmental burdens associated with farming are relatively high, especially for arable farming that results in rapid depletion of soil carbon. Here environmental costs can range between -£500 and -£950/ha. The current land use regimes result in combined agricultural and environmental negative returns of between -£200 and -£500/ha.

For assumptions made, the restoration of peatlands, either without agricultural use or with extensive grazing, could generate net benefits of between £200 and £500/ha. These estimates are sensitive to assumptions about the degree of carbon sequestration by restored peats, and the price of carbon. Extensive livestock farming, supported by payments such as those under the High Level Environmental Stewardship Programme, could achieve a range of environmental outcomes, including carbon storage and biodiversity targets. Farming under these conditions is unlikely to be financially viable. There will be a need for payments to farmers for environmental services.

A high level assessment of environmental benefits of wetlands was derived using a ‘benefit transfer’ model. Average benefits associated with ecosystem services from restored peatlands in the Target Areas probably range between £550 and £2,000/ha, excluding the benefits of stored carbon.

The profitability of continued intensive farming of arable peatlands will decline over time as soils degrade, probably to the point where it is no longer financially viable to farm. Intensive cropping will probably switch elsewhere on to soils that are easier to manage. At this point farmers may be interested in other options for land use, provided that adequate incentives are available. This may include the sale of peatland for restoration, enabling farmers to purchase land elsewhere. (It is noted that in some cases, large tracts of arable peatlands are owned by investment companies and occupied by tenant farmers, for whom relocation may be difficult).

It does not appear that national food security will be threatened by the scale of land taken from agriculture on peatlands identified here. This impact will probably be lessened by the relocation, using an existing skill base, of high value production onto other soils, facilitated in some cases by contract farming. It is assumed that taking land out of agriculture in the Target Areas will not impede agricultural production in adjoining areas, much of which, such as the Fens and Humberhead Levels, are dependent on continued flood defence and land drainage.

For the assumptions made, it seems that taking land out of intensive farming in peatland areas could result in an overall welfare gain. This is because the marginal benefits of retaining these areas in farming (indicated by value added) appear to be less than the marginal environmental costs associated with continued agricultural use (indicated by environmental burdens and the loss of potential benefits from peatlands in a restored condition). Famers would, however, suffer loss of incomes, unless they were compensated in some way, either through land sales/swaps, assistance with relocation, or through payments for environmental services under new land management regimes.

Objective 5: In the light of the above, what recommendations can be made on the benefits and costs of current and (potential) future agricultural management on peatlands?

A number of options can be explored relating to the benefits and costs of agricultural management of lowland peatlands and their restoration.

Identifying the scope and practicability of measures to conserve peatlands in arable usage in order to reduce carbon loss would enable better targeting of management to conserve peat carbon. There is particular scope to achieve peatland conservation under grassland management systems, but this is under-researched.

There is already existing awareness in the farming and food producing communities of the agricultural and environmental limits of arable farming of peatlands, the inevitability of degradation and loss of comparative advantage, and the options for future peatland management. Future activities that reinforce and deepen this awareness would help to ensure that the farming community were fully engaged with any future efforts to promote more sustainable land use in lowland peatland areas.

Detailed assessment of locally relevant farming systems would help to identify opportunities for reconciling agricultural and environmental outcomes, balancing for instance food production with the maintenance of soil carbon. Examination of cultivation practices, such as minimum tillage, and controls of water levels and soil moisture on arable peats would provide useful management information to help control peat wastage, reduce carbon loss and extend the longevity of peats. The development of extensive grassland systems suited to peatland conservation/restoration, especially in areas that are currently mainly arable, would also help support land use change. This would help to provide feasible and potentially attractive agricultural options for farmers that can fulfil multiple objectives of food production, soil conservation, nature conservation, enjoyment of the countryside and rural livelihoods.

The development of case study examples, in more detail than has been possible here, would help to produce more robust and comprehensive estimates of outcomes. These would use farming and other land use data obtained locally, further applying the environmental accounting and ecosystems framework. These case studies would seek to involve farmers and associated agri-business in participatory workshops, supported by modelling of farming systems, peat degradation, and environmental and economic assessments. The case studies would provide a platform for further collaboration amongst the range of stakeholders with interests in peatland management.

For each of the Target Areas, identification of the likely “switching points” would inform land management decisions that took account of the wider environmental and economic benefits and costs. Here, the financial benefits to farmers of continued intensive use of peatlands use decline to the point where alternative land uses and funding options become attractive. Such switching points are likely to occur before peatlands are fully degraded.

In this respect, it would help to develop peatland management practices that can conserve peats under grassland regimes, for example by controlling stocking densities and machine travel to avoid soil damage. The rate of peat wastage under arable farming, for example, could be controlled by the development, in collaboration with farmers, of technologies for reduced tillage and the management of soil-water relationships.

Exploration of the scope for markets in environmental (often referred to as ecosystem) services provided by peatlands could help to design policies to promote and reward beneficial change in peatland management. This would also help to lessen the financial burdens that otherwise might be placed on existing farmers and land managers as they adopt more sustainable land management practices. Policies might include environmental charges for emissions, such as carbon release from land and farming, or environmental receipts for environmental services, such as avoided emissions, carbon sequestration, flood regulation, biodiversity and recreation.

5.1 Closing Statement

In summary, agriculture in the Target Areas support a range of farming systems, from intensive arable cropping in the Fens and Humberhead Levels, through to a combination of relative intensive dairy farming and extensive grassland under stewardship agreements in the Somerset Moors and the Lyth Valley. Farmed intensively for vegetables, they are extremely productive and profitable. The environmental costs associated with greenhouse gas release from soils and agricultural activities are high and are likely to rise in line with increased future carbon prices. Furthermore, continued agricultural use will degrade their productive capacity, such that their comparative advantage in farming will decline. The restoration or conservation of peatlands can reduce the current environmental burdens associated with intensive use and potentially provide a range of other environmental services. The analysis here suggests that this could be achieved without a major impact on food security. Modification of the incentives and rewards so that peatland managers are encouraged to use peat soils as sustainably as possible would serve the overall public interest.

At the present time, the farming communities and related agricultural industries in many peatland areas in England are both vulnerable and resilient. They have been buffeted by, and have demonstrated an ability to adapt to, considerable and often rapid changes in agricultural and environmental policy, markets, technologies and the availability of resources, especially labour and water. The depletion of peat soils, especially in the arable case, has been a further challenge to contend with. In the process these areas have developed some of the UKs most enterprising and market oriented farming systems, with a highly developed skill base born of local knowledge and experience. Taking land out of farming is a very sensitive issue, especially in arable areas where farming productivity is obvious. It is important therefore that any review of options for future land management should fully engage the farming communities involved, taking a long term view that respects the interests, livelihoods and history of those who work the land.

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Appendices

Appendix 1: Peat soils and their contribution to UK self-sufficiency and food security

1. Introduction

This appendix assesses how the case study areas and the peat soils within those areas contribute towards food security in the UK. First the appendix reviews the way in which food security is assessed in the UK, concluding that UK agricultural production is just one element of national food security, which also includes international trade, an efficient food chain and strategies to minimise waste. Production from the case study sites contributes to UK "self-sufficiency", which is an element of the larger issue of food security. It is against this criteria of self-sufficiency that the productivity of the case study areas are assessed, as food production overseas go beyond the influence of farmers in the peat soil areas.

2. Food security

The socio-economic contribution of agriculture in the UK and its constituent countries is shown by three main indicators: contribution to national Gross Domestic Product (0.5 per cent for the UK); employment (0.9 per cent of the UK workforce) and to the national food supply. For much of the last 50 years, the latter has been measured in terms of 'self sufficiency', which is the proportion of the UK's total food requirements sourced from UK farms. In 2009, provisional results show that the UK was 59 per cent self sufficient for all food consumed in the UK and was 73 per cent self-sufficient, for food that can be grown in the UK (indigenous). Self sufficiency has been declining from its peak in 1984, when self-sufficiency for all foods was about 78 per cent for all foods and 95 per cent for indigenous food (Defra, 2010a).

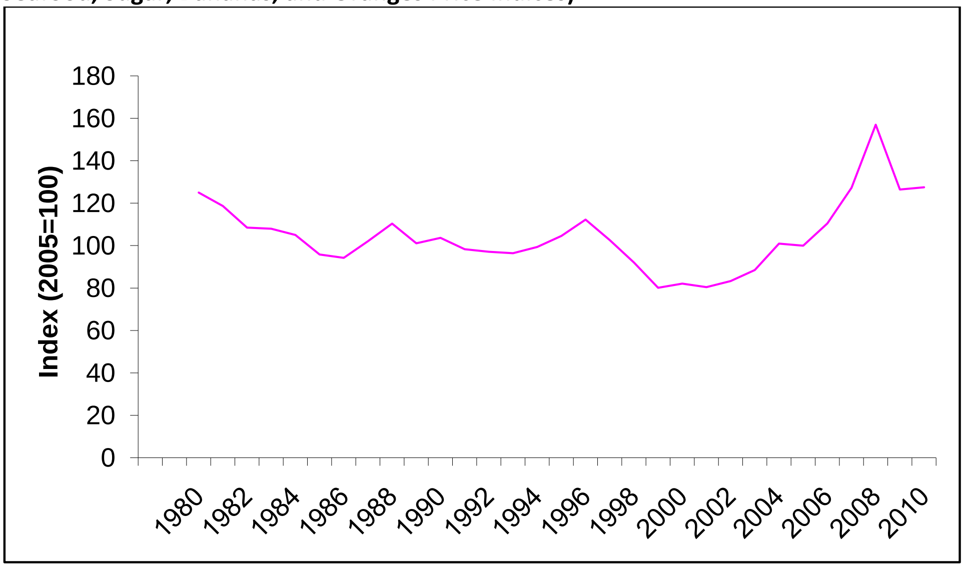
More recently, the UK Government has adopted the concept of 'food security' rather than self sufficiency as a guiding principle. Food security is sought by 'guaranteeing households access to affordable nutritious food'. The UK Food 2030 strategy (Defra 2010b) charges UK agriculture, along with the food industry as a whole, with 'ensuring food security through strong UK agriculture and international trade links with EU and global partners' (Defra 2010b). In this respect, UK agriculture is expected to be domestically efficient and internationally competitive. From an economist's perspective, this implies that UK farmers should focus on types of farming and land use in which they have comparative economic advantage.

In this competitive, but essentially (as far as food markets are concerned) benign world view, domestic production competes favourably with potential imports, in the absence of subsidies. Furthermore, assuming unrestricted international markets, UK agriculture can export where it has significant competitive advantage. However, the reality is that international agricultural commodity markets are not free. Developed countries in particular have exerted considerable resistance over many years to agricultural trade liberalisation under United Nations Conference on Trade and Development (UNCTAD) and World Trade Organisation (WTO) negotiations (Potter and Tilsey, 2007). This reflects a legacy of agricultural protectionism previously justified in terms of (i) feeding the nation (often borne out of major international conflicts) and (ii) alleviating rural poverty through income support. The traditional view of food security was based in a cold war mentality of the primacy of increasing domestic food supply and minimising reliance on imports. The contemporary concept of food security is based on international trade and co-operation that delivers healthy and nutritious food with minimal environmental impact.

The adoption of 'food security', set in an international context, is compatible with trends in agricultural policy. The 2005 Reforms to the Common Agricultural Policy, with the 'decoupling' of production and income support, now mean that UK farm commodity prices are for the most part determined by world market conditions (although some EU market protection remains for livestock products and proteins). A review by Defra and HM Treasury in 2006 concluded that food security was not a major concern, because the UK would be able to purchase food in world markets should the need arise, especially as most food is sourced from 'friendly' trading partners (implying that other types of commodity securities , such as energy, may not be).

However, UK Government concern with food security was heightened following the spike in agricultural commodity and related food prices in 2005-08 (Figure A1.1). Although prices have fallen back, they remain higher than they were before 2005. The FAO is forecasting that agricultural prices will remain at relatively high levels over the next few years (OECD, 2009).

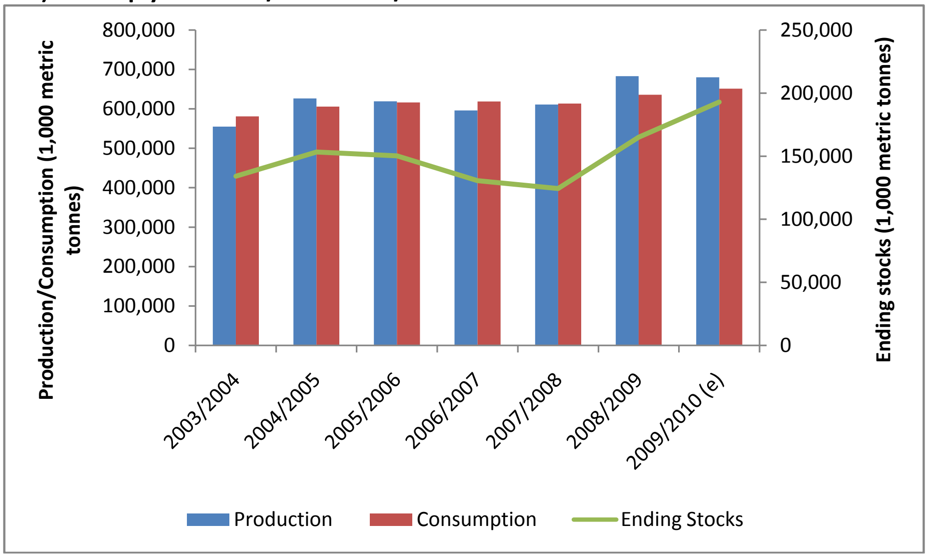
Figure A1.1: IMF commodity food price index (includes Cereal, Vegetable Oils, Meat, Seafood, Sugar, Bananas, and Oranges Price Indices)



Source: IMF data and statistics (http://www.imf.org/external/data.htm)

The causes of the price spikes were both short term and structural change. a combination of international factors, including a succession of harvest failures and strong demand from newly industrialising countries, such as India and China. This is shown on Figure A1.2, where wheat consumption exceeded production for three of the five crop years between 2003/04 and 2007/08, with a subsequent reduction in closing stocks. Other influences include the, unprecedented redirection of food crops into biofuel markets, commodity speculation and, to a degree by the success of policies in developed countries to cut back on agricultural production, but the exact contribution of these factors are unclear (Defra, 2010c; IFPRI, 2007; Trostle, 2008; Piesse and Thirtle, 2009).

Figure A1.2: World wheat production, consumption and ending stocks (1,000 metric tonnes) for crop years 2003/04 to 2009/10



Source: USDA, 2010. (e) = estimate.

In the 2007/8 period, UK cereal prices more than doubled to almost £150/tonne. These higher foods prices reduced standards of nutrition and disposable income among poor and vulnerable social groups (IFPRI, 2007). Predictably, there was a surge in international supply in response to high commodity prices that in turn depressed prices, albeit not to their 2006 levels (FiguresA1.1 and A1.2). The UK wheat output for example in 2008 (compared with the previous year) rose by 30 per cent because of increased plantings (13 per cent) linked to the withdrawal of set-aside and higher yields (15 per cent).

It was this exposure to the risk of high food prices, induced by global shortages, that prompted Government to revisit the issue of self sufficiency, which had been central in the UK's policy of 'Food From Our Own Resources' (MAFF, 1975). However, reviews by HM Treasury (ref) and Defra (2006), favoured food security as: (i) conforming to the principle of comparative economic efficiency in an international setting; and (ii) recognising the vulnerability of the population at large and poorer groups in particular to high food prices and constrained choice caused by supply disruption.

The renewed focus on food security is an international trend. Several organisations and countries have developed monitoring procedures to measure food security and identify potential threats. For instance, the US Department of Agriculture completes a household survey to determine the proportion of families that have ready access to healthy and nutritious food (USDA, 2009).

Defra have undertaken a similar assessment for the UK (Defra 2010c). Following stakeholder consultation, Defra defined food security as a set of elements common in the majority of published definitions of food security. These elements were (Defra 2010c):

- Availability of food
- Access to food;
- Affordability of food;
- Food safety; and
- Food chain resilience.

These elements were used to provide six themes that taken together provide a full assessment of food security in the UK. These themes and their rational are described in Table A1.1.

Table A1.1: The Defra selected themes of food security and their rationale

Theme	Rationale
Global availability of food	The UK food supply is underpinned by international supply. Therefore, a well-functioning world food market is important for UK security.
Global resource sustainability	Food systems that are unsustainable risk the potential of reducing the ability to produce food in the future.
UK availability and access to food	Sourcing nutritious food from a diverse range of stable trading partners assures domestic security by spreading risks and keeping prices competitive.
UK food chain resilience	The UK food supply is dependent on global availability of food and other resources. The UK food sector is particularly reliant on energy from international suppliers.
UK household food security	Everyone should have access to health and nutritious food.
Safety and confidence	UK public confidence in UK food is based on the safety of food.

Defra assess each theme against a headline indicator, which in turn is assessed against a set of supporting indicators that measure threats to food security. An example of this rationale is shown below in Table A1.2:

Table A1.2: An example of the UK food security assessment framework

Theme	Rationale	Headline indicator	Supporting indicators	Threats
Global availability	Global food supply underpins the UK food supply.	Trends in global output per capita	• Demand growth trend • Yield growth by region • Stock to consumption ratio • Share of production traded • Concentration in world markets • R&D expenditure on agriculture • Impact of animal disease	• Population and economic growth • Rising incomes in emerging economies harvest shortages • Trade protectionism • Breakdown in trade • Lack of investment • Warming and more volatile climate

Source: Defra, 2010c

The assessment is based on identifying the direction of past and expected trends that are favourable, mixed, or unfavourable to UK food security based on evidence that has emerged over the last 10-15 years and predictions of how these trends are likely to change over the next decade. The historic or predicted trends are assessed against the following qualitative statements:

- Indicator is in a favourable position.
- Indicator is somewhat unfavourable/uncertain/mixed.
- Indicator is in a very unfavourable position.

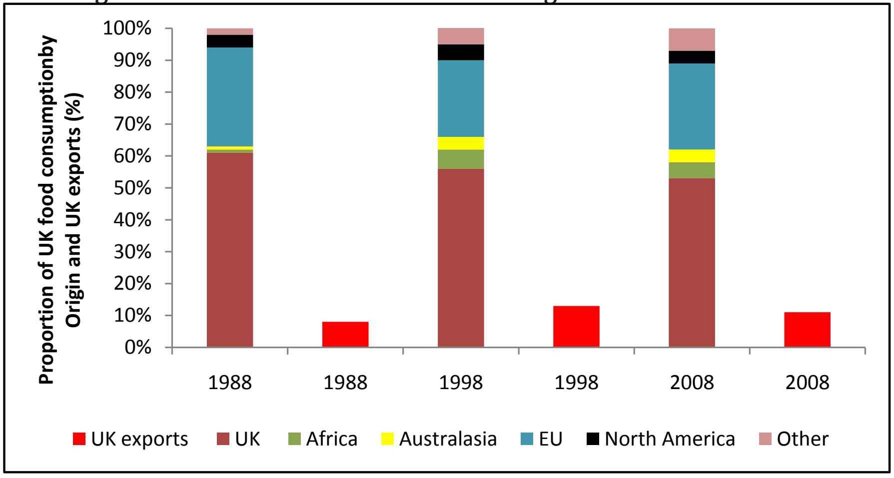
The assessment framework is not designed to be comprehensive and definitive. Rather, it is designed to provide evidence that informs a wide understanding of the different dimensions of food security and highlight emerging risks and trends that are likely to influence the food supply now and over the next decade. The timeframe of analysis looks backwards to 1990 and forward to 2020.

Accordingly there is no conclusive judgement on the relative security of food supply in the UK. The broad messages that arise from the latest assessment are that the UK has a relatively secure food supply. In the event of extreme isolation, the calorific potential of UK agriculture would be more than sufficient, as long as there was a large reduction in livestock production for crops. Agricultural yields in the UK, in common with other EU countries are increasing and access to spare land means that the UK can be relatively responsive to any future needs for increased agricultural production.

3. UK domestic food supply: self sufficiency

UK agriculture supplied about 60 per cent of all food consumed in the UK and around 70 per cent of all indigenous food (food that can be commercially produced in the UK; Defra 2008c), this is down from a peak of 75 per cent of indigenous foods in the mid 1970s. In 2007, 25 countries together, including the UK, accounted for 90% of UK food supply. About 3 per cent of fruit and vegetables consumed in UK households in 2008 came from non-commercial sources, such as gardens and allotments. Table 3 shows UK self-sufficiency and exports as a percentage of domestic production in 2009, Figure A1.3 shows the origins of food consumed in the UK and the relative proportion of food commodities exported.

Figure A1.3: Origin of UK food imports and relative proportion of UK exports of agricultural commodities based on farm-gate value of raw food[10]



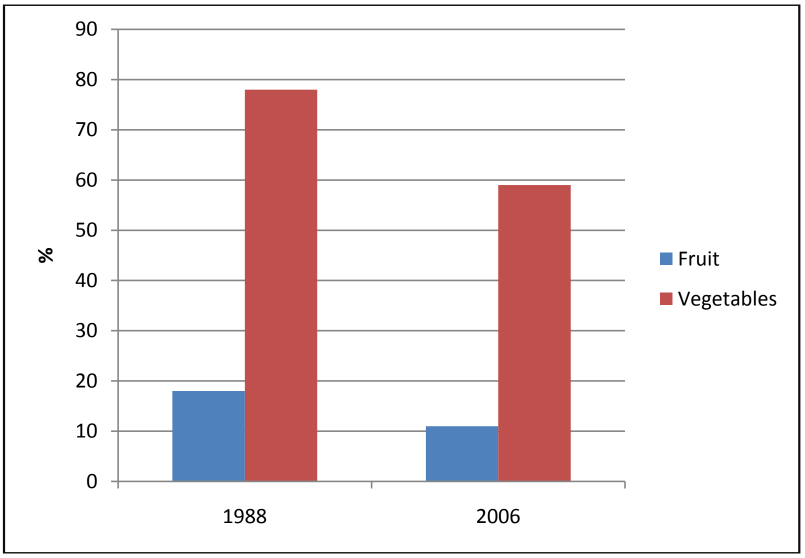
Source Defra 2010a

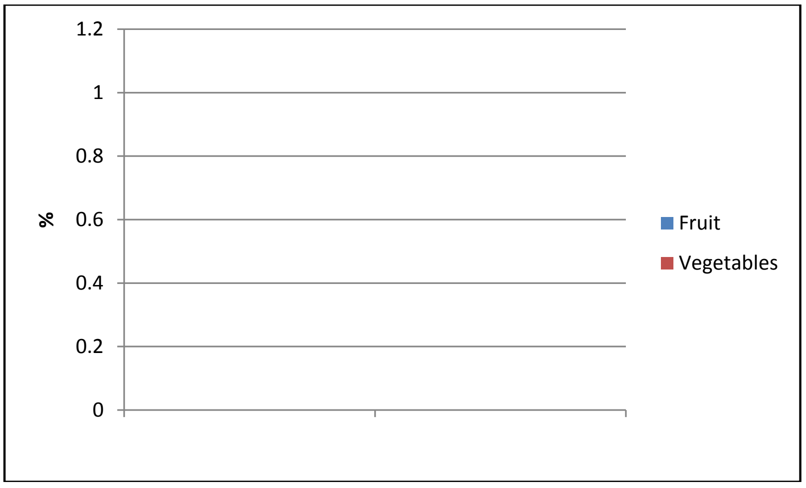
Table A1.3: UK production, self-sufficiency and exports as a proportion of domestic production in 2009

Product	Production ('000 tonnes)	Self-sufficiency (%)	Exports as a proportion of domestic production (%)
Cereal	22 037	104	15
Wheat	14 379	80	17
Barley	6 769	112	12
Oats	757	102	4
OSR	1 938	88	6
Linseed	56	153	46
Sugar (refined basis)	1 280	64	41
Fresh Veg	2 597	59	3
Potatoes	6 423	83	11
Fresh fruit	415	12	34
Cattle, calves, beef, veal	856	83	11
Pork	703	52	18
Sheep, lambs, mutton	315	88	31
Poultry and poultrymeat	1 459	91	17
Hen eggs	747	79	2

Source: Defra 2010a

Figure A1.4: UK home production of fruit and vegetables as a proportion of new supply 1988-2006





Source: Barling et al. 2008[87]

For most indigenous horticultural crops the areas planted and production declined between 1997 and 2006 (Figure A1.4 shows UK self-sufficiency for fruit and vegetables in 1988 and 2006). The exceptions have been carrots, onions (dry and green), leeks, apples and plums, where a reduced planted area was more than offset by increases in yields on retained areas. There are no data regarding how land released from cropping has been used, but it is reasonable to assume that the proportion of wheat production has increased on areas previously occupied by vegetables. Strawberries and asparagus were the only crops that increased in terms of planted area and production over the period (Barling et al. 2008). The

[87] Barling, D., Sharpe, R., and Lang, T. 2008. Rethinking Britain's Food Security. Report to Soils Association. City University, London

restoration of peatlands would result in further decline in the area vegetables in particular, unless this production moves onto other soils.

By comparison, the EU as a whole has a high level of self sufficiency in food, with the notable exception of soya products for animal feeds [88]. The overall EU trade position in agricultural and food commodities has oscillated around a near balance, although net exports of finished and intermediate food products have tended to offset net imports of raw commodities. Overall the EU is self sufficient in temperate cereals, selected vegetable oils and most livestock products. The degree of self sufficiency in agricultural commodities varies across the member states (Table A1.4).

[88] Barling, D., Sharpe, R., and Lang, T. 2008. Rethinking Britain's Food Security. Report to Soils Association. City University, London

Table A1.4: Self-sufficiency of selected agricultural products in selected EU Member States (%) (from Barling et al, 2008)

Product	Denmark	France	Germany	Italy	Netherlands	Portugal	UK
Cereals	105	213	129	87	22	27	106
Potatoes	n/a	108	109	62	n/a	71	83
Eggs	80	97	73	106	n/a	75	88
Meat	351	109	99	76	n/a	75	88
Oils and fats	0	89	n/a	37	n/a	n/a	n/a

Source: Agriculture in the European Union Statistical and Economic Information 2007, chart 8.3: http://ec.europa.eu/agriculture/agrista/2007

The relative importance of different trading partners varies by types of food. For instance, 90 per cent of vegetables consumed in the UK are sourced from 24 countries; 90 per cent of meat and meat products are sourced from 4 countries; 90 per cent of dairy products and birds egg supply are sourced from 3 countries and 90 per cent of the supply of cereals and cereal preparations (including rice) are sourced from 9 countries (Defra, 2009b).

The UK has an overall trade deficit for food, feed and drink, meaning the value of imports exceeds the value of UK exports for those products. The value of imports in 2007 was £26.6 billion compared to £11.4 billion for exports, giving a trade gap of £15.2 billion. Between 1995 and 2007, the UK trade gap for food, feed and drink has increased by 80 per cent. In 2007, the largest trade deficit if for fruit and vegetables (£5.8 billion).

This assessment of food security in the UK is relatively positive. The USDA estimated that approximately 85 per cent of US households had food security (hade easy access to nutritious food); 9 per cent had low food security; and 6 per cent had very low food security (USDA, 2009a). Worldwide, it is estimated that in 2009 approximately 883 million people lived in conditions of food insecurity (USDA, 2009b).

Agricultural production contributes to the domestic supply of food and forms part of a supply chain than ensures food is safe and nutritious. However, this represents a small part of the international supply chain that is set to ensure UK food security. Therefore, although food security has replaced self-sufficiency as a strategic assessment of the stability and reliability of the food supply, peatlands can only be assessed against the quantity of food produced and its importance within the domestic supply chain. Defra define self-sufficiency as the farm-gate value of raw food production divided by the value of raw food for consumption (Defra, 2010). This is used as a measure of agriculture's competitiveness rather than food security, which is a more complex issue.

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4. UK Agriculture and the contribution of peatlands to self-sufficiency and food security

Agriculture is the single largest land use in the UK. In 2009 approximately 17.5 million hectares of UK land (including common land used for grazing) was used for agricultural purposes, accounting for 77 per cent of total land in the UK (Defra, 2010). This proportion is higher than other European countries: about 50 per cent of land in France, Germany and Spain is used for agricultural purposes (Eurostat, 2009). 77

Agricultural land use varies across the UK according to climate, soils and topography. This results in a relative concentration of grassland and livestock farming in the north and west of the UK, and arable farming in the south and east. Horticulture, including the production of high-value vegetable and salad crops, is mainly concentrated in areas of peat or light mineral soils, usually involving irrigation and controlled drainage. These are mainly in East Anglia, the West Midlands, south west Lancashire, and south Yorkshire. Pig production does not follow the east-west geographical divide, with approximately 60 per cent of pig production located in Yorkshire and Humberside and the East region. Table A1.5 shows the economic importance of each of these activities and the proportion of UK land taken by these activities.

Table A1.5: Economic output and land use by agricultural activities as a proportion of the total for UK agriculture

Agricultural activity	Proportion of total UK agricultural economic output (%)	Proportion of UK agricultural land used by activity (%)
Crop outputs	22	25
Meat and meat product outputs	49	60
Horticulture	10	1.1

Source: Defra 2010a

In England crop activities play a more important role. Crop activities produce 50 per cent of English agricultural gross output at basic prices on 50 per cent of land, horticulture produces 11 per cent of output on about 1.3 per cent of land and livestock provides 30 per cent on 43 per cent of land. Within horticultural production, the UK vegetable sector accounted for 46 per cent of horticultural output in 2008, using 72 per cent of the land area devoted to horticultural production; non-edibles accounted for 33 per cent of output on 8 per cent of the total horticultural area; and fruit growing produced 20 per cent of output on 20 per cent of horticultural land takes up 20% of land area and produces 20% of output (Crane and Vaughan, 2010).

Agriculture plays a further role in the economy, supporting the larger agri-food sector, which also includes manufacturing, marketing and wholesaling. This larger sector generated 6.7 per cent of total UK economic output (Table A1.6) and employed 14.1 per cent of the UK workforce in 2009 (Defra, 2010). Agriculture makes a relatively small contribution to the sector's GVA, but is nonetheless central to the activities further along the supply chain. The supply chain is considered to be part of the food security issue, as improved food storage techniques and waste minimisation can improve the efficiency of the supply chain.

Table A1.6: Gross Value Added by the UK agri-food sector in 2009

	Gross Value Added (GVA (£ million)	% contribution to total GVA of agri-food sector
Agriculture	7,658	10
Food manufacturing	22,751	30
Food wholesaling	9,490	12
Food retail	22,925	30
Food non-residential catering	11,121	15
Total GVA	75,953	

Source: Defra, 2010

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5. The contribution of the Peatland case study sites to food production, self-sufficiency and food security

As discussed earlier, agricultural production on peat soils contributes to food security through its role of supplying agricultural commodities to the UK agri-fod sector. Table A1.7 below compares the total area of agricultural land in each peatland case study site and the cropping and grassland land use, relative to the UK as a whole.

Table A1.7: Agricultural land use in the peatland case studies and the UK in 2009 (ha)

	Lyth Valley	Humberhead Levels	East Anglian Fens	Somerset Levels	Total for the peatland case studies	UK
Agricultural area	3,620	14,234	132,131	16,127	166,112	18,752,000
Wheat	90	3,132	46,786	637	50,646	1,814,000
Total Barley	7	736	3,993	136	4,871	1,160,000
Oats	0	17	131	12	160	131,000
Other cereals	0.06	67	133	14	215	28,000
Potatoes	2	279	10,106	16	10,402	149,000
Peas & beans	0	53	985	1	1,039	233,000
Maize	13	14	51	433	511	166,000
Oilseed rape	0	592	3,482	50	4125	581,000
Sugar beet	0	358	14,231	0	14,589	116,000
Linseed	0	111	1,030	10	1,151	29,000
Permanent grass	1951	525	5,408	9,050	1,6934	10,259,000
Temporary grass	198	412	1,357	1,119	3,086	1,262,000
Rough grazing (sole right)	420	59	1,669	298	2,445	4,174,000
Hardy nursery stock, bulbs & flowers	2	5	236	1	243	12,000
Total small fruit	0	0	66	1	67	
Total fruit	2	1	224	48	274	24,000
Total veg in the open	1	638	6,504	17	7,160	124,000
Under glass or plastic	0	10	126	25	160	2,000
Total Horticulture	4	653	7,090	90	7,838	172,000

Table A1.8 below shows the proportion of the total UK crop and grassland area that is located on the peatland case study areas. The peatland case studies cover 0.9 per cent of the total UK agricultural area; provide 2.8 per cent of the total wheat area, 12.6 per cent of the sugar beet area, almost 1 per cent of the oilseed rape area; 7 per cent of potatoes, and 8 per cent of the horticulture area. However, excluding the Cambridgeshire Fens, the case study areas make up a very small percentage (0.2 per cent) of the total UK agricultural area. The Cambridgeshire Fens contributed approximately 2.5 per cent of UK land used to grow wheat, 12.2 per cent of the land under sugar beet, 7 per cent of land used for potato production, 3.5 per cent of the area used to grow Linseed and 4.5 per cent used for horticulture.

Table A1.8: Proportion of UK crop or grassland area located in peatland case study areas in 2009 (%)

	Lyth Valley	Humberhead Levels	East Anglian Fen	Somerset Levels	Total peatland
Area	0.019	0.076	0.705	0.086	0.886
Wheat	0.005	0.173	2.579	0.035	2.792
Barley	0.001	0.063	0.344	0.012	0.420
Oats	0.000	0.013	0.100	0.009	0.122
Other cereals	0.000	0.241	0.475	0.051	0.767
Potatoes	0.001	0.187	6.782	0.011	6.981
peas & beans	0.000	0.023	0.423	0.001	0.446
Maize	0.008	0.008	0.031	0.261	0.308
Oilseed rape	0.000	0.102	0.599	0.009	0.710
Sugar beet	0.000	0.308	12.268	0.000	12.577
Linseed	0.000	0.383	3.551	0.035	3.969
Permanent grass	0.019	0.005	0.053	0.088	0.165
Temporary grass	0.016	0.033	0.108	0.089	0.245
Rough grazing (sole right)	0.010	0.001	0.040	0.007	0.059
Hardy nursery stock, bulbs & flowers	0.017	0.040	1.964	0.006	2.027
Total fruit	0.007	0.003	0.935	0.199	1.144
Total veg in the open	0.001	0.514	5.245	0.014	5.774
Under glass or plastic	0.000	0.480	6.287	1.235	8.002
Total Horticulture	0.003	0.380	4.122	0.053	4.557

The Cambridgeshire fens comprise a part of the East Anglian Fens, which were estimated to cover an area of 36,636 ha in 1989, of which 24,000 ha were peat soils (Holman, 2009). The agricultural importance of the East Anglian fen was reviewed by the NFU (2008), they estimated that 89 per cent of fenland is grade 1 or 2 agricultural land; 50 per cent of all UK grade 1 agricultural land. The area is disproportionately productive compared with its size: it produces 37 per cent of UK vegetables, one farm business in the East Anglian Fens grows 50 per cent of the UK's beetroot; 24 per cent of potatoes.

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Table A1.9: Proportion of UK horticultural area located in peatland case study areas in 2004 (%)

	Lyth Valley	Humberhead Levels	East Anglian Fens	Somerset Levels	Peatland case studies
Total horticulture	0.00	0.33	4.35	0.04	4.72
All other vegetables	0.004	3.1	35.6	0.1	38.8
Turnips etc	0.06	0.18	0.54	0.06	0.83
Peas for harvesting dry	0.0	4.5	76.8	0.0	81.4
Broad beans	0.00	0.00	0.07	0.01	0.08
Runner beans	0	0	0.009	0.007	0.016
Peas	0.0	0.1	1.4	0.0	1.5
Strawberries	0.00	0.00	1.14	0.06	1.20
Raspberries	0.0	0.0	0.8	0.0	0.8
Blackcurrants	0.000	0.000	0.094	0.000	0.094
Total fruit	0.006	0.003	0.828	0.176	1.013
Total veg in the open	0.0	0.5	5.6	0.0	6.1

The peatland case studies, in particular the Cambridgeshire Fens are important for peas for dry harvesting, with 81 per cent of land used for this purpose. It also is an important area for

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"all other vegetables", which includes asparagus, celery, leeks, lettuce, rhubarb and watercress.

6. Contribution of peat soils within the peatland case study sites to UK self-sufficiency

The case study sites have a range of soil types including peat soils. This section focuses on the food production from peat soils within the case study sites, reporting the estimated absolute production and value of production as well as expressing these estimates as a percentage of the total for the UK. Table A1.10 shows the UK area, production and value of agricultural commodity production as an average of the years 2007-2009. An average is taken to counteract the effect that exceptional weather events have on production and agricultural commodity prices.

Table A1.10: UK areas, production and value of agricultural commodities as an average of the years 2007-2009

Commodity	Area (ha)	Production (tonnes)	Value (£)
Wheat	1,908,000	14,942,333	1,719,706,875
Barley	1,030,000	5,997,333	686,409,573
Oilseed Rape	620,341	2,010,636	506,081,112
Peas for harvesting dry	25,000	102,000	14,000,000
Field beans	144,000	541,000	75,000,000
Sugar Beet	121,000	7,568,000	204,000,000
Potatoes	144,211	6,044,059	698,568,215
Field Veg	120,000	2,551,000	1,075,000,000
Horticulture	170,000	N/A	2,441,000,000
Fruit	28,000	410,000	528,000,000
Other (non food)	85,711	N/A	1,108,000,000
Total crops	4,623,000		6,781,800,000
Total Grass	11,506,000		
milk production			3,128,000,000
meat production			5,138,000,000
Total dairy and livestock			8,266,000,000
Total Gross Output £000			14,996,700,000

Source: Agriculture in the UK 2009

Table A1.11 expresses area, production and value of agricultural commodities from the peat soils in the Great fen case study site as a proportion of the UK averages of 2007-09.

Table A1.11: Area, production and value of agricultural commodities from the peat soils in the Great fen case study site as a proportion of the UK averages of 2007-09

	Fens			Humber head			Lyth			Somerset		
	Area	Production	Value	Area	Production	Value	Area	Production	Value	Area	Production	Value
Wheat	0.797%	0.814%	0.834%	0.02%	0.02%	0.02%	0.003%	0.003%	0.003%	0.16%	0.15%	0.13%
Barley	0.00196	0.192%	0.159%	0.00%	0.00%	0.00%	0.000%	0.000%	0.000%	0.06%	0.06%	0.05%
Oil Seed Rape	0.00422	0.456%	0.434%	0.00%	0.00%	0.00%	0.000%	0.000%	0.000%	0.08%	0.08%	0.08%
Peas for harvesting dry	0.03658	3.496%	3.821%	0.07%	0.08%	0.08%	0.000%	0.000%	0.000%	0.72%	0.66%	0.72%
Field beans	0.00635	0.676%	0.683%	0.02%	0.03%	0.03%	0.002%	0.002%	0.002%	0.13%	0.13%	0.13%
Sugar Beet	0.02762	2.562%	2.756%	0.07%	0.06%	0.07%	0.007%	0.005%	0.004%	1.18%	0.72%	0.69%
Potatoes	0.01771	2.197%	2.662%	0.04%	0.05%	0.06%	0.001%	0.001%	0.001%	0.03%	0.03%	0.03%
Field Vegetables	0.01393	3.701%	1.274%	0.03%	0.08%	0.03%	0.000%	0.000%	0.000%	0.03%	0.06%	0.02%
Horticulture	0.01243	0.000%	1.577%	0.03%	0.00%	0.03%	0.002%	0.000%	0.003%	0.08%	0.00%	0.08%
Fruit	0.00225	0.461%	0.143%	0.00%	0.01%	0.00%	0.001%	0.003%	0.001%	0.33%	0.58%	0.18%
Other (non food)	0.00147	N/A	N/A	0.00%	N/A	N/A	0.002%	N/A	N/A	0.01%	N/A	N/A
Total crops	0.00682	0.000%	1.413%	0.01%	0.00%	0.03%	0.002%	0.000%	0.002%	0.13%	0.00%	0.12%
Total Grass	0.00029	0.000%	0.000%	0.00%	0.00%	0.00%	0.010%	0.000%	0.000%	0.15%	0.00%	0.00%
milk production	0	0.000%	0.005%		0.00%	0.00%		0.000%	0.039%		0.00%	0.52%
meat production	0	0.000%	0.052%		0.00%	0.00%		0.000%	0.015%		0.00%	0.20%
Total dairy and livestock	0	0.000%	0.034%		0.00%	0.00%		0.000%	0.024%		0.00%	0.32%
Total Gross Output £000	0	0.000%	0.658%	0.00%	0.00%	0.01%	0.000%	0.000%	0.014%	0.00%	0.00%	0.23%

Table A1.11 shows that except for the Great fen case study, land use, production and value of production in the Humber head, Lyth valley and Somerset case studies makes up less than 0.8 per cent of the UK totals. The peat soils on the Great fen generally make up a small percentage of UK the land used to produce agricultural commodities; the highest proportion is for wheat (approximately 0.8 per cent). However, in terms of production, the peats soils in the fens are disproportionately productive, relative to its size, producing approximately 3.5 per cent of UK peas for harvesting dry; 2.5 per cent of UK sugar beet; 2 per cent of UK potatoes; and 3.7 per cent of UK field vegetables. The contribution of value from the peat soils in the great fen as a proportion of the UK totals for each commodity are of the same order as the proportions for land use with the exception of horticulture, which makes up only a small proportion of UK horticultural land use, but contributes approximately 1.5 per cent of the value of the UK horticultural crops.

7. Current and predicted UK demand for food

In 2009 approximately 61 million UK consumers spent £173 billion on food, of which £92 billion was spent on household food consumption and £81 billion on catering services. In 2008, 11 per cent of the average UK household budget was spent on food, although this proportion rises to almost 16 per cent for low income households. The average UK household expenditure in 2009 on all food and non-alcoholic drinks was £50.70 per person per week, of which £46.70 was spent on food. Of this weekly food bill, approximately 11 per cent was spent on bread, rice and cereals, 23 per cent on meat and meat products, about 5 per cent on milk, and approximately 14 per cent on fresh fruit and vegetables (Table A1.12).

Table A1.12: UK Household expenditure on food and non-alcoholic drinks in 2009

	Household Expenditure (£ per week)	Total UK household expenditure in 2009 (£ million)	Proportion of weekly food bill (%)
Food & non-alcoholic drinks	**50.70**	**1,302**	
Food	46.70	1198	
Bread, rice and cereals	4.90	125	10.5
Beef (fresh, chilled or frozen)	1.60	41	3.4
Pork (fresh, chilled or frozen)	0.60	17	1.3
Lamb (fresh, chilled or frozen)	0.60	17	1.3
Poultry (fresh, chilled or frozen)	1.90	49	4
Bacon and ham	0.90	24	1.9
Other meats and meat preparations	5.20	133	11.1
Fish and fish products	2.30	59	4.93
Milk	2.60	68	5.6
Cheese and curd	1.70	43	3.64
Eggs	0.60	16	1.28
Other milk products	1.90	48	4.07
Fresh fruit	3.00	76	6.42
Fresh vegetables	3.70	96	7.92
Potatoes	0.90	23	1.93
Sugar and sugar products	0.30	8	0.64

Source: National Statistics, 2009

Food consumption is influenced by a number of factors such as population, dietary requirements, income, food retail prices, and changing taste among others. The UK population is increasing. Between 2001 and 2008 the UK population increased by almost 4 per cent to approximately 61 million and is expected to grow to 71 million people by 2031 (IGD, 2010). All things remaining equal, an increase in population will increase demand for food. However, counteracting the consumption effect of an increase in population has been a long-term decline in rates of physical activity, which caused energy intake per person from food and drink to decline by 29 per cent between 1974 and 2008 (Defra 2010b). The perceived healthiness of foods also influences consumption. For instance, the average consumption of fruit and vegetables was 3.7 portions per person per day in 2008, compared with 3 portions per person per day in 1975 (Defra 2010b). This is part of a trend to healthier eating, driven in part by government policy.

Low-income households tend to buy more bread and cereals, milk, cheese and eggs, sugar and confectionery but less meat and bacon, vegetables, fruit and other foods than more affluent families. In 2007 low income households in the UK consumed an average of 3.5 portions of fruit and vegetables per person per day, compared with an overall UK average of 3.9 portions. Price changes also influence consumption. When food prices increase, consumers buy less beef, lamb, cheese and fruit, but buy more bread, biscuits and cakes, bacon, butter, preserves and milk. As food is essential, consumers will tend to buy cheaper produce as prices increase; these goods that are "traded down" include: pork; poultry; eggs; sweets and chocolate; potatoes and vegetables (Defra, 2010b). Table A1.13 shows how the consumption of major food groups has changed between the 1940s and 2000s.

Table A1.13: Household purchases of major food groups (grams/week)

	1940s	**1950s**	**1960s**	**1970s**	**1980s**	**1990s**	**2000s**
Total milk and cheese	2137	2892	2989	2870	2502	2220	2081
Total cheese	101	62	88	100	108	114	110
Total fruit	197	559	692	684	763	930	1120
Total potatoes	1877	1816	1484	1324	1160	901	707
Total vegetables	2901	2794	2424	2472	2408	2194	1986
Total cereals	593	693	714	688	676	708	788
Total meat and meat products	746	821	1069	1073	1097	950	966

Source: Foster and Lunn (2007)

Table A1.13 shows the broad changes in food consumption within different food groups. It does not show how consumer choice has changed over this time. For instance, although the quantities of bread consumed fell between the 1940s and 2000s, there has been a large increase in the varieties of bread available and an increased in the consumption of speciality breads over the last few years. Total milk and cheese consumption has remained relatively stable over time, but within this category there has been a substitution of full-fat to skimmed milk. Similarly the quantity of meat consumed over time has remained relatively constant, but this masks large annual fluctuation caused by health issues, such as the BSE crisis and a large substitution from red to white meat; poultry now being the most popular meat. There have been long-term declines in the quantity of potatoes and vegetables consumed, although the fall in vegetable consumption has been reversed in recent years by government health campaigns (Foster and Lunn, 2007). Conversely there has been an increase in the quantity of cereal and fruit consumed per person, with the banana overtaking the apple as the most popular fruit.

Morris et al. (2005) estimated future UK supply and demand of agricultural commodities based on these long-term trends in population income growth and changes in consumer taste (assumptions shown in table A1.15). Indicative estimates were produced for likely UK aggregate food demand from 2002-2050 under different scenarios. These scenarios were based on those used by the Foresight Programme (Berkhout *et al.*, 2002, OST 2002), in which futures are distinguished in terms of social values and governance. Four scenarios, World Markets (WM), Global Sustainability (GS), National Enterprise (NE) and Local Stewardship (LS) were used to define possible agricultural futures, recognising the dominant influence of the agricultural policy regime as a key driver of agricultural change (Table A1.14). A 'Business as Usual' case was included to represent a continuation of the existing regime.

Table A1.14: Links between Foresight and Agricultural Policy Scenarios

Foresight Scenario	Agricultural Policy Scenario	Intervention regime
Business as usual (BAU)	Baseline	Moderate: Existing price and income support, export subsidies, with selected agri-environment schemes
World Markets (WM)	World Agricultural Markets (without CAP)	Zero: Free trade: no intervention: entirely market driven
Global Sustainability (GS)	Global Sustainable Agriculture (Reformed CAP)	Low: Market orientation with targeted sustainability 'compliance' requirements and programmes
National Enterprise (NE)	National Agricultural Markets (Similar to pre-reform CAP)	Moderate to High: price support and protection to serve national and local priorities for self sufficiency, limited environmental concern.
Local Stewardship (LS)	Local Community Agriculture	High: locally defined support schemes reflecting local priorities for food production, incomes and environment

(Source: Morris et al, 2005)

Table A1.15: Assumptions of important trends in UK food demand used in Morris et al. (2005)

Criteria	Units	Scenarios				
		BAU	WM	GS	NE	LS
Population growth,	% per annum	0.25	0.29	0.22	0.25	0.175
National income growth	% per annum	2	2.75	2.25	1.75	1
Income elasticity of demand by commodity	Demand:GDP	0.12	0.10	0.12	0.15	0.17
Crops for bio-fuel (cereals, oil seed, sugar beet and potatoes)	PJ required from biofuel crops in a given year – examples for 2050	91	59	187	91	155
UK food self sufficiency (net export:import ratio) by commodity	% per annum	0.95	0.8	0.9	1.05	0.91

Coefficients were also derived for each scenario to reflect likely changes in consumer preferences. For instance, as income increase there will be more demand for higher quality foods, such as a shift from staples such as cereals and potatoes to meat. The scenarios also imply different changes in food preference, such as a trend towards organics, vegetarianism and healthy foods.

For the purpose here, only the BAU, WM and NE scenarios are used to estimate future food commodity demand, as these scenarios are relatively more relevant to current and future trajectories. These estimates also considered the potential impact of energy cropping on the demand for agricultural commodities. Table 15 presents the estimates of how demand for food commodities that are affected by energy demand will change between 2002 and 2050 under the BAU, WM and NE scenarios.

Under the NE scenario there is strong demand for domestic produce and demand for all commodities reported in the Table A1.16 increases. In the BAU scenario there is an estimated increase demand for wheat and oilseed rape and decrease in sugar beet and potato production with and without energy cropping. Conversely potatoes and sugar beet production declines in all scenarios, reflecting long-term declines in the consumption of potatoes and a reduction in UK sugar quotas.

Table A1.16: Estimated demand for wheat, oilseed rape, potatoes and sugar beet in 2002, 2012, 2035 and 2050 under BAU and WM scenarios with and without biofuel production (Source: Morris et al. 2005)

	BAU				World Markets				National Enterprise			
	Non-biofuel scenario		Biofuel cropping		Non-biofuel scenario		Biofuel cropping		Non-biofuel scenario		Biofuel cropping	
	Domestic consumption (000 tonnes)	Domestic consumption as a proportion of 2002 (%)	Domestic consumption (000 tonnes)	Domestic consumption as a proportion of 2002 (%)	Domestic consumption (000 tonnes)	Domestic consumption as a proportion of 2002 (%)	Domestic consumption (000 tonnes)	Domestic consumption as a proportion of 2002 (%)	Domestic consumption (000 tonnes)	Domestic consumption as a proportion of 2002 (%)	Domestic consumption (000 tonnes)	Domestic consumption as a proportion of 2002 (%)
Wheat												
2002	14292	-	14292	-	14292	-	14292	-	14292	-	14292	-
2012	14457	101%	15336	107%	13835	97%	14060	98%	15084	106%	15308	107%
2025	14739	103%	15945	112%	13365	94%	13917	97%	16353	114%	17231	121%
2050	15472	108%	17331	121%	13492	94%	14698	103%	19297	135%	21157	148%
Oilseed rape												
2002	1205	-	1205	-	1205	-	1205	-	1205	-	1205	-
2012	1256	104%	1520	126%	1241	103%	1308	109%	1284	107%	1352	112%
2025	1331	111%	1694	141%	1289	107%	1455	121%	1400	116%	1665	138%
2050	1517	126%	2077	172%	1485	123%	1848	153%	1679	139%	2239	186%
Sugar beet												
2002	15208	-	15208	-	15208	-	15208	-	15208	-	15208	-
2012	14398	95%	13883	91%	14638	96%	13944	92%	16033	105%	16094	106%
2025	13410	88%	12219	80%	13739	90%	12369	89%	17203	113%	17442	115%
2050	11696	77%	9818	65%	12203	80%	10147	82%	19839	130%	20346	134%
Potatoes												
2002	5525.85	-	5525.85	-	5526	-	5526	-	5526	-	5526	-
2012	5435	98%	5262	95%	5515	100%	5283	96%	6001	109%	6022	109%
2025	5342	97%	4904	89%	5451	99%	4954	94%	6713	121%	6793	123%
2050	5254	95%	4445	80%	5423	99%	4554	92%	8472	153%	8641	156%

In terms of other arable crops and vegetables, under both BAU and WM scenarios protein peas and beans are projected to decline, as protein becomes cheaper to import, while vegetable production will increase in line with a growing preference for healthy food. Barley production will increase in the BAU, but decrease in the WM scenario, largely reflecting the increased trade of cereals assumed under the WM conditions (Table A1.17).

Table A1.17: Demand for barley, peas, beans and vegetables (carrots) in 2002, 2012, 2025 and 2050 under BAU and WM scenarios

	BAU		World Markets		National Enterprise	
	Domestic consumption (000 tonnes)	Domestic consumption as a proportion of 2002 (%)	Domestic consumption (000 tonnes)	Domestic consumption as a proportion of 2002 (%)	Domestic consumption (000 tonnes)	Domestic consumption as a proportion of 2002 (%)
Barley						
2002	6200	-	6200	-	6200	-
2012	6368	103%	6066	98%	6592	106%
2025	6622	107%	5925	96%	7189	116%
2050	7230	117%	6075	98%	8720	141%
Peas (protein)						
2002	249	-	249	-	249	-
2012	192	77%	210	84%	273	110%
2025	183	74%	163	66%	293	118%
2050	161	65%	103	41%	418	168%
Beans (protein)						
2002	618	-	618	-	618	-
2012	477	77%	521	84%	680	110%
2025	455	74%	406	66%	728	118%
2050	400	65%	256	41%	1040	168%
Vegetables/carrots						
2002	2721	-	2721	-	2721	-
2012	2858	105%	2890	106%	2833	104%
2025	3072	113%	3156	116%	3004	110%
2050	3638	134%	4101	151%	3431	126%

Source: Morris et al., 2005

Table A1.18 shows that demand for meat will increase under both scenarios for all types of meat. This is driven largely by an increase in income, which will in turn increase meat consumption. Poultry meat will remain the most popular meat the increase in consumption will outstrip the increase in consumption of other meats, reflecting a growing preference for white over red meat.

Table A1.18: UK demand for beef, dairy milk, sheep meet and chicken meat in 2002, 2012, 2025 and 2050 under BAU and WM scenarios

	BAU		World Markets		National Enterprise	
	Domestic consumption (000 tonnes)	Domestic consumption as a proportion of 2002 (%)	Domestic consumption (000 tonnes)	Domestic consumption as a proportion of 2002 (%)	Domestic consumption (000 tonnes)	Domestic consumption as a proportion of 2002 (%)
Beef						
2002	651	-	651	-	651	-
2012	704	108%	697	107%	725	111%
2025	780	120%	751	115%	838	129%
2050	958	147%	898	138%	1126	173%
Dairy milk						
2002	14117	-	14117	-	14117	-
2012	14464	102%	14241	101%	14946	106%
2025	14947	106%	14253	101%	16136	114%
2050	16046	114%	14753	105%	18882	134%
Sheep meat						
2002	306	-	306	-	306	-
2012	322	105%	334	109%	349	114%
2025	346	113%	373	122%	416	136%
2050	405	132%	488	160%	595	195%
Pork						
2002	718	-	718	-	718	-
2012	771	107%	807	112%	824	115%
2025	849	118%	935	130%	991	138%
2050	1044	145%	1315	183%	1442	201%

Source: Morris et al., 2005

In a separate study, Arnoult et al. (2010) estimated the land use implication of improving the healthiness of the average UK diet. They imposed nutritional input constraints, recommended by the UK Department of Health, on the average UK diet and modelled the resulting demand for agricultural commodities and the implications for land use. The diet optimisation meant a large decrease in consumption of cheese and sugar-based products, along with lesser cuts of fat and meat products. Conversely, consumption of fruit and vegetables, cereals, and flour would increase to meet dietary fibre recommendations The impacts on land use was largely to increase vegetable and fruit production, decrease the land area used as pasture, with the cereal and oilseeds area being little affected. This had implications for the regional variation of the value of agricultural output. Those regions largely used for such a shift in demand would dramatically affect production patterns: arable dominated landscapes would be little affected, but there would be more focus on high margin horticultural crops. However, pastoral landscapes would suffer through loss of grazing management and, possibly, land abandonment, especially in upland areas.

8. Conclusions

This appendix reviewed the UK definition of food security and how the peatland case study areas contribute towards this goal. Food security, as defined by Defra, is the extent to which the UK can secure an ample supply of sustainably produced, nutritious food. Defra takes a broad view of the food supply, including domestic and international sources, and incorporates measures to make the food chain more efficient, such as the development of new refrigeration techniques, or reducing food waste. An important element of food security is self-sufficiency, the extent to which UK food demand can be satisfied from domestic sources; it is through this criterion that food production in the peatland case studies contributes to UK food security.

Collectively, the three peatland case studies cover 0.9 per cent of the total UK agricultural area; provide 2.8 per cent of the total wheat area, 12.6 per cent of the sugar beet area, almost 1 per cent of the oilseed rape area; 7 per cent of potatoes, and 8 per cent of the horticulture area. However, excluding the Cambridgeshire Fens, the case study areas make up a very small percentage (0.2 per cent) of the total UK agricultural area. The Cambridgeshire Fens contributed approximately 2.5 per cent of UK land used to grow wheat, 12.2 per cent of the land under sugar beet, 7 per cent of land used for potato production, 3.5 per cent of the area used to grow Linseed and 4.5 per cent used for horticulture.

Including only the peat soils from the case study area, agricultural activity in the Humber head, Lyth valley and Somerset case studies makes up less than 0.8 per cent of UK total. However, the peat soils on the Great fen are disproportionately productive accounting for a small percentage of UK agricultural land use, but producing approximately 3.5 per cent of UK peas for harvesting dry; 2.5 per cent of UK sugar beet; 2 per cent of UK potatoes; and 3.7 per cent of UK field vegetables. The contribution of value from the peat soils in the great fen as a proportion of the UK totals for each commodity are of the same order as the proportions for land use with the exception of horticulture, which makes up only a small proportion of UK horticultural land use, but contributes approximately 1.5 per cent of the value of the UK horticultural crops.

This appendix also identified long term trends in food consumption that look set to continue into the foreseeable future. The aggregate energy consumed through food is following a downward trend, associated with declining levels of physical activity. Specifically, there are downward trends in the consumption of potatoes, bread and red meat consumption. There are also trends associated with government policy and increased incomes that are pushing fruit, vegetables and white meat on upwards trends. This has implications for production on peat soils. Peats soils are relatively more fertile and as such as good growing mediums for vegetables. With consumption of vegetables set to increase, these soils may continue to have strategic importance. Furthermore, the Cambridgeshire fens are also nationally important for potato production and sugar beet. All these crops have the potential to move to other areas if the peat soils are removed to production, except sugar beet. Sugar beet production is located close to the sugar refineries and moving production away from these centres would be inefficient.

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Appendix 2: Conditions for peat formation and conservation and rates of peat wastage

Hydrological requirements:

Peat can only form where oxidation of organic matter is restricted due to saturated or near saturated conditions. Therefore under a "peat formation" scenario there should be:

- High and stable water table. Price and Whitehead (2001) and Lucchese et al. (2010) suggested that a mean water table position within 25cm of the ground surface was required.
- High soil moisture content in the unsaturated zone. Price and Whitehead (2001) suggested >50% by volume, i.e. close to saturation.

Timmermann et al., (2006) observed that the spread of peat forming plants was largely restricted to long-term, shallow inundated sites.

Vegetation requirements: Peat formation requires a continuous supply of organic matter, therefore to maximise peat formation vegetation should not be removed by cutting (harvesting) or grazing. Water quality is also of great importance (Gorham & Rochefort, 2003) in determining the type of vegetation. Nutrient rich water will lead to domination by tree species (and potentially drying out of the surface layers).

Therefore, the peat formation scenario is not compatible with agricultural production because:

1. Agriculture leads to the removal of organic matter (cropping, grazing)
2. High water tables and wet soil conditions are not compatible with cropping or grazing due to impacts on plant growth and risk of poaching.

Peat loss is associated with drying out of the peat surface and loss of peat due to oxidation and wind erosion. This can be limited by (seasonally) high water tables and would be compatible with low intensity livestock grazing.

Price and Whitehead (2001)
Distinct hydrologic conditions were observed where *Sphagnum* has successfully recolonized, providing a basis for establishing thresholds that can be targeted by peatland restoration managers. Sites where *Sphagnum* mosses recolonized were characterized by high water table (mean-24.9 ± 14.3 cm), soil moisture (ϕ) > 50%, and soil-water pressure (Ψ)$\geq$ 100 mb.

Gorham & Rochefort (2003)
According to Price and Whitehead (2001), hydrologic conditions where *Sphagnum* has recolonized block-cut trenches on a cutover peatland suggest three threshold conditions for its re-establishment: high water-table (mean –29 ± 14 cm), soil moisture > 50%, and soil water-pressure –100 cm for the whole season, allowing the moss to extract water from the decomposed and compacted cutover peat.

McNeil & Waddington (2003)
While blocking ditches will raise the water table level, the physical characteristics of deep peat (i.e. catotelm) will impede constant water table levels (Price & Whitehead 2001). It may be that fluctuations will remain problematic until a sufficiently deep acrotelm has been regenerated. However, it is not yet known what thickness of Sphagnum layer is needed to stabilize the water table.

This research demonstrates that restoration of cutover peatlands must include companion species and a constant moisture supply above the minimum threshold for Sphagnum mosses.

Timmermann et al., 2006
The assumed significance of site hydrology for secondary succession after rewetting (e.g. Roth et al. 1999) has again been proved in this study.

Within the period of early succession we investigated a significant spread of potentially peat-forming plants was largely restricted to long-term shallow inundated sites. Restoration projects which aim to stimulate peat growth in restored species-poor grasslands should accordingly adapt the site hydrology.

Restoring a long-term peat growth within river valleys requires more than potentially peat-forming plants, namely a continuing rising water level which compensates for the gradual terrestrilization due to accumulation of peat or gyttja.

Lucchese et al. (2010)
We argue that a *Sphagnum*-dominated peatland can only be considered functionally 'restored' once organic matter accumulation has achieved a thickness where the mean water table position in a drought year does not extend into the underlying formerly cutover peat surface.

… high and stable water levels, which enable the slow decay of plant matter and transfer for storage into the catotelm. A healthy acrotelm is what links together these ecohydrological processes operating in natural *Sphagnum* dominated peatlands. It ensures that water table levels can be maintained high and above the catotelm even during periods of high water deficits such as those experienced in the summer months. In this manner, we argue that the successful restoration of a cutover peatland will be defined by the re-establishment of a functional acrotelm. In the short-term, the return of key moss species such as *Sphagnum* is the main goal of peatland restoration, and for this the hydrology of cutover sites must be manipulated to ensure adequate conditions are met for these non-vascular plants to grow (Gorham and Rochefort, 2003).

Hydrological ecosystem services

Peatlands provide a range of hydrological services associated with flood risk management , water quality and water balance, mainly depending on the type of land cover and land use (Table A2. 1).

Table A2.1. Hydrological ecosystem services

Service	Peat forming vegetation	Low intensity grass land	High intensity grassland	Arable	Horticulture
Flood risk management (*Value is very dependent on the position in the catchment and vulnerability of downstream receptors*)	Medium/Low Flood water storage may be incompatible with natural vegetation due to water quality. High water table means reduced below-ground storage and high runoff rates	Med / High Lower water table means more below ground storage. Grazing stock may be at risk from summer flooding	High Lower water table means more below ground storage. Well developed drainage networks means rapid evacuation of flood water Summer flooding causes less damage to conserved grass than grazing stock	High Lower water table means more below ground storage. Well developed drainage networks means rapid evacuation of flood water Arable crops tolerant of short-term, occasional flooding.	Low Flooding is incompatible with high value horticultural land uses.
Water quality	High Low nutrient input results in low leaching. Wetlands may serve to remove nutrients from surface waters	High Low nutrient input results in low leaching.	Medium Higher nutrient input results in some leaching.	Low High nutrient input results in significant (?) leaching.	Low High nutrient input results in significant (?) leaching.
Water balance	High High summer water tables may serve to sustain baseflow in drought conditions	High/Med Higher summer water tables may serve to sustain baseflow in drought conditions	Med Low summer water tables will not contribute to sustain baseflow in drought conditions	Med Low summer water tables will not contribute to sustain baseflow in drought conditions	Low Abstraction for irrigation may serve to exacerbate low flows during drought conditions.

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Review of Evidence of Peat Wastage.

In addition to the famous wastage at Holme Post described by Hutchinson (1980), Holman (2009) and Holman and Kechevarzi (2010) have collated other estimates of peat wastage:

- average wastage value in the Fens of 0.6 cm/yr for the 200 years of wind pump drainage and about 2.5 cm/yr for the later more intensive drainage and cultivation period (Fowler et al. 1931)
- peat wastage of 1.8 cm/yr over the period 1934-1962 at Shippea Hill, Isle of Ely (Clark et al., 1935 and Clark and Godwin, 1962)
- mean annual wastage of 2.5cm/yr at Bourne South Fen, Lincolnshire (Miers, 1970)
- mean annual wastage between 1952-1962 of 0.7 cm/yr for shallow peat (less than 90cm depth) and 2.1 cm/yr for deeper peat, based on a systematic grid pattern of peat depth measurement at 131 points across the southern area of the Fens (Herbert, 1971).
- mean wastage rate of 1.37 (±0.78) cm/yr between 1941-1971 at 14 sites across the Fens (Richardson and Smith, 1978). When the data was sub-divided between 1941-55 and 1955-1971, wastage rates were higher at all but one site in the earlier period
- mean wastage rates for ‘thick’ and ‘thin’ peat of 1.27 cm/yr and 0.19 cm/yr, respectively are used for drained lowland wetlands including the East Anglian Fens by Milne et al. (2006). Although ‘thin peats’ have depths of up to 1 m, the low wastage rate used by Milne et al. (2006) for this group is likely to reflect the inclusion of non-peat ‘Skirtland’ soils.
- Burton (1989) estimated a mean decline of 1 cm/yr at seven coincident sampling sites from surveys undertaken in 1961/2 and 1984/9 for the peat soils at the Arthur Rickwood Experimental Husbandry Farm (EHF) in Mepal Fen, Cambridgeshire.
- Burton (1995) reports mean annual wastage rates of 1.27 cm/yr at Fortreys Hall, Mepal Fen over 22 years (Mendham series) and 1.06 cm/yr at Conington over 18 years (Turbary Moor series)
- Mean wastage rates between 1982 and 2004 at Methwold Fen are reported by Dawson et al. (2010). The lowest rate (1.05 cm/yr) was found for fibrous peats underlain by Fen Clay, with the highest (1.21 cm/yr) being for humified peat without underlying Fen Clay. Fibrous peat without underlying Fen Clay had an intermediate wastage rate of 1.19 cm/yr.

- Brunning (2001) suggests that peat wastage in pasture fields in the Somerset Levels is occurring at rates of between 44 cm and 79 cm a century
- Studies in the Netherlands show land levels lowering by 1 cm yr^{-1} under normal agricultural use (Acreman and Miller, 2007)

Within assessment of recent peat wastage in the Fens and Humberhead peatlands, Holman (2009) and Holman and Kechevarzi (2010) used values of 0.1 – 2.1 cm/a, depending on peat thickness and land use.

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Appendix 3: Biodiversity Characteristics and Designations in the Peatland Study Areas

This appendix reviews the biodiversity and related designations in the peatland areas. This informed the assessment of existing land use, including the intensity of farming practices and the agricultural and environmental impacts of further peatland conservation and restoration in the Target Areas.

1. The Fens

The Fens are a low lying flat landscape dominated by intensive agricultural production. The area drains into the Wash Estuary. As with the Humberhead Levels there has been a long history of drainage going back to as early as the 14th century. The landscape is dominated by highly modified rivers, drains and ditches. To control flooding parallel water courses were created and the area known as washes between the drains could be flooded.

Fens occur in waterlogged conditions where they receive nutrients and water from the surrounding land and from rainfall. The type of peat that is formed can vary considerably depending on the vegetation type, reed or sedge or moss peats can be formed. Modification and destruction of the once extensive fen habitat by draining and conversion to agricultural land has left only small isolated remnants of the original fen vegetation.

Table 1 shows designations in the Fen Target Areas. Less than 1,000ha of fen habitat remain at Holme Fen, Woodwalton Fen, Wicken Fen & Chippenham Fen. Species-rich fen-meadows (NVC classification, M24 *Molinea caerulea – Cirsium dissectum*) listed under Annex 1 of the Habitats Directive (Table 2) is found at Chippenham Fen, while large areas of calcareous fens vegetation with *Cladium mariscus* are found at all three SAC sites.

Table 1 Designations within the Fen Target Areas

<table>
<tr><th>Site</th><th>SSSI</th><th>NNR</th><th>RAMSAR</th><th>SAC</th><th>SPA</th></tr>
<tr><td>Holme Fen</td><td>✓</td><td>✓</td><td></td><td></td><td></td></tr>
<tr><td>Woodwalton Fen</td><td>✓</td><td>✓</td><td>✓</td><td rowspan="3">✓*</td><td></td></tr>
<tr><td>Wicken Fen</td><td>✓</td><td>✓</td><td>✓</td><td></td></tr>
<tr><td>Chippenham Fen</td><td>✓</td><td>✓</td><td>✓</td><td></td></tr>
<tr><td>Nene Washes</td><td>✓</td><td></td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Ouse Washes</td><td>✓</td><td></td><td>✓</td><td>✓</td><td>✓</td></tr>
</table>

*Fenland Special Area of Conservation

Table 2. Selected Habitats Listed in Annex I of the EC Habitats Directive

- 7110 – Active raised bogs
- 7120 – Degraded raised bogs still capable of natural regeneration
- 7210 – Calcareous fens with *Cladium mariscus* and species of the *Caricion davalliance*
- 6410 – Molinia meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)
- 91EO – Alluvial forest with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanoe, Salicion albae)

The creation of the washes for flood storage has created nationally and internationally important sites for wintering wildfowl and nationally important sites breeding waterfowl at the Ouse and Nene washes including the Black Tail Godwit (*Limosa limosa icelandica*) and the Bewick's swan (*Cygnus columbius bewickii*) and an important area of unimproved neutral grassland.

The Fen Target Areas are not within a target area for Higher Level Stewardship (HLS). However the area does come under the East of England: Higher Level Stewardship Theme Statement. Nationally important wetland BAP priority habitats include; wet woodland, fens, reedbeds and coastal and floodplain grazing marsh. Restoration and creation of these priority habitats would have considerable impact on current agricultural practices (see Somerset Levels and Moors).

2. Humberhead Levels

The Humberhead Levels is a low lying flat landscape dominated by intensive agricultural production criss-crossed by dykes. The area is the floodplain of the rivers which drain into the Humber including the Rivers Ouse, Aire and Trent. There has been a long history of drainage in the area. It was started in the 1620s by the Dutch engineer Cornelius Vermuyden.

Habitat of conservation importance is very limited in this intensively farmed landscape. Thorne and Hatfield Moors are remnants of the once-extensive bog and fen peatlands which occurred within the Humberhead Levels. Very little of original bog surface has survived after large-scale peat extraction. Thorne and Hatfield Moors are designated under Annex 1 of the EU Habitats Directive (Table 3) as degraded raised bog still capable of natural regeneration. Peat is not currently forming in degraded bogs. The area is an important international site for European Nightjar (*Caprimulgus europaeus*) and is designated a Special Protection Area (SPA) under the EC Wild Birds Directive. Other important peatland sites include Haxey Turbary and Epworth Turbary where traditional strip peat cutting, known as Turbary, took place.

Table 3 Designations within the Humberhead Levels

Site	SSSI	SAC	SPA	NNR
Haxey Turbary	✓			
Epworth Turbary	✓			
Thorne Moor	✓#	✓	✓*	✓^
Hatfield Moor	✓	✓		

#Thorne, Crowle & Goole Moors SSSI *Thorne and Hatfield Moors SPA
^Humberhead Peatlands NNR

The Humberhead Levels are not within a target area for Higher Level Stewardship (HLS). However the area does come under the Yorkshire and the Humber: Higher Level Stewardship Theme Statement. Nationally important wetland BAP priority habitats (Table 4) include coastal and floodplain grazing marsh.

Table 4. UK Biodiversity Action Plan priority wetland habitats in Lowland England

- Coastal and floodplain grazing marsh
- Lowland fens
- Lowland raised bogs
- Reedbeds
- Wet woodland

As previously indicated improved and semi-improved grasslands that support intensive grazing and silage production they are rarely flooded even in the winter. Restoring or creating grazing marsh/wet grassland and providing habitat for wet grassland birds would directly affect intensive agricultural practices.

3. Somerset Levels and Moors

The Somerset Levels and Moors is an extensive area of wet grassland and wetland habitats along the floodplains of the Rivers Axe, Brue and Parrott and their tributaries. Table 5 shows the main designations. The area has a distinctive landscape of low-lying levels and moors interspersed by a large network of ditches and rhynes. Modification of the former fen system and areas of raised peat bog for agriculture and peat extraction has created an area of considerable conservation importance both nationally and internationally. The majority of the area is used for agriculture and a large part has been agriculturally improved to various extent. However there are areas which are less intensively farmed supporting species-rich communities including species-rich flood pastures (MG8 *Cynosurus cristatus* – *Caltha palustris* grassland) fen-meadows (M24 *Molinea caerulea* – *Cirsium dissectum* listed under Annex 1 of the Habitats Directive) (Table H.H) and hay meadows (MG5 *Cynosurus cristatus* –*Centaurea nigra* grassland).

Within the floodplain other types of floodplain grassland and washland vegetation is also found. Important but small areas of fen, reedbed, wet woodland and raised bog vegetation remain. The ditches and rhynes are important habitats for many aquatic invertebrates. The area is also an important international site for wintering wildfowl including the Bewick's swan (*Cygnus columbius bewickii*) and breeding waders such as Lapwing (*Vanellus vanellus*). The Somerset Levels and Moors is protected by a series of Sites of Special Scientific Interest (SSSI). It is also designated a Ramsar site and a Special Protection Area (SPA) under the EC Wild Birds Directive.

Table 5 Designations within the Somerset Levels and Moors

Site	SSSI	NNR^	RAMSAR	SPA
Westhay Moor	✓	✓	✓	✓
Westhay Heath	✓		✓	✓
Tealham & Tadham Moor	✓	✓	✓	✓
Chilton, Edington & Catcott	✓	✓	✓	✓

Shapwick Heath	✓	✓	✓	✓
Moorlinch	✓	✓	✓	✓
Kings Sedgemoor	✓	✓	✓	✓
West Sedgemoor	✓	✓	✓	✓
Wet Moor*	✓		✓	✓
West Moor*	✓		✓	✓
Southlake[*]	✓	✓	✓	✓
Curry & Hay Moor*	✓		✓	✓
Langmead and Weston Level[+]	✓			
North Moor[+]	✓			

* Clays or clay over peat soils; [+] Peat and clay soil
^ Parts of these sites are designated a NNR

The Somerset Levels and Moors is a priority target area for Higher Level Stewardship (HLS) management due to its significant contribution to both biodiversity and landscape objectives. Farmers are encouraged to maintain, restore or create grazing marsh/wet grassland, fen, reedbed and wet woodland habitats, protect and restore raised bog, and provide habitat for wet grassland birds (lapwing, snipe, redshank, curlew and yellow wagtail).

The main conservation objectives in the Somerset Levels and Moors are:

- Breeding waders;
- Wintering wildfowl;
- Species-rich plant communities;
- Aquatic invertebrates; and
- Wetland habitats including fen, raised bog, reedbed and wet woodland.

Wintering wildfowl require different water-depths. A mixture of splash, shallow (10cm – 30cm) and deep water (over 75cm) is needed during the winter months (December to February) to support shallow feeding species while other species such as Swans require water need deeper water. Breeding waders require areas which are free from water after March in order to breed but require shallow pools and the water table close (-20 cm to 0 cm) to the ground surface for feeding, and a varied vegetation structure of different heights.

The composition of plant communities is very sensitive to changes in water-regime, the position of the water-table, whether it fluctuates or is stable and the timing of inundation are all important factors. Improved and semi-improved grasslands that support intensive grazing and silage production are rarely flooded even in the winter. Restoring or creating grazing marsh/wet grassland and providing habitat for wet grassland birds would directly affect intensive agricultural practices. Creating extended periods of surface water during the winter for wildfowl and maintaining water-levels at or near the surface in the spring and summer for breeding waders would provide low-intensity summer grazing or hay for stock. Existing species-rich plant communities have developed under traditional low-input agricultural management and are of high conservation value. To safeguard the integrity of these sites it is important to continue appropriate water-management as well as hay cropping and/or grazing. Reedbed, fen and raised bog habitats require waterlogged conditions through most of the year, largely excluding agricultural production. Winter mowing for reed and traditional crops such as sedge thatch, litter and fodder can be provided.

4. Lyth Valley

The flat agricultural land of the Lyth and Winster Valleys along the floodplains of the Rivers Winster, Gilpin and Pool is characterised by small rectangular fields bounded by ditches and hedges and surrounded by steep limestone scarps of Whitbarrow, Scout and Cunswick Scars, the Kent estuary and Morecambe Bay. The Lyth Valley is largely agriculturally improved grassland although it is important area of floodplain grazing marsh for wet grassland birds. The extensive raised bog which covered the area has been largely converted to agriculture. However, raised peat bogs at Meathop Moss, Foulshaw Moss and Nicols Moss, all designated SSSIs and collectively known as Witherslack Mosses Special Area of Conservation (SAC) (Table 6), and some small fragments of raised peat bog in the northern part of the Lyth Valley still remain.

Table 6 Designation within Lyth Valley

Site	SSSI (ha)	SAC (ha)
Foulshaw Moss	✓	✓*
Meathop Moss	✓	
Nicols Moss	✓	

*Witherslack Mosses Special Area of Conservation

These raised bogs have developed from thousands of years of peat accumulation. They typically formed a raised dome which is fed by rainfall and are 1m - 2m higher than the surrounding agricultural land. They are very acid and poor in nutrients and support bog-mosses *Sphagnum* spp., cotton-grasses *Eriophorum* spp., heather *Calluna vulgaris* and the carnivorous sundews *Drosera* spp. The Mosses at Witherslack are designated under Annex 1 of the EU Habitats Directive as active raised bog and degraded raised bog still capable of natural regeneration. The European Commission define 'active' as 'supporting a significant area of vegetation that is normally peat-forming', and degraded raised bog capable of natural regeneration', as sites 'where there is a reasonable expectation of re-establishing vegetation with peat-forming capability within 30 years'. The mosses have been degraded by peat cutting and commercial forestry plantations, which are now being removed.

The Lyth Valley is in the Morecambe Bay Limestones priority target area for Higher Level Stewardship (HLS). Farmers are encouraged to maintain, restore or create lowland raised bog, fens and reedbed habitats, maintain and restore characteristic field boundary patterns, protect and restore and enhance the traditional damson orchards, and provide habitat for wet grassland birds (lapwing, snipe, redshank, curlew and yellow wagtail).

The main conservation objectives in the Lyth valley are:

- Raised bog;
- Wet grassland birds;
- Fen;
- Reedbed; and
- Traditional damson orchards

The raised bogs within the Lyth valley all support peat-forming vegetation. To continue the peat-forming process, a high and stable water-table must be maintained. Where agricultural land surrounding the raised bog is drained, water is drained more quickly from the raised bog. Removing drainage from the surrounding land will help maintain the water-table within the bog. The loss of agriculturally productive land would be offset by the possible environmental benefits from these changes including the reversion to grazing marsh or fen vegetation and suitable habitat for breeding waders.

5. Areas of Designations in the Target Areas

The designated areas in the Peatland Target Areas are given below ("n/d" means none designated).

East Anglian Fens

Site	SSSI (ha)	NNR (ha)	RAMSAR (ha)	SAC (ha)	SPA (ha)
Cam Washes	166.52	n/d	n/d	n/d	n/d
Holme Fen	269.4	269.4	n/d	n/d	n/d
Woodwalton Fen	208.64	210.31	208.13	618.64*	n/d
Wicken Fen	255.03	249.19	254.39		n/d
Chippenham Fen	155.56	112.42	112.13		n/d
Nene Washes	1512.38	n/d	1517.49	88.19	1517.49
Ouse Washes	2513.55	n/d	2469.08	311.15	2447.26

*Fenland Special Area of Conservation

Humberhead Levels

Site	SSSI (ha)	SAC (ha)	SPA (ha)	NNR (ha)
Haxey Turbary	14.38	n/d	n/d	n/d
Epworth Turbary	32.89	n/d	n/d	n/d
Thorne Moor	1919.04#	1911.02	2438.46*	2887.49^
Hatfield Moor	1420.25	1360.92		

#Thorne, Crowle & Goole Moors SSSI *Thorne and Hatfield Moors SPA
^Humberhead Peatlands NNR

Lyth Valley

Site	SSSI (ha)	SAC (ha)
Foulshaw Moss	346.84	486.81*
Meathop Moss	66.11	
Nicols Moss	93.71	

*Witherslack Mosses Special Area of Conservation

Somerset Levels and Moors

<table>
<tr><th>Site</th><th>SSSI (ha)</th><th>RAMSAR (ha)</th><th>SPA (ha)</th></tr>
<tr><td>Westhay Moor</td><td>521.74</td><td rowspan="12">6395.47</td><td rowspan="12">6395.47</td></tr>
<tr><td>Westhay Heath</td><td>26.38</td></tr>
<tr><td>Tealham & Tadham Moor</td><td>917.01</td></tr>
<tr><td>Chilton, Edington & Catcott</td><td>1085.17</td></tr>
<tr><td>Shapwick Heath</td><td>397.44</td></tr>
<tr><td>Moorlinch</td><td>226.61</td></tr>
<tr><td>Kings Sedgemoor</td><td>831.49</td></tr>
<tr><td>West Sedgemoor</td><td>1020.83</td></tr>
<tr><td>Wet Moor*</td><td>497.95</td></tr>
<tr><td>West Moor*</td><td>213.15</td></tr>
<tr><td>Southlake[#]</td><td>197.01</td></tr>
<tr><td>Curry & Hay Moor^</td><td>474.62</td></tr>
<tr><td>Langmead and Weston Level[+]</td><td>166.18</td><td>n/d</td><td>n/d</td></tr>
<tr><td>North Moor[+]</td><td>671.42</td><td>n/d</td><td>n/d</td></tr>
</table>

[#] Midelney clay over peat * Midelney and Fladbury clays
^ Alluvial clay over reed peat
[+] Peat and clay soil

6. Designations in the Target Areas

As noted elsewhere, peatlands are responsible for a wide variety of benefits of different types. Estimating the value of ecosystem benefits is stymied by both lack of physical data in terms of understanding what the quantity and quality of these benefits as well as their economic value.

Here, a benefit transfer approach was taken, supplemented with knowledge of the Target Areas. This necessitated quantifying the area of land that might be deemed to be providing different types of ecosystems services on peatlands. This was done by cross referencing the spatial data on peatlands with a variety of spatial data on land cover, land use and land designations within the Target Areas.

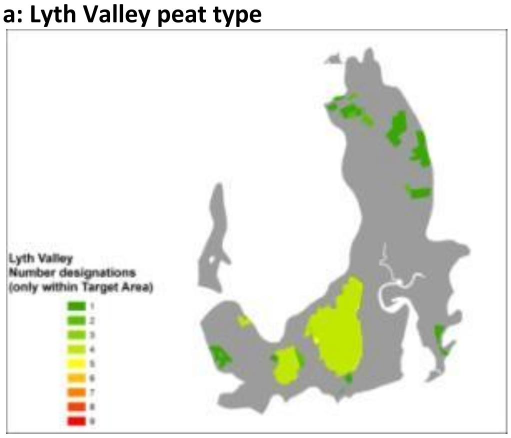
In order to calculate the area of land that might be assigned to different levels of ecosystems delivery, the following spatial data was mapped:

- AONB
- Coast floodplain BAP
- Countryside stewardship (Just HLS)
- Fen BAP
- Important bird area
- Local nature reserve
- Lowland meadows BAP
- Lowland raised bog BAP
- RAMSAR
- Reedbed BAP
- RSPB reserves
- SSSI

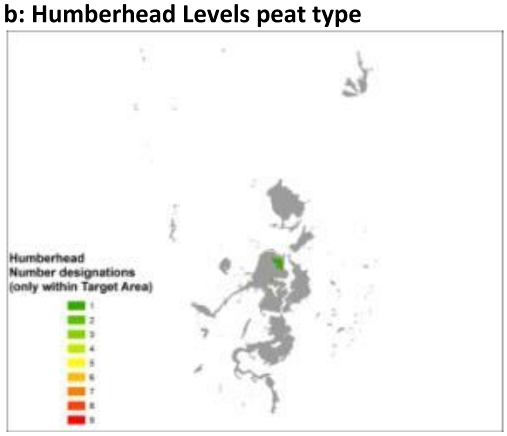
The mapping of these layers, in particular, the degree to which they overlap, are shown in Figure 1. The areas of these different layers and their area on the peats within the Target Areas are shown in the

Whilst the proportion of different types of agricultural land use was estimated from Defra statistics for 2004 (AgCensus data) and the LCM2000 data layer, the area of land that might be considered to provide high levels of benefits along the lines shown in Table (SSSIs in good condition) was calculated by taking the total SSSI.

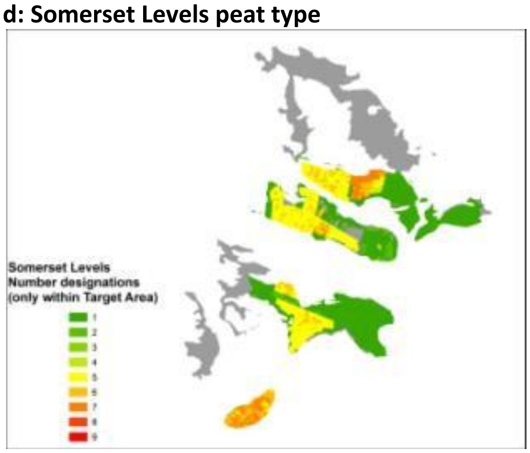
a: Lyth Valley peat type



b: Humberhead Levels peat type



d: Somerset Levels peat type



c: Fenland

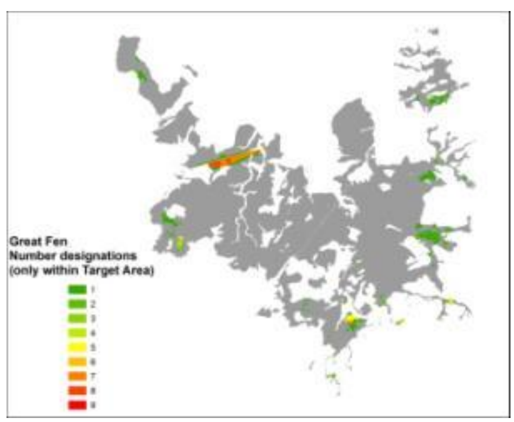


Figure 1 Number of Designations by Target Areas

Table 7 Target Areas: Stewardship and Designation Areas

	Fen	Lyth	Somerset	Humber
Total target area (ha)	34,869	1,284	23,996	673
Total target area in peat (ha)	20,545	612	13,545	364
Entry Level plus Higher Level Stewardship	1,202	55	2,356	0
Entry Level Stewardship	6,117	1	576	253
Higher Level Stewardship	1,346	416	325	0
Organic Entry Level Stewardship	264	0	71	0
Coastal floodplain BAP	1,847	194	11,947	1
Fen BAP	446	386	1,782	6
Lowland meadow BAP	1,093	0	1,330	0
Reedbed BAP	463	0	26	0
SSSI	2,086	383	6,342	6
RSPB reserves	1,824	0	2,788	0
RAMSAR sites	1,279	0	6,304	0
SPA	103	0	6,304	4
SAC	591	383	0	6
Lowland raised bog	0	396	387	7
Area of target are with non-peat soils (ha)	14,324	672	10,451	309
Proportion of target area with peat	59%	48%	56%	54%
Proportion of target area without peat	41%	52%	44%	46%
Area of peat on target area with no SSSI (ha)	18458.2	229.3	7203.1	357.5
Proportion of peat in target area with no SSSI	90%	37%	53%	98%
Total area designated	18,661	2213.9	40537.4	282.6
As a proportion of total area on peat	91%	362%	299%	78%
Total area considering overlap	5,852	571.8982	13057.53	214.8456
As a proportion of total area on peat	28%	93%	96%	59%

7. Peatland Habitats and Agricultural Systems

The agricultural and habitat characteristics of pealtands are strongly influenced by surface and soil water regimes. Table 8 (adapted from Rouquette et al, 2010) shows : the range of possible habitats and their hydrological requirements. This framework was further developed to estimate the crop type and yields, and livestock types and stocking rates for peatlands in the Target Areas under different scenarios.

Table 8: Selected possible peatland habitats and their hydrological requirements.

Habitats	NVC communities*	Summary of habitat and hydrological requirements	Typical prescriptions
Arable & horticulture:			
Root crops	OV9,13,14	Unable to tolerate inundation and requires low water table.	
Cereal & oilseed rape	OV7-11	Can tolerate occasional winter flooding only.	
Temporary leys	MG7a, b	Can tolerate occasional winter flooding only.	Sown highly productive grasslands - mown throughout growing season for silage / or providing grazing (high application of fertilisers – 150-300kg/ha N).
Permanent grass	MG6,7	Improved permanent pasture. Low risk of inundation and moderate to low water tables.	Permanent pasture often grazed in rotation throughout year usually by cattle (chemical fertiliser, 25- 150kg N plus inorganic fertiliser)
Wet grazing:		*Improved wet grasslands typically managed by low intensity cattle grazing.*	
Floodplain grazing marsh	MG13	Subject to frequent inundation in winter and spring, with water table falling for remainder of year.	Low-intensity summer grazing (mainly cattle) – nutrients deposited from flood water
Other rough grazing	MG9,10	Subject to regular inundation, moderate to poor drainage.	Usually grazed by cattle
Purple moor grass & rush pasture	M24,25	Periodic inundation but high water table year round.	Can be grazed by cattle April through to November (0.2-0.5 LU/ha/year)* or mown annually or biennially, sometimes managed by burning
Lowland meadows:		*Semi-natural neutral grasslands with low artificial inputs. Traditionally managed for hay with aftermath grazing.*	
Floodplain meadow	MG4	Well drained and subject to periodic winter flooding.	Cut for hay late June/July – the after-math (regrowth) grazed usually by cattle (0.5-2.5 LU/ha in the autumn) (sometimes horses/sheep) from mid-august (Lammas day – 12th August) onwards traditionally through

			the winter to Lady Day (25^{th} February) nutrients deposited from flood water
Old hay meadow	MG5	Traditional dry hay meadow.	Cut for hay late June/July – the after-math grazed (0.5LU/ha/yr)* often through the winter – farmyard manure applied in early spring every 3-5 years and sometimes lime added.
Water meadow	MG8	Subject to frequent winter inundation. Moderate to good drainage.	Traditionally grazed pasture from March/April onwards until autumn (some sites maybe shut-up for a hay crop taken in June/July).
Fen, marsh and swamp:			
Lowland Fen	S24,25, M27	Species-rich. Water above ground level for most of year.	Mown rotationally in summer (every four/five years) usually too wet for grazing. M27 - occasional mowing
Reedbed	S4	Dominated by *Phragmites australis* (common reed). Water above ground level year-round.	Winter cutting of reed from December/January (once flag leaf is shed) through to March (annual/biennial)
Woodland:			
Alluvial forest	W5-7	Wet woodland on neutral soils. Variable hydrological regimes but generally subject to periodic winter flooding and moderate to high water tables.	
Bog woodland	W2,4	Wet woodland on peat soils. Subject to frequent inundation in winter and spring and high water tables year-round.	

*NVC is the UK National Vegetation Classification community type.

Adapted from Rouquette et al, (in press)
Gowing et.al (2001);* Crofts, A. and Jefferson, R.G. (1999)

8. Environmental Stewardship

Restoration of Target Biodiversity Action Plan priority habitats in the four case study areas can largely be achieved through implementation current management options of the Higher Level Stewardship (HLS) Agri-environment Scheme. The extent to which they generate peat formation depends on the management of drainage and vegetation management for any associated agricultural use.

The scheme is however discretionary. Selected options and payment levels are shown in Table 9

Table 9: Selected HLS Options and Payments

Code	Option	Payment	Unit
	Options for boundary features		
HB14	Management of ditches of very high environmental value	£36	100
	Option for grassland		
	Management of grassland for waders and wildfowl		
HK9	Maintenance of wet-grassland for breeding waders	£335	ha
HK10	Maintenance of wet-grassland for wintering waders and wildfowl	£225	ha
HK11	Restoration of wet-grassland for breeding waders	£335	ha
HK12	Restoration of wet-grassland for wintering waders and wildfowl	£255	ha
HK13	Creation of wet-grassland for breeding waders	£355	ha
HK14	Creation of wet-grassland for wintering waders and wildfowl	£285	ha
	Options for wetland		
	Reedbeds		
HQ3	Maintenance of reedbeds	£60	ha
HQ4	Restoration of reedbeds	£60	ha
HQ5	Creation of reedbeds	£380	ha
	Fens		
HQ6	Maintenance of fen	£60	ha
HQ7	Restoration of fen	£60	ha
HQ8	Creation of fen	£380	ha
	Lowland raised bogs		
HQ9	Maintenance of lowland raised bog	£150	ha
HQ10	Restoration of lowland raised bog	£150	ha
	Options for orchards		
HC18	Maintenance of high-value traditional orchards	£250	ha
HC20	Restoration of traditional orchards	£250	ha
HC21	Creation of traditional orchards	£190	ha

Appendix 4: Towards an approach for peatland ecosystem valuation

1. Introduction

From an economic perspective, the environment is valuable in so far as it provides human welfare. Whilst some of the benefits it provides, such as food and raw materials are obvious and traded in the market place, commanding prices that reflect their value in use, many of the benefits are non-market goods and services which are enjoyed as public rather than private goods. Problems arise when beneficial yet often hidden flows of goods and services are lost due to over use or damage, with consequences for human welfare. In this context, the concept of ecosystems functions and services has emerged as a means of explicitly linking natural capital with social welfare. Natural capital supports a number of interrelated ecosystem functions (production, regulating, habitat, carrier, and information functions) which produce a variety of ecosystem goods and services that have value for humans (de Groot, 2002) (Figure 1) (Table 1).

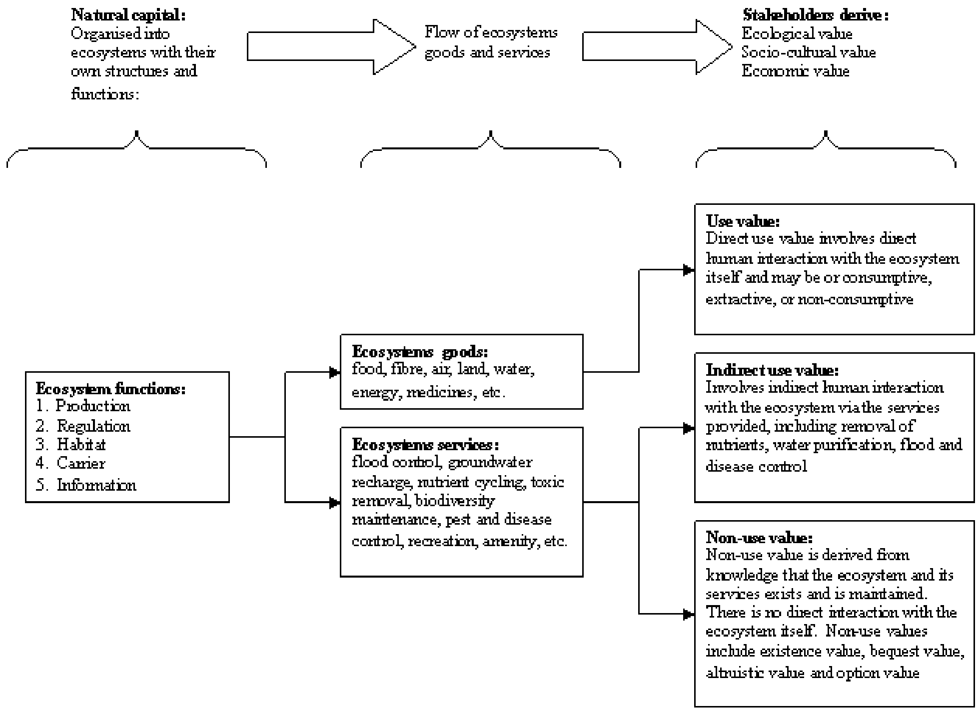


Figure 1: The relationship between natural capital, ecosystem services and stakeholders (developed from de Groot et al, 2002 and de Groot, 2006, Hawken et al., 1997, Newcome et al., 2005)

In peatlands, traded benefits accrue primarily to private owners. Non-marketed goods and services (e.g. wildlife habitat, archaeological archive, landscape character, water quality, flood water storage, climate regulation) tend to have indirect use value or non-use value and are consumed as public benefits (Figure 1). However, these are of significant importance to human health, well-being and prosperity (Defra, 2007b). Yet the many goods and service that flow from peatlands are under threat. In Europe, 100,000km^2 of peatland has been lost and the remainder are under threat (Rawlins and Morris, 2008). For example, in the UK Fens an estimated 16% of the peat stock recorded in 1850 remains and much of the remaining stock will be irreversibly degraded in the next two to three decades (Oats, 2002) and in the Somerset Levels, there has been extensive subsidence and shrinkage estimated to be 1 to 1.5 cm per year, even under extensive grazing regimes (Brunning, 2001). Despite this, the importance of UK peatland for example for storing carbon is still significant and the conservation of many peatland habitats is being promoted through the UK Biodiversity Action Plan, agri-environment schemes and other wider countryside measures.

In pristine peatlands, the decay of organic material is relatively slow. In their degraded state, however, this increases, leading to reduced carbon sequestration rates, or, in extreme cases, large losses of carbon through a combination of increased carbon emissions in gaseous as well as dissolved forms and losses of particulate carbon through soil erosion. Reducing carbon losses through restorative efforts has several benefits, for example, enhanced carbon sequestration which is important in climate regulation. Such sequestration can be given an economic value. For water companies, the potential economic gains of improving peatland condition may occur, for example, through lower operating costs due to reduced peatland erosion. Peatlands are especially important for their cultural and habitat services. They can play an important part in the aesthetics of the landscapes, and people's identity and sense of naturalness and the extent to which peatlands evoke these sentiments will influence the value placed on them. Peatlands are also major habitats for threatened species of animals and plants, and restoration efforts have focused on improving such habitat services.

The importance of such non-market benefits has been recognised in the natural environment Public Service Agreement (Defra, 2007b). Defra, in order to deliver against this agreement, is "committed to developing a more strategic framework for policy-making and delivery on the natural environment, based on the principals of an ecosystems approach" (Defra, 2007b). Much research has been commissioned to determine how this can be done. This, for example, has explored use of monetary and deliberative and participatory methods to determine social preference for ecosystem goods and services (e.g. Defra, 2007; Defra project: CTE0938), and has sought to understand how organisations are using an ecosystems approach in their own decision-making (Defra project: CTE0941). The steps required to value ecosystem services, for example, are mapped out in Defra's "impact pathway approach to valuation of ecosystem services" (Defra, 2007a).

A major challenge is to give the ecosystem services provided by peatlands an economic value. The following text develops an economic valuation as far as it can, of some of these benefits using the MA framework (Table 1) in accordance with many other valuation projects.

Table 1: The ecosystems framework as proposed by the MA (2006)

Provisioning services	Typical benefits
Fresh water	√
Food (e.g. crops, fruit, fish, etc.)	√
Fibre and fuel (e.g. timber, wool, etc.)	
Genetic resources (used for crop/stock breeding and biotechnology)	
Biochemicals, natural medicines, pharmaceuticals	
Ornamental resources (e.g. shells, flowers, etc.)	
Regulatory services	
Air quality regulation	
Climate regulation (local temperature/precipitation, GHG* sequestration, etc.)	
Water regulation (timing and scale of run-off, flooding, etc.)	
Natural hazard regulation (i.e. storm protection)	
Pest regulation	
Disease regulation	
Erosion regulation	
Water purification and waste treatment	
Pollination	
Cultural services	
Cultural heritage	
Recreation and tourism	
Aesthetic value	
Spiritual and religious value	
Inspiration of art, folklore, architecture, etc.	
Social relations (e.g. fishing, grazing or cropping communities)	
Supporting services	
Soil formation	
Primary production	
Nutrient cycling	
Water recycling	
Photosynthesis (production of atmospheric oxygen)	
Provision of habitat	

2. Ecosystem services of lowland peatlands

The synthesis below relating to the provisioning, regulating, and cultural services of peat has been synthesised from the Ecosystem Services of Peat project, report no SP0572

Provisioning services

In the UK, lowland peatlands provide an important range of food, fibre and fuel. Peatlands provide some of the most fertile land in the UK. The majority of lowland peatlands are used for some form of agricultural production and few lowland peatlands in the UK are still in their natural state[89]. In the lowlands, peats have been shaped by their conversion to arable and horticultural land and grazing of dairy and beef cattle in the lowlands. Peatland is converted to arable land through drainage and warping, and because it is productive, used for high value crops. Whilst lowland peatlands may be used for timber production, this is usually at a local level, and economically unimportant. For example, willow production used to be important in some lowland peatlands, but the advent of synthetic materials reduced the area of land under willow, which is now commercially produced mostly for hot air balloon baskets, cricket bats, charcoal and so on. A major material produced by lowland peat is the

[89] Bonn et al., (2010). Ecosystem Services of Peat – Phase 1. (SP0572). Report submitted to Defra 141 pp

peat itself. Once extracted, this may be used as fuel, or used as a soil dressing. Currently, extracted peat is used for horticultural purposes. Freshwater provision from peat is more important in the uplands and it has been suggested that upland catchments provide over 70% of the freshwater in Britain. In the lowlands, the role of peat in freshwater provision is relatively minor, except sometimes, where peat is allowed to exist in its natural state. For example, water is pumped from the Somerset Levels into the Huntspill River in summer to maintain baseflow levels.

Regulating Services

Much of the recent interest in peatland restoration stems from its importance in climate regulation. Whilst peatlands in their natural state may be a source of nitrous oxide and methane[90], UK peatlands are also thought to store over 5000 million tonnes of soil carbon, which is much greater than the 92 million tonnes that is stored in UK woodlands[91]. Land management particularly in the lowlands has generally caused the flux of greenhouse gasses from peat to increase. However, through appropriate management, it is possible to ensure that these fluxes can be greatly reduced and that peatlands can even be used to sequester atmospheric carbon. A recent study over three catchments (Migneint, Thorne & Hatfield, Somerset Levels) modelled the effect of different land management practices on greenhouse gases for a number of scenarios[92]. The results showed that whilst pursing a food security policy showed large net losses to the atmosphere, a variety of restoration options in fact resulted in the net sequestration of carbon large quantities of carbon. Methane emission may also be reduced through appropriate water level management and research on Tadham Moor suggested that whilst methane was produced when the water table was above 10cm from the soil surface, the moor was in fact a net sink for methane when water levels were below 10cm from the soil surface[93].

Flood risk management is of considerable importance to human wellbeing. However, the role of peatlands in this is not yet clear. Whilst peat in its natural state stores large quantities of water and peat forming conditions require very wet soil conditions throughout much of the year, peat catchments are subject to high peak flows and rapid increases and decreases in water flows, resulting in flood risk to downstream areas[94] and difficulties in providing consistent supplied of domestic water because of poor base flows[95]. Modelling research has suggested that this might be improved through appropriate revegetating of upland areas in order to reduced overland flow velocities in comparison with bare areas. In lowland areas, peatlands are not as likely to cause downstream flooding, but are more likely to be the

[90] Baird, A.J., Holden, J., Chapman, P.J. 2009. A literature review of evidence of emissions of methane from peatlands. Defra project report SP0574.

Bonn et al., (2010). Ecosystem Services of Peat – Phase 1. (SP0572). Report submitted to Defra 141 pp

[91] Milne, R., Brown, T.A. 1997. Carbon in the vegetation and soils of Great Britain. Journal of Environmental Management, 49, 413-433.

[92] Bonn et al., (2010). Ecosystem Services of Peat – Phase 1. (SP0572). Report submitted to Defra 141 pp

[93] Bonn et al., (2010). Ecosystem Services of Peat – Phase 1. (SP0572). Report submitted to Defra 141 pp

[94] Holden, J., Chapman, P., Evans, M., Hubacek, K., Kay, P., Warburton, J. (2007). Vulnerability of organic soils in England and Wales. Final technical report to DEFRA and the Countryside Council for Wales.

[95] Holden, J. (2005). Peatland hydrology and carbon release: why small-scale process matter. Philosophical Transactions of the Royal Society A 363, 2891-2913.

recipient of floodwater from other areas, acting as a potential area for floodwater storage[96], therefore acting to reduce downstream flooding. Use of this service can reduce peak flows in rivers resulting in enhanced wellbeing in so far as flood damage and possibly loss of life is reduced. In the UK, there is increasing interest in finding and designating areas and making arrangements with farmers to use floodplains adjacent to rivers to store floodwater water. The Parrett Catchment Project is a case in point, and is seeking to understand what is needed to implement and increase storage capacity by 392,000m^3 [97].

Peatlands are known to affect water quality and have significant implications, in particular in upland peatlands, where they are known to be able to buffer or store atmospheric pollutants such as sulphates and nitrates, which can help to reduce problems of acidification and eutrophication. This is aided by conditions that favour good vegetation management of Sphagnum and other bryophytes. Removal of vegetation either through burning or acid rain can contribute to the problem. However, it is possible for peatlands in good condition to create ecosystem "dis-services" in the form of dissolved organic carbon and particulate organic carbon. Whilst providing some benefits for aquatic ecosystems, dissolved organic carbon is expensive to treat. Particulate organic matter causes problems in terms of reduced landscape quality as well as reduced water quality and reservoir life. With the exception of dissolved organic carbon, it is likely that most of these water quality problems can be improved through peat restoration options.

Cultural services

Peatlands provide a range of cultural services to society in terms of enjoyment of biodiversity, landscape, and recreation. Peatlands, in particular, upland peatlands, are therefore a major tourist destination for many people and the benefit that society gains from this is reflected in policy that created the Countryside and Wildlife Act (1949) and the European Landscape Convention (2000). Recreational activity is particularly important for millions of people in the UK. This may be determined by access opportunities, as well as visitor access to information and the provision of visitor facilities, such as car parks, visitor centres, and boardwalks, paths, bridleways and so on. Whilst many millions of visitors may visit the uplands, bird-watching and fishing may be important in lowland peatland areas. Many thousands of visitors come to see the 6-10 millions of starlings that roost in the Brue Valley in the Somerset Levels study site. A variety of fish potentially exist in lowland areas, such as Dace, Eel, Chub, Brown Trout and Salmon par (EA, 2008) and in England and Wales, it has been estimated that over £2.7 billion was spent on freshwater fishing in 2005 (EA, 2006). Shooting is also a popular recreational activity with some people. In the UK as a whole, 47,000 people are thought to take part in grouse shooting. However, this is restricted to upland areas.

Deleted: Par

Deleted: generally more common in

Visitors may also come for the open views that are provided in low lying wetland landscapes, and access to these landscapes can be improved through paths, bridleways, and cycle routes. Educational opportunities are important, and lowland peatlands provide the opportunity for children and adults alike to learn about many different aspects of the natural and historic environment. As noted above, good access and visitor facilities can enhance this service.

[96] Bonn et al., (2010). Ecosystem Services of Peat – Phase 1. (SP0572). Report submitted to Defra 141 pp

[97] Bonn et al., (2010). Ecosystem Services of Peat – Phase 1. (SP0572). Report submitted to Defra 141 pp

Of particular importance is the ability of peat to preserve organic material. This has especial importance in archaeology and palaeoecology. The natural and manmade remains in peat have therefore provided many of the objects through which we understand our cultural history as well as the ecological changes that have occurred over the last 10,000 years (Simmons 2003, Olivier and Can der Noort, 2002). Some of the human artefacts are extremely old and rare. The most ancient plank boat in the world outside Egypt was found in the Humberhead Peatlands. Trackways over the bogs date back to Neolithic times and have been found in the Humberhead and Somerset peatlands. Prehistoric roundhouses have also been found in the Somerset Levels[98].

Within the MA, biodiversity is seen as a supporting service, on which other services are dependent. This is to prevent problems related to double-counting, in that the value of biodiversity to society is already captured in willingness to pay for recreational activities, for example bird watching, and spiritual pleasure in the existence value of biodiversity is more difficult to capture. Lowland peatlands are important areas for biodiversity and 116 of the threatened 555 species on the Red List for the UK are found in peatland areas, as well as various UK Biodiversity Action Plan Target Areas.

3. Valuing Ecosystem Services

A range of methods is used in valuation, broadly classified into two groups, economic and deliberative/participatory methods (Eftec, 2006). In the case of economic methods, where environmental goods and services are traded in the market place, market prices can be used to indicate value and consumer surplus. Where environmental goods and services are not traded in the market place, two broad categories of methods can be used: i) "cost and income-based" methods, which estimate the value of an environmental change through its effect on income or costs using market or related proxy prices, and shadow (alternative) project investment, and ii) "demand-based measures" which attempt to estimate willingness to pay or accept compensation for an environmental change. This comprises two main types, "revealed preference" whereby actual behaviour and willingness to pay provides the estimate of value, and "stated preference" whereby respondents are asked to express a willingness to pay in order to gain or avoid constructed, hypothetical but potentially real environmental options.

Deliberative and participatory methods attempt to elicit preferences for environmental goods and services through discourse and exchange. These include unstructured interviews, focus groups, panels, citizens juries, discussion fora, learning schools, away days and 'walk abouts' (sondeos), game playing, and various forms of interactive visualisation. Deliberative methods attempt to determine why individuals behave in particular ways or hold particular perspectives. Such approaches attempt to understand the process of decision-making itself, and to determine what individuals think are the appropriate actions for the achievement of social justice. In this respect, deliberative and participatory methods are different from economic methods insomuch as they attempt to consider the moral dimension of those preferences. A further difference is that, whereas economic methods tend to "treat preferences as pre-existing and stable constructs", deliberative and participatory methods tend to consider that "preferences about complex environmental matters are only formed through deliberation". Many of the methods involve the knowledge exchange between all participants, including 'experts' providing information in response to perceived need to know.

[98] Bonn et al., (2010). Ecosystem Services of Peat – Phase 1. (SP0572). Report submitted to Defra 141 pp

Table 2: Methods for the derivation of environmental values (Developed from Eftec, 2006)

Economic methods
Market price proxies use the prices that can be observed in markets to value environmental goods and services,
Production function methods rely on determination of the relationship between ecosystem goods and service and a marketed product and are used to capture indirect use value
Hedonic pricing uses the prices of traded commodities to determine the value of environmental characteristics that are thought to affect the price of the item. .
Travel cost uses costs, such as travel costs, entrance fees and time, incurred in visiting a particular site for recreation or other purposes as a proxy of the value of that site for the purpose.
Contingent valuation is a survey-based approach that constructs hypothetical markets to determine individual willingness to pay for environmental goods and services using a questionnaire.
Choice experiments/ modelling assess the extent to which preferences and willingness to pay are influenced by the level of attributes of environmental goods and services.
Random utility models are a subset of choice modelling that considers the variability of factors influencing values and preferences.
Deliberative and participatory methods
Personal survey approaches involve unstructured interviews can could be used to explore respondent views about environmental valued.
Focus groups bring together to jointly discuss and possibly rank preferences on issues of environmental change.
Citizen's juries involve groups of representative citizens that reach a judgement about a particular environmental option.
Health-based methods measure the impact of an alteration to the flow of ecosystem goods and services on health, in terms of quality of life and life expectancy, sometimes linked to income lost.
Q-methodology is a survey-based approach that attempts to understand how patterns of values and perceptions on the environment that are shared.
Delphi survey and systematic reviews involve the derivation of successive rounds of expert opinion on particular environmental goods and services.

Since collecting economic valuation data is expensive and time-consuming, a more recent development has been to collect data on social preferences and compile them in databases[99] or environmental accounting systems[100] for use in research and policy-making. In this way, data derived from a "study site" is transferred for use at a "policy site" so that they can be used in equivalent circumstances, a process termed 'benefits transfer' (Defra, 2007). In practice, the number of studies on ecosystem services specifically relating to peatlands is small, limiting the use of benefit transfer values[101].

Table 3: Valuation data taken from Bonn et al. (2010), Jacobs (2008), Turner et al. (2008)

Reference	Indicator of value/cost	Valuation approach	Value
Water quality and supply			
NERA and Accent (2007)	Benefits from water quality improvements due to the Water Framework Directive	Contingent valuation	£44.5 to £167.9 per household per year (BT)
Johnstone and Markandya (2006)	Use value of rivers for angling in uplands and lowlands.	Travel cost method	CS value for a 10% improvement in specific river attributes is

[99] e.g. Environmental Valuation Reference Inventory (EVRI). http://www.evri.ca/

[100] e.g. Jacobs report (2007); Eftec report (2004)

[101] Bonn et al., (2010). Ecosystem Services of Peat – Phase 1. (SP0572). Report submitted to Defra 141 pp

			£0.04 to £3.93 per trip
Developed in the Jacobs report (2008)	Value of water in the environment as a "national average"		£0.29 m3
Hynes S. and Hanley N.(2006)	Recreational use value of white-water rafting in Ireland	Travel cost method	CS value of £220 per trip
Pretty et. al (2003)	Damage costs of freshwater eutrophication in England and Wales	Damage costs	£75-114.03 million per year
Developed in the Jacobs report (2008)	Damage to freshwater lakes in the UK	Damage costs	£56.91million per year in the UK
Spurgeon et. al (2001)	Value of public to pay for environmental benefits of having healthy fisheries in England and Wales.	Contingent valuation	£2.40 per household per year
Willis K.G. and Garrod G. (1999)	Recreational benefits (including angling benefits), of increasing flow of rivers in South-West England	Contingent valuation and choice experiments	Anglers WTP £3.80 per day
Developed in the Jacobs report (2008)	Surface water quality in rivers and transitional waters	Damage cost	£5.988 per km per year
Developed in the Jacobs report (2008)	nitrates in drinking water in England and Wales	Damage cost	£79.86 million per year
Developed in the Jacobs report (2008)	pesticides in drinking water in England and Wales	Damage cost	£56.91 million per year
Developed in the Jacobs report (2008)	Cryptosporidium in England and Wales	Damage cost	£37.40 million per year
Developed in the Jacobs report (2008)	Sediment in drinking water in England and Wales	Damage cost	£37.34 million per year
Downstream flooding			
Jacobs (2008)	Total economic value flood control and storm buffering benefits provided by a subset of England's habitats	Market value, consumer surplus and total WTP.	£1.2 million
Werrity 2002, Werrity and Chatterton 2004	Damage to property	Direct economic loss	Approximately £30 million for Tay/Earn flood in 1993 £100 million for Strathclyde flood in 1994
RPA (2005)	Household benefits of reduced flood impacts	Contingent valuation, choice experiment and cost-benefit analysis	Approximately £200 per household
Developed in the Jacobs report (2008)	Flood damage costs in the UK	Damage costs	£1.17 billion per year
Developed in the Jacobs report (2008)	Flood prevention measures in the UK	Defensive expenditure	£500 million per year
Carbon sequestration			
DECC (2009)	Marginal abatement costs required to reach UK target (target consistent approach)	Social cost of carbon	Short term traded price of £25 per tonne in 2020, with a range £14-31. Short term non-traded price of £60 per tonne, with a range of £30 to £90.
O'Gorman & Bann (2008)	Total economic value of benefits from woodlands and associated soils, wetlands and peatlands in England.	Market value, consumer surplus and total WTP.	£1007 million per annum
Developed in the Jacobs report (2008)	GHG emission including carbon, methane and nitrous oxide in tonnes of CO_2 equivalent per year		£25 per t CO_2 equivalent per year
Air quality regulation			
Developed in the Jacobs report (2008)	VOCs		£1,564 per t per year
Developed in the Jacobs report (2008)	Sulphur dioxide		£1,452 per t per year
Developed in the Jacobs report (2008)	PM10		£8,733 per t per year
Developed in the Jacobs report (2008)	Ammonia		£1,435 to £2,091 per t per year
Developed in the Jacobs report (2008)	NOx		£681 to 993 per t per year
Recreational opportunities			
Zanderson and Tol (2009)	Recreational value of forests	Meta-analysis of TCM	CS values of £0.45-£77.26 per

		method	trip
Liston-Heyes and Heyes (1999)	Value of day trip to Dartmoor National Park in England	Travel cost method	CS values of £10.18 to £13.28 per day trip
Bateman, I. et al., (1992)	Average WTP to preserve present landscape. Service use: habitat, non-use value	Average WTP	Use value: £78 to £105 per person per year Non-use value of local population: £14.7 per person per year; Non-use value of the rest of UK: £4.8 per person per year
Foster, V et al., (1998)	Land purchases, species preservation and habitat conservation. Service use: habitat, rare or endangered species	Value of RSPB fund-raiser to protect reedbed habitat for bittern in Ramsey Island	£268,430 for the UK
Klein, R.J.T. and I.J. Bateman (1998)	WTP for recreational value of Cley Reserve. Service use: recreation, habitat	WTP a fee per visit or per household per year; WTP a tax per annum per party	WTP fee of £1.58 to £2.22 per visit or per household per year; WTP tax of £48.15 to £62.08 per party per annum
Willis , K.G. (1990)	Service use: recreation, habitat	WTP for preservation of current state of wetlands.	Total use value of £44 per ha Total non-use value of £807 per ha
Developed in the Jacobs report (2008)	Indirect use and non-use value of broad habitat types including non SSSIs and SSSIs in poor condition: neutral grassland, calcareous grassland, acid grassland		£90 per ha per year
Developed in the Jacobs report (2008)	Indirect use and non-use value of broad habitat types including non SSSIs and SSSIs in poor condition: fen marsh and swamp		£99 per ha per year
Developed in the Jacobs report (2008)	Indirect use and non-use value of SSSIs in good condition including: improved grassland, neutral grassland, calcareous grassland, acid grassland, fen marsh and swamp, and bog		£773 per ha per year

Benefit Transfer Models

Comprehensive estimates are not available of the economic value of the ecosystem services that are , or could be, provided by peatlands in the study areas. Because of the expense of carrying out site specific valuation studies, the ‘Meta-analyses’ of previously developed data sets has been developed to provide generic estimates of benefits that can be ‘transferred’ to previously un-surveyed sites. Table 4 contains a summary of such studies produced by Eftec, 2010, together with indicative values of benefits for selected services.

Table 4 Estimates of Wetland Benefits derived from Benefit Transfer Analysis (Source: Eftec, 2010)

Reference	*Study good*	*Definition of the Good*	*Study good site*	*Substitutes*	*Mean WTP (currency and year of data)*	*Population*
Brouwer et al. (1999)	Fresh and salt water wetlands	Mean WTP for all wetland functions relating to freshwater wetlands	US and other developed countries	Not considered	Mean WTP for freshwater wetlands = $73.48 per hectare ($2008 - OECD) Broad meta-analysis that derives values for specific wetland functions and wetland types	n=30 studies
Woodward & Wui (2001)	Wetlands	Value of single wetland functions only	North American and European studies	Not considered	$ per hectare (2001) Mean val. / Lower val. / Upper val. Flood 971 220 4317 Quality 1030 311 3405 Quantity 314 12.36 6353 Rec.fish 882 235 3316 Com.fish 1922 267 13882 Birdhunt 173 61.78 487 Birdwatch 2995 1305 6874 Amenity 7.41 2.47 34.59 Habitat 756 235 2424 Storm 586 27.18 12706	n=39 studies
WWF (2004)	Fresh and salt water wetlands	Value per ha per year Freshwater marsh	Global studies	Not considered	Average value derived from studies $3.83 ($2001)	n=89 studies
Brander et al. (2006)	Fresh and salt water wetlands, mangroves Freshwater woodland Freshwater marsh	Per hectare value of wetland type	Global source of studies	Not considered	$ 2000 Freshwater woodland: Median $206 Freshwater marsh: Median $145	n=80 studies
Troy & Wilson (2006)	Fresh water wetland	Value per ha per year	US studies only	Not considered	$8474 ($2001) Lower-upper band $ 18,979 - $ 38,167	n=42 studies (USA based)
Brander et al. (2008)	Fresh and salt water wetlands, mangroves, peat bogs	Value per ha per year	Based on global studies	Considered	Mean values not reported but function is available	n = 166
Ghermaldi et al. (2008)	Fresh and salt water wetlands, mangroves, peat bogs	Value per ha per year	European wetlands	Considered	€4129 mean value per hectare. Function described by Ghermaldi can be used within a function transfer for the policy site and a per ha value derived	n=166 studies yielding 265 observations)

Appendix 5: Benefit valuation of peatland restoration using a meta analysis approach

1. Value Transfer method

The approach presented by Brander et al. (2008) has been used to estimate the value of the restoration of peatlands for Target Areas in the East Anglian Fens, Humberhead Levels, Lyth Valley and Somerset Levels.

The procedure followed is described in detail for the case of The Great Fen project. The same approach has been used for the other Target Areas and the results are given.

2. The meta-analysis function

The function proposed in Brander et al. (2008) has been used to estimate the value of fen restoration. This function is the result of a meta-regression model of wetland values applied for 264 observations. Table 1 shows the explanatory variables used in the meta-regression model and the coefficients of each of these variables. This table also shows the variables that are included for The Great Fen project valuation.

Table 1: Economic value function for The Great Fen Project (adapted from Brander et al., 2008)

Constant	Coefficient value	The Great Fen: value of explanatory variable	Comments	Evidence
Wetland type	0.114 -1.356	Inland marshes Peatbogs	The Great Fen contains areas of “Raised bogs” equivalent to “Peat bogs” in Corine classification and areas of “Rich fens/reedbeds” equivalent to “Inland marshes”.	CEH Project C02041A. “CORINE Land Cover 2000: semi-automated updating of CORINE Land Cover in the UK
Economic valuation method	Various coefficients	0	Set to zero since the meta-analysis function is not being used to predict the value of an economic valuation study for the area	
Marginal or average value	1.195	0/1	Both will be tested	
Ln Wetland size	-0.297	Ln area(ha)	Ln (3594)	The target area is predominantly inland marsh
Flood	1.102	1	One of the aims of The Great	http://www.greatfen.org.uk/

control			Fen Project is to store flood water for the protection of the Middle Level System and properties	about.php
Surface and ground water supply	0.009	0/1	The target area will probably be a net user of water associated with retained summer water levels for restoration.	CEH Project C02069.2002. "Wildlife habitats and their requirements within the Great Fen Project" PACEC. 2004. "The Great Fen Socio Economic Study" http://www.greatfen.org.uk/about-management.php
Water quality improvement	0.893	1	Using the standard General Quality Assessment, water varied from "fairly good" to "poor": the project aims to improve this quality, reducing diffuse pollution from agriculture and nutrient recycling	CEH Project C02069.2002. "Wildlife habitats and their requirements within the Great Fen Project"
Recreational fishing	-0.288	1	The Great Fen provides recreational fishing	http://www.greatfen.org.uk/faq5.php PACEC. 2004. "The Great Fen Socio Economic Study"
Commercial fishing and hunting	-0.040	1	The area is mainly managed for natural conservation, no assumption of this service provision, but it is possible	http://www.greatfen.org.uk/about-business.php
Recreational hunting	-1.289	0/1	Recreational hunting is possible but only within limits that do not compete with conservation : limits: Test for this variable	PACEC. 2004. "The Great Fen Socio Economic Study" Recreational shooting – controlled
Harvest of natural material	-0.554	0/1	The Great Fen will be managed for wildlife conservation, but it also enables reed and sedge harvesting, commercial cutting and cutting for the benefit of wildlife: Test for this variable	http://www.greatfen.org.uk/about-business.php
Material for fuel	-1.409	1	Peat conservation is a major aim of the Great Fen creation, therefore there is no assumption of peat extraction service	http://www.greatfen.org.uk/about-importance.php
Non-consumptive recreation	0.340	1	The Great Fen is open to the public and has over 30 km of footpaths, for informal recreation including birdwatching	http://www.greatfen.org.uk/visit.php
Amenity and aesthetic services	0.752	1	The project enhances landscape and enjoyment of the countryside , including heritage and lifestyle benefits	http://www.greatfen.org.uk/visit.php

Biodiversity	0.917	1	The nature conservation is the key aspect of the project. The Great Fen has areas designated as Ramsar Site, cSAC, SSSI, NNR, GCR Site with habitats that are species rich	http://www.greatfen.org.uk/about-designations.php
Ln (GDP per capita (2003 US $))	0.468	ln 28735 $	Data downloaded from EUROSTAT database for Lincolnshire and East Anglia (area-weighted mean). Converted from € 2003 to US $ 2003	EUROSTAT database http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database
Ln (Population within 50 km)	0.579	ln 1712172	Population within 50 km radius.	http://casweb.mimas.ac.uk/ data downloaded from Casweb (ONS 2001 Census) in a CAS wards basis
Ln (Wetland area within 50 km (ha))	-0.023	5811	LCM2000	
		5124	CORINE2000	
		5466	Designated sites Test for variation	

Firstly, six different combinations have been tested, combining average and marginal values with the three data sources identified as wetland substitutes and with all services included. The calculations for the average and marginal value using LCM2000 as substitute sites are shown below:

3. Average value

The average value of The Great Fen is calculated from the parameters set out in table 1, by multiplying the coefficients with the value set for the fen and summing all the rows. The wetland type has been set to "Inland marshes".

$/ha/year= -3.078 + (0.114*1)- (0.297*ln(3594))+ (1.102*1)+ (0.009*1)+(0.893*1) -(0.288*1)-(0.04*1)-(1.289*1)-(0.554*1)-(1.409*1)+(0.34*1)+(0.752*1)+(0.917*1)+ +(0.468*ln(28735))+ (0.579*ln(1712172))-(0.023*ln(5811)) = ln 7.95

The result (7.95) of the function is in natural log terms, so it has to be transformed by raising the exponential to the power of 7.95.

Value = e^7.95 = 2844.3 $ per hectare per year (2003 US $)

Using an OECD Purchasing Power Parity exchange rate to convert $ 2003 into £ 2003 and inflated to 2010 £ using the Treasury GDP deflators (HM Treasury website):

$ 2,844.3*0.64= 1,820.3 £ 2003
1,820.3*1.20= 2,184.4 £ 2010

This calculated value is per hectare and per year. The aggregate value for all the Great Fen area will be:

2,184.4 *3,594 ha= 7,850,835 £/year

4. Marginal value

The procedure of calculation of the marginal value has been the same as for the average value. The exponential has been raised to the power of 9.1 (result of the function for marginal value) and the value has been transformed from 2003 US $ to 2010 £.

Value= e^9.1= 9396.3 $ per hectare per year (2003 US $)

$ 9396.3*0.64= 6013.7 £ 2003
6013.7*1.2= 7216.4 £ 2010

This calculated value is per hectare and per year. The aggregate value for all the Great Fen area will be:

7216.4*3594 ha = 25935688.9 £/year

The following table shows the different per hectare and per year values obtained for The Great Fen for different assumptions on substitute sites:

Table 2: Per hectare annual values for Great Fen for different substitutes sites sources

Value of Great Fen restoration in £/year	Marginal	Average
LCM2000	7216,4	2184,4
CORINE 2000	7237,3	2190,7
Designated sites	7226,5	2187,5

There is a large difference between the average and marginal valuation. However, the three methods used to obtain the substitutes sites give similar results, since the total area of substitutes achieved from the three datasets hardly differ between them. Next, a brief description of how each variable has been calculated is presented:

Income per capita

The values of real GDP per capita used in the meta-regression are estimated in US$ referring to the year 2003 (Brander et al., 2008). The income per capita information was downloaded from EUROSTAT database[102].

The Great Fen project area is located in Cambridgeshire county, that is, in East Anglia. According to the EUROSTAT database, the GDP per capita in 2003 € is 25000.

Table 3: GDP per capita in 2003 € for three counties of England for the period 1996-2004

GEO/TIME	1996	1997	1998	1999	2000	2001	2002	2003	2004
East Midlands (ENGLAND)	15400	19100	20400	21800	24400	25000	25900	24900	26600
Lincolnshire	14300	17600	17700	17900	19500	21300	22100	21400	22000
East Anglia	15800	19100	19900	21400	23900	24800	25800	**25000**	27100

[102] EUROSTAT: http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/

Using OECD purchasing power parity rate (Eftec, 2010), it can be converted from € to 2003 US $:

Converted to $ 2003 = 25000.55€ /0.87 = 28735.63218

Population within a 50 km radius

This information was downloaded using the Casweb extraction data tool. Data of population has been downloaded for the following counties:

Lincolnshire
Cambridgeshire
Norfolk
Rutland
Leicestershire
Northamptonshire
Suffolk
Hertfordshire
Bedfordshire

However, some information is missing. ONS 2001 Census Data for Milton Keynes is not available in Casweb and part of this county falls into the buffer area of 50 km radius (See figure 2).

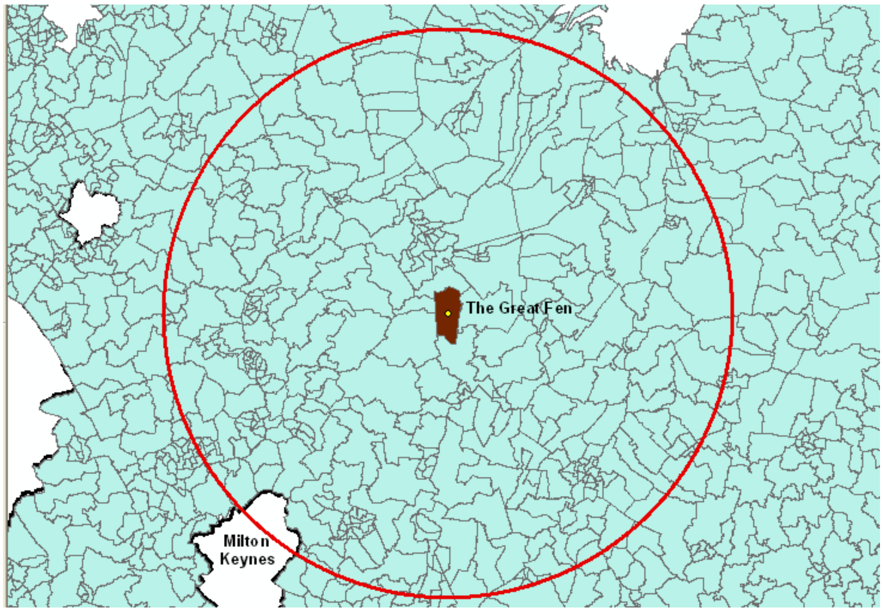


Figure 2: Counties with information of population density that fall within the buffer area

Casweb gives information of number of habitant per CAS wards, as well as specifying the number of males and females, people living in households or in communal establishments and the number of students away from home.

To calculate e average density within a 50 km radius, the total area with data of population within the buffer was calculated (7,796 km^2), as well as the total of people living there (1,707,119). Eventually, population density in inhabitants/km^2 was obtained by dividing the number of inhabitants by the total area.

Average population density= 1,707,119 / 7796 = 218 inhabitants per km^2

As the function input should be expressed in "inhabitants in 50 km radius in year 2000" (Brander et al., 2008). The population density was multiplied by the area of the circle of 50 km radius, that is $\pi * r^2$ ($3.1416*50^2=7,854\ km^2$):

218 inhabitant/km^2*7,854 km^2= 1712172 inhabitants

Substitute wetland sites

Substitute wetland sites are defined as the amount of wetland habitat within a 50 km radius of the target area.

In order to get information about the area of the substitute sites for The Great Fen project, we have investigated three different approaches: to use Land Cover Map 2000 produced by CEH, to use the CORINE 2000 land cover dataset and to use the designated wetland sites. The following categories have been selected as possible wetlands substitutes for each of the three approaches:

Approach 1. LCM2000

Land cover classes	LCM Number
Water (inland)	13.1
Saltmarsh	21.2
Bogs (deep peat)	12.1
Fen marsh and swamp	11.1

Approach 2. CORINE 2000

Land cover classes	Code
Inland marshes	4.1.1.
Peat bogs	4.1.2.
Salt marshes	4.2.1.
Salines	4.2.2.
Intertidal marsh	4.2.3.

Approach 3. Designation sites

Type of Designations
RSPB sites
Ramsar
BAP: Coast floodplain
BAP: Fens
BAP: Lowland raised bogs
BAP: Reedbed

The application of three different data sources will allow us to investigate the difference between them and the most accurate method.

For all the cases, the polygons containing the target categories present within the 50 km radius of the target area were selected (those wetlands falling within the target area were excluded) and the total area was calculated.

5. Applications for Lyth Valley, Humberhead Levels and Somerset Levels

This same approach has been applied for the Lyth Valley, Humber and Somerset Levels. Since the wetland substitutes area within a 50 km radius obtained with the three dataset are very similar, just one of them (LCM 2000) has been chosen to carry out the valuation of the rest of the peatlands.

The data collated on wetland size, population, GDP per capita and availability of substitute wetland sites for the rest of the peatlands are presented in Table 4:

Table 4: Data collected for peatland sites

	Great Fen	Lyth	Humber	Somerset (Middle Parret Floodplain)	Somerset (New Brue Bown)
Wetland size (ha)	3594	610	673	6878	12474
GDP per capita (€)	28735	24023	24885	25632	25632
Population density within 50 km (inhabitant/km2)	218	85	472	248	276
Total population	1712172	667590	3707088	1947792	2167704
Wetland substitutes sites within 50 km (ha)	5811	28566	6849	8416	8702

The results of the application of the meta-analysis function are summarized in the following table:

Table 5: Results of applying Brander et al (2008) meta-analysis function for 5 target peatlands

	Area of TA (hectares)	Average value in £/ha/year	Marginal value in £/ha/year	Aggregate average value in £/year	Aggregate marginal value in £/year
Lyth Valley (TA inside the peat)	610	1,901	6,280	1,159,549	3,830,636
Humber	673	5,233	17,289	3,522,134	11,635,574
Somerset1 (Middle Parret Floodplain)	6,877	1,430	4,723	9,833,369	32,485,102
Somerset2 (New Brue Boun)	12,473	1,505	4,972	18,772,305	62,015,394
The Great Fen	3,594	2,184	7,216	7,850,836	25,935,689

Due to the resulting values are much bigger than expected, a new assessment was carried out for each peatland. This time the valuation was done assuming the wetland type as peatbogs, since the 5 target peatlands have some area of peatbogs. The values obtained are much lower.

Then, it can be interpreted that the peatland values range from a low value (that for peatbogs valuation) and a high value (that for inland marshes). These ranges are presented in table 6.

Table 6: Estimate ranges for the 5 Target Areas (lowest value: peatbog assessment; Highest value: inland marshes assessment)

	Average value in £/ha/year	Marginal value in £/ha/year	Aggregate average value in £/year	Aggregate marginal value in £/year
Lyth Valley (TA inside the peat)	437-1,901	1,444-6,280	266,610-1,159,549	880,761-3,830,636
Humber	1,203-5,233	3,975-17,289	809,828-3,522,134	2,675,315-11,635,574
Somerset1 (Middle Parret Floodplain)	329-1,430	1,086-4,723	2,260,942-9,833,369	7,469,153-32,485,102
Somerset2 (New Brue Boun)	346-1,505	1,143-4,972	4,316,231-18,772,305	14,258,920-62,015,394
The Great Fen	502-2,184	1,659-7,216	1,805,107-7,850,836	5,963,276-25,935,689

The highest per hectare marginal values are that achieved for the Humber peatland (between 3,975 and 17,289 £/ha/year) and strongly differs from the Somerset, Lyth and Great Fen per hectare values (between 1,000 and 8,000 £/ha/year).

A table showing the relative contribution to the value of different coefficients in the meta-analysis function for each site is shown in Table 7. These results are achieved assuming marginal value and Land Cover Map 2000 as wetland substitutes sites. This table reflects how much each variable contribute to the final value and allows us to identify which parameters are responsible of the difference in per hectare values between sites. The highest contribution to the final value is given by population density within 50 km radius variable, followed by GDP. Such important contribution of population density to the final value is the main cause of the extremely high values achieved in this study: England is the most densely populated country in Europe (apart from small principalities), then the benefits assessed for English wetlands using this function are higher.

In terms of ecosystem services included, the final value is mainly influenced by "flood control", which adds value to the result and "material for fuel" as well as "recreational hunting", which rest value. Biodiversity is also an important service adding value.

Comparing the per hectare value for the different sites, the population within a 50 km radius area, together with the wetland size, seem to be the most important parameters in terms of variance in the final result. As it was pointed above, Humber peatland has the highest per hectare value and in Table 7 it can be seen that it is due to a combined effect of its large population density and its small size (Table 4). However, these considerations should be taken carefully since some of the variables are expressed in natural log terms.

Sensitivity analysis

Due to some uncertainties in the application of this model, a brief sensitivity analysis has been carried out in order to analyse the influence of the definition of the services provided. It has been focused on the following services:

- Surface and groundwater supply
- Recreational hunting
- Harvesting of natural material

Such services can be an issue when restoring wetlands since they can compete with wetland conservation. The level at which such services can be provided without producing a decline in wetland quality has to be explored. The difference between the estimate values of the peatlands providing and not providing these services has been studied. The type of wetland has been set to "Inland Marshes".

The per hectare marginal value of the 5 Target Areas are presented in table 6 for seven cases.

Table 6: Per hectare marginal value obtained for 7 different assumptions. Ticks cells represent the services that have been included in each test.

Services included	Case 0	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Surface and ground water supply		√	√	√				√
Recreational hunting	√	√		√	√			
Harvest of natural material	√		√	√		√		
Aggregate value (£/year)								
Great Fen	7,152	12,558	26,189	7,216	12,445	25,955	45,166	45,575
Lyth	6,223	10,928	22,790	6,280	10,830	22,586	39,304	39,659
Humber	17,134	30,087	62,745	17,289	29,817	62,183	108,210	109,189
Somerset (Middle Parret Floodplain)	4,681	8,219	17,141	4,723	8,145	16,987	29,561	29,828
Somerset (New Brue Boun)	4,927	8,652	18,043	4,972	8,574	17,881	31,116	31,398

The exclusion of "surface and ground water supply" doesn't cause a big change in the estimate value. However, the exclusion of "harvesting of natural material" as well as "recreational hunting" causes a large increase in the value. The effect of taking out "recreational hunting" is bigger than that produced by the extraction of "harvesting". The introduction of both services lead to a decrease in the aggregate marginal value of the peatland. The effect is similar for the 5 Target Areas.

For all the peatlands, the lowest value is obtained when "recreational hunting" and "harvesting of natural material" is included but "surface and groundwater supply" is not taken into consideration (Case 0). The highest value is that obtained when water supply is provided and recreational hunting and harvesting of material are set to 0 (Case 7).

The results of this test show a high variation in the estimate values depending on the provision of ecosystem services considered. This highlights the importance of choosing carefully the variables taken into account in the application of the meta-analysis function, especially those that have a high coefficient in the function, such as recreational hunting or material for fuel.

6. References

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7. Coefficient values for meta-analysis function

Table 7: The relative contribution of different coefficients for the meta-analysis function for each site

Variable	Value of explanatory variable for the Great Fen	Value of explanatory variable for Lyth	Value of explanatory variable for Humber	Value of explanatory variable for Somerset (Middle Parret Floodplain)	Value of explanatory variable for Somerset (New Brue Bown)	Somerset (New Brue Bown)
Constant	-3.08	-3.08	-3.08	-3.08	-3.08	-3.08
Wetland type	0.11	0.11	0.11	0.11	0.11	0.11
Economic valuation method	Various	0.00	0.00	0.00	0.00	0.00
Marginal or average value	1.20	1.20	1.20	1.20	1.20	1.20
Ln Wetland size	-0.30	-2.43	-1.90	-1.93	-2.62	-2.80
Flood control	1.10	1.10	1.10	1.10	1.10	1.10
Surface and ground water supply	0.01	0.01	0.01	0.01	0.01	0.01
Water quality improvement	0.89	0.89	0.89	0.89	0.89	0.89
Recreational fishing	-0.29	-0.29	-0.29	-0.29	-0.29	-0.29
Commercial fishing and hunting	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
Recreational hunting	-1.29	-1.29	-1.29	-1.29	-1.29	-1.29
Harvest of natural material	-0.55	-0.55	-0.55	-0.55	-0.55	-0.55
Material for fuel	-1.41	-1.41	-1.41	-1.41	-1.41	-1.41
Non-consumptive recreation	0.34	0.34	0.34	0.34	0.34	0.34
Amenity and aesthetic services	0.75	0.75	0.75	0.75	0.75	0.75
Biodiversity	0.92	0.92	0.92	0.92	0.92	0.92
Ln GDP per capita	0.47	4.80	4.72	4.74	4.75	4.75
Ln Population within 50 km	0.58	8.31	7.77	8.76	8.39	8.45
Ln Wetland area within 50 km	-0.02	-0.20	-0.24	-0.20	-0.21	-0.21
natural log terms		9.15	9.01	10.02	8.97	8.85
Value per hectare and per year (£2010)		7216.39	6279.73	17289.11	6026.92	5368.75

Appendix 6: Miscellaneous Text Tables and Figures

1. The acquisition and identification of data and information for the case study sites

A variety of data was identified and provided by the Natural England project officers to the Cranfield project team. This included a number of documents and website linkages as well as in particular a GIS shapefile and attribute table on the location of lowland peatlands and an indication of their use and condition. The Cranfield project team contacted the case study representatives on the 31 March 2010, with a request for data against an indicator list based on an ecosystems framework that would be useful for the research. This was necessarily broad in nature to scope the range of benefits that might be derived from peatlands.

2. Identification of lowland peatland areas

Early in 2010, the Natural England project officers circulate a GIS shapefile to Cranfield University. This showed the extent of lowland peatland areas in the UK, and has attached with it a variety of attributes, providing some indication of the condition of the peat and land use (Figure A6. 1).

Peatland status attributes
Afforested
Bare
Burnt
Cultivated
Eroded
Extracted
Gripped
Improved
Molinia
Overgrazed
Peat Cutting
Polluted
Pristine
Removed
Restored
Scrub
Semi-natural non peat forming
Wasted
Wooded

Figure A6. 1. The distribution of lowland peatland areas in England (provided by the Natural England)

3. Identification of four case study sites

During the inception meeting, it was suggested that different farming practices for land use on peatlands might include typical farming usage and management under intensive or extensive management. With the help of the project officers from Natural England, the project team agreed a set of four case study sites that are currently representative of a range of arable and livestock enterprises (Table A6. 1).

Table A6. 1. Selected case study sites and there characteristics

Site	Description
Somerset Levels	Currently in pasture, restoration mainly through HLS, with some continued agricultural production
Lyth Valley	Currently in pasture, restoration to floodplain grazing marsh, reedbed and fen with little or limited continued grazing production
Great Fen	Currently in arable and horticultural production, restoration to fen/grazing marsh/reedbed with little or no production
Humberhead Level	Currently in production (varied), restoration of areas to floodplain and fen lagg, with potentially significant ecosystem services benefits including flood protection

The peatland area for the four case study sites was extracted from the peatland area map (Figure A6. 2). There was some discussion with the project officers as to whether these should form the exact boundaries of the case study sites. Initially, it was thought that the project area boundaries should include adjacent areas of mineral soils which might be included within restoration boundaries. However, it was concluded that as the project objective are essentially to determine how restoration of current peatland affects food security and ecosytems goods and services, these areas should be restricted to those areas occuring on the peatland map (Figure A6. 2).

The one proviso however, was that the peatland areas identified should fall broadly within their appropriate landscape character areas. Consequently, the UK National Character Areas were overlain against the peatland areas extracted for the case studies as shown in Figure A6. 4. The results in Figure A6. 4 show that the peatland areas extracted fall almost wholly within their appropriate National Character Areas with only slight boundary infrigement of peatland into adjacent National Character Areas. A minor exception to this is in the case of the peatland area extracted for the Great Fens where a minor area of peatland lies outside “The Fens” and in the “North-west Norfolk” National Character Area. Consequently, it was agreed that these peatland areas could indeed form the basis of future analysis.

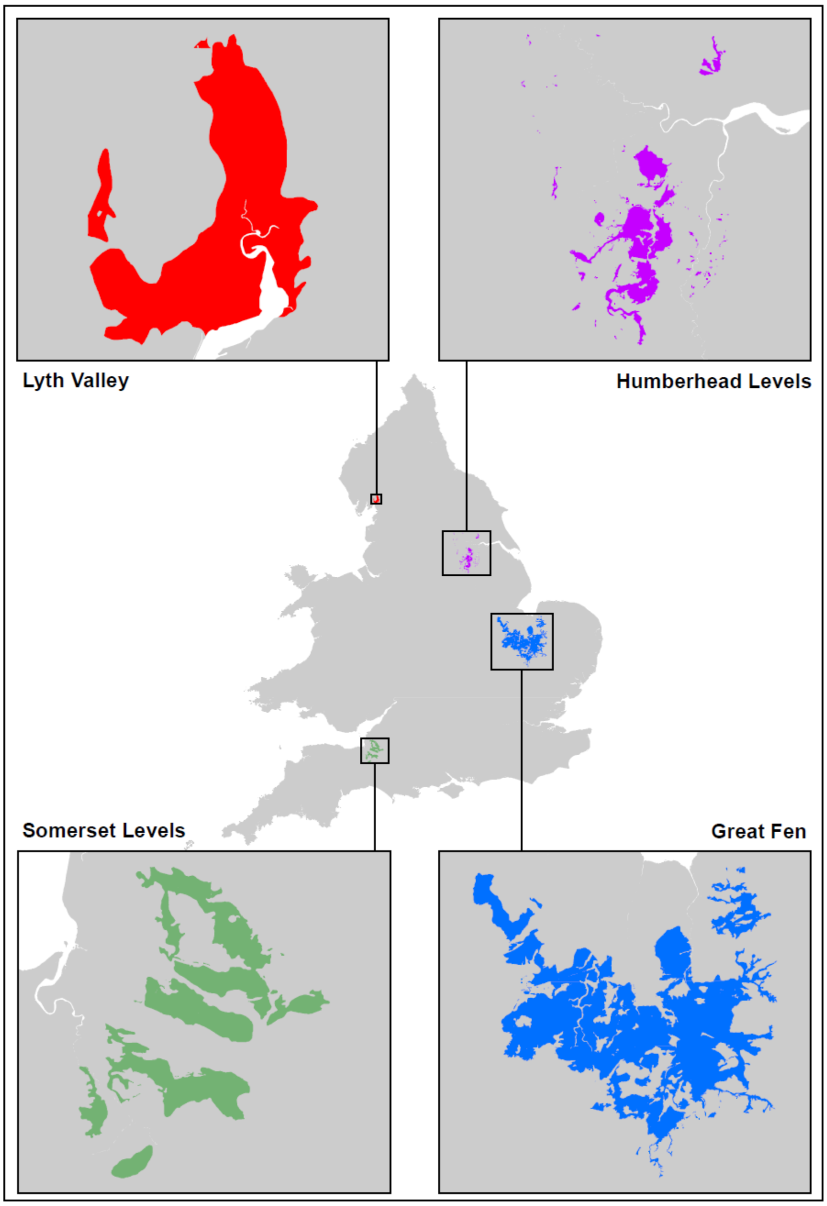


Figure A6. 2. Peatland areas extracted for each of the four case study sites from the Natural England data

4. Calculation of land use areas

Extracting land use data for these areas of peatlands using original Defra statistics is complicated by disclosure issues, since the ward level data appropriate for this scale of analysis is often suppressed to prevent identification of land use by individual or small groups of farmers. For this reason, data from the AgCensus project[103] was obtained. This is based on equations developed by the University of Edinburgh which make use of the Landuse Framework for interpreting the June Census data collected each year in the UK by the English, Scottish, and Welsh governments. The output is a spatial interpretation of land use data in 10km, 5km and 2km grids. In the case of England, the latest complete dataset is provided for 2004.

The 2km AgCensus gridded layer for England for 2004 was overlain against the peatland data for each of the case study sites. The data in each AgCensus 2km grid cell was weighted according to the proportion of that cell in the peatland area and the data for each case study aggregated. An example of this process for the East Anglian Fens is shown (Figure A6. 3).

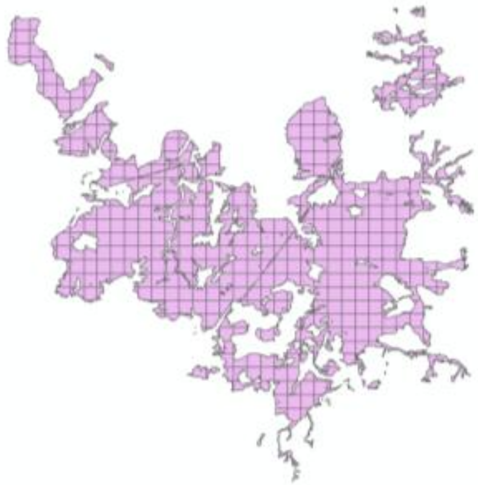


Figure A6. 3. The East Anglian Fen peatland area cross referenced with AgCensus 2km grid containing land use data for 2004

The land use areas were converted to a proportion of the total area of the peatland at each case study site (Table A6. 2) whilst the livestock data were converted to livestock units using livestock equivalent values from Nix (2009). The data confirms that the peatland areas of the Great Fens and Humberhead Levels tend to be dominated by crops whilst the Lyth Valley and the Somerset Levels are dominated by grazing. The data were crossed-referenced with data provided by Defra for the case study sites for 2009, and these showed that the broad areas for crops were similar.

[103] AgCensus: http://edina.ac.uk/agcensus/description.html

This is an initial analysis and it is worth noting that we do hope to be able to conduct a similar analysis with Tier 3 LCM data.

Table A6. 2. Areas of different land uses in the case study sites obtained from overlaying the lowland peatland map against the AgCensus 2km grid map

	Lyth Valley	Humberhead Levels	Great Fen	Somerset Levels
Area	3619.9	14234.2	132131.3	16126.8
Wheat	2.5%	22.0%	35.4%	3.9%
winter barley	0.1%	2.6%	1.7%	0.6%
spring barley	0.1%	2.6%	1.3%	0.3%
Oats	0.0%	0.1%	0.1%	0.1%
other cereals	0.0%	0.5%	0.1%	0.1%
Potatoes	0.0%	2.0%	7.6%	0.1%
peas & beans	0.0%	0.4%	0.7%	0.0%
all other vegetables	0.0%	3.4%	4.1%	0.1%
Top Fruit	0.1%	0.0%	0.1%	0.3%
hardy nursery stock	0.0%	0.0%	0.0%	0.0%
bulks & flowers	0.0%	0.0%	0.1%	0.0%
turnips etc	0.1%	0.0%	0.0%	0.0%
field beans	0.0%	0.8%	1.9%	0.3%
peas for harvesting dry	0.0%	1.8%	3.3%	0.0%
Maize	0.4%	0.1%	0.0%	2.7%
other crops for stockfeed	0.1%	0.2%	0.2%	0.1%
oilseed rape	0.0%	4.2%	2.6%	0.3%
sugar beet	0.0%	2.5%	10.8%	0.0%
Linseed	0.0%	0.8%	0.8%	0.1%
other arable crops	0.0%	0.1%	0.5%	0.2%
bare fallow	0.0%	0.4%	0.4%	0.1%
permanent grass	53.9%	3.7%	4.1%	56.1%
temporary grass	5.5%	2.9%	1.0%	6.9%
rough grazing (sole right)	11.6%	0.4%	1.3%	1.8%
Woodland	1.1%	1.0%	0.9%	0.6%
set-aside	0.0%	6.0%	6.4%	1.0%
broad beans	0.0%	0.0%	0.0%	0.0%
french beans	0.0%	0.0%	0.4%	0.0%
runner beans	0.0%	0.0%	0.0%	0.0%
Peas	0.0%	0.3%	0.4%	0.0%
Strawberries	0.0%	0.0%	0.0%	0.0%
Raspberries	0.0%	0.0%	0.0%	0.0%
Blackcurrants	0.0%	0.0%	0.0%	0.0%
Gooseberries	0.0%	0.0%	0.0%	0.0%
Blackberries	0.0%	0.0%	0.0%	0.0%
other small fruit	0.0%	0.0%	0.0%	0.0%
hardy nursery stock, bulbs & flowers	0.1%	0.0%	0.2%	0.0%
under glass or plastic (c15)	0.0%	0.0%	0.0%	0.0%

Table A6. 3. Livestock units in the case study sites obtained from overlaying the lowland peatland map against the AgCensus 2km grid map

Livestock density (lu ha^{-1} grassland)					
LU coefficient		Lyth Valley	Humberhead Levels	Great Fen	Somerset Levels
dairy herd	lu/ha	0.41	0.21	0.02	0.52
beef herd	lu/ha	0.09	0.16	0.21	0.11
heifers in 1st calf dairy	lu/ha	0.09	0.05	0.01	0.08
heifers in 1st calf beef	lu/ha	0.02	0.02	0.03	0.02
bulls 2 yrs & over	lu/ha	0.01	0.01	0.01	0.01
bulls 1 yr & under 2 yrs	lu/ha	0.00	0.00	0.00	0.00
female dairy herd replacement 1yr & over	lu/ha	0.09	0.03	0.01	0.08
female beef herd replacement 1yr & over	lu/ha	0.07	0.01	0.02	0.03
male over 2 yrs	lu/ha	0.01	0.01	0.02	0.05
female over 2 yrs for slaughter	lu/ha	0.00	0.00	0.01	0.04
male cattle 1 yr & under 2 yrs	lu/ha	0.07	0.10	0.10	0.11
female cattle slaughter 1yr & under 2 yrs	lu/ha	0.03	0.04	0.06	0.07
other cattle over 1yr	lu/ha	0.12	0.17	0.19	0.27
male calves under 1 yr	lu/ha	0.05	0.07	0.06	0.06
female calves under 1 yr	lu/ha	0.08	0.07	0.04	0.08
intended for slaughter under 1 yr	lu/ha	0.00	0.00	0.00	0.00
Ewes	lu/ha	0.20	0.10	0.06	0.05
other breeding sheep	lu/ha	0.02	0.01	0.01	0.00
Rams	lu/ha	0.01	0.00	0.00	0.00
other sheep	lu/ha	0.01	0.01	0.00	0.01
other sheep over 1 y	lu/ha	0.01	0.00	0.00	0.00
lambs under 1yr	lu/ha	0.10	0.04	0.02	0.02
dairy goats	lu/ha	0.00	0.00	0.00	0.00
non dairy goats	lu/ha	0.00	0.00	0.00	0.00
other goats	lu/ha	0.00	0.00	0.00	0.00
Total	**lu/ha**	**1.50**	**1.13**	**0.87**	**1.61**

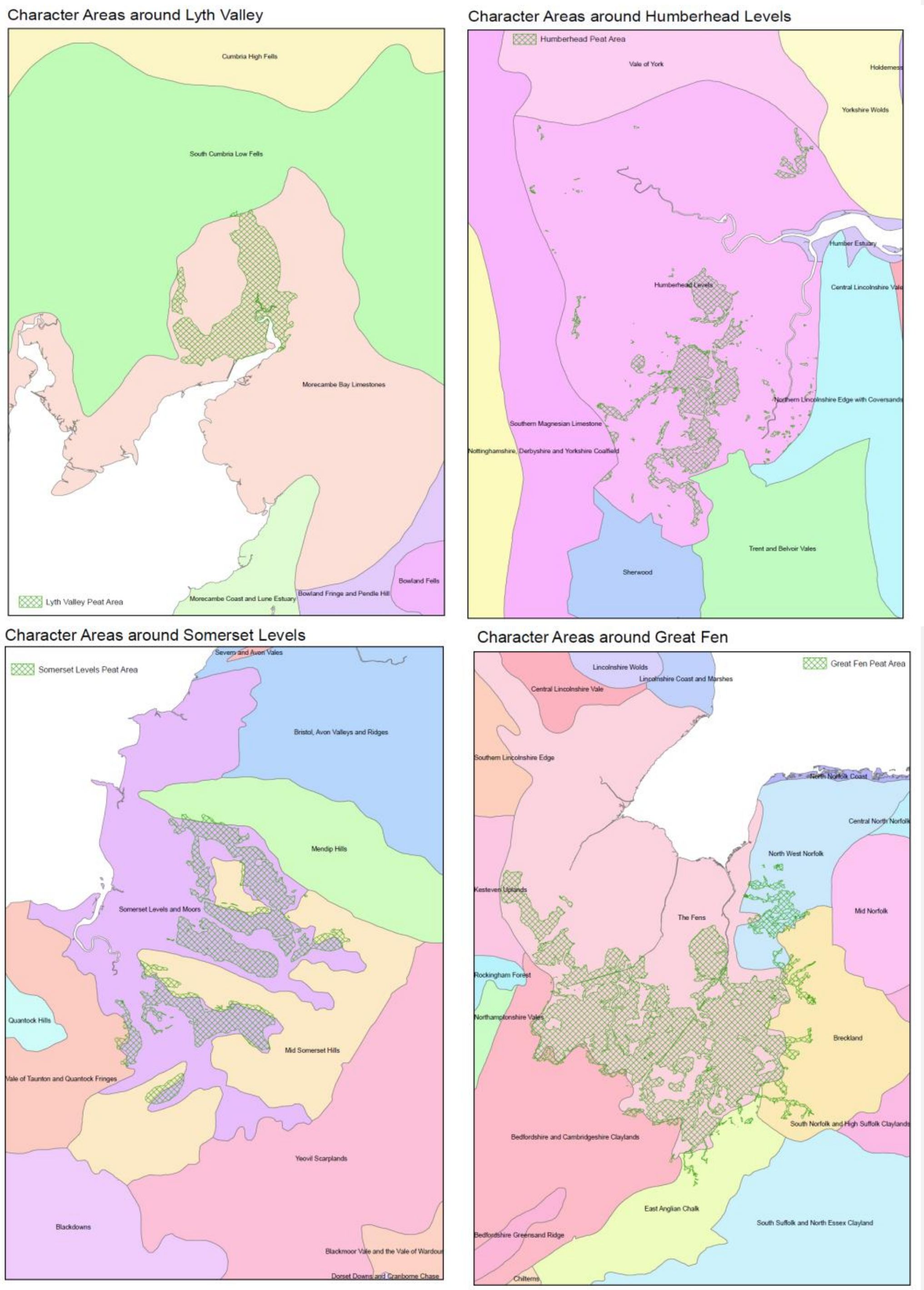


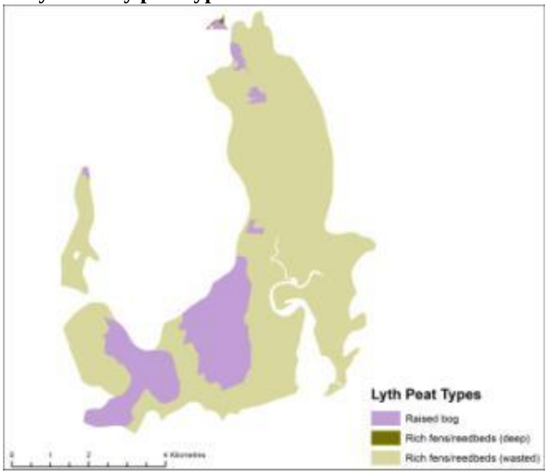
Figure A6. 4. Peatland areas and landscape character areas

Table A6. 4. Land use areas (ha) (Source: Natural England)

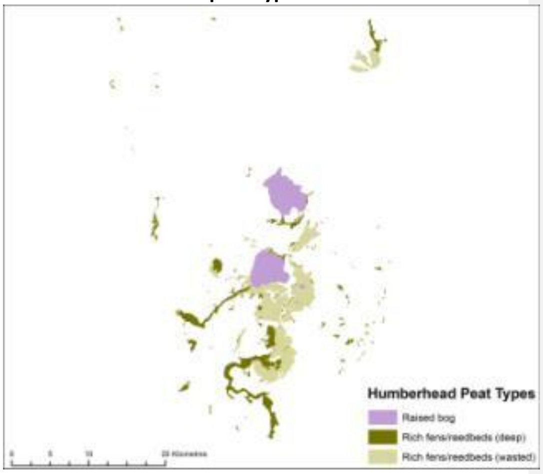
	Raised bog	Rich fens/reedbeds (deep)	Rich fens/reedbeds (wasted)	**Total**
East Anglian Fens				
Afforested	0.5	192.3	563.0	**755.9**
Cultivated	968.9	17055.4	80558.9	**98583.2**
Extracted				
Improved	27.7	1353.5	2957.9	**4339.1**
Overgrazed				
Peat Cutting	2.2	11.3	48.3	**61.9**
Polluted	1492.8	1456.1	25.1	**2974.0**
Pristine		50.5	23.8	**74.3**
Removed	15.7	344.1	2239.6	**2599.3**
Restored		1162.8	668.9	**1831.7**
Scrub		10.7	27.6	**38.3**
Wasted			104119.5	**104119.5**
Wooded	289.8	957.9	1716.8	**2964.5**
Semi-natural non peat forming	5.1	2693.8	896.0	**3594.9**
Total	1492.8	26518.9	104119.5	**132131.2**
Humberhead Levels				
Afforested	201.2	48.6	55.5	**305.3**
Cultivated	296.9	2638.8	4566.2	**7501.9**
Extracted	3010.8	0.2	0.0	**3011.0**
Improved	16.7	528.2	209.0	**753.9**
Overgrazed		1.4		**1.4**
Peat Cutting	3260.4	103.2	145.9	**3509.4**
Polluted	3677.7	59.7	4.3	**3741.6**
Pristine		9.8	0.4	**10.2**
Removed	12.3	89.2	74.5	**175.9**
Restored	1084.8	52.3	45.5	**1182.6**
Scrub	2.3	10.4		**12.7**
Wasted	50.0		6075.3	**6125.2**
Wooded	793.0	266.2	85.0	**1144.2**
Semi-natural non peat forming	2300.8	126.0	80.3	**2507.0**
Total	3677.7	4687.6	6075.3	**14440.6**
Lyth Valley				
Afforested	289.1		3.2	**292.3**
Cultivated	7.7		220.3	**228.0**
Extracted				
Improved	217.5	2.2	2048.8	**2268.5**
Overgrazed		0.0	113.2	**113.2**
Peat Cutting				
Polluted	759.3		0.0	**759.3**
Pristine				
Removed	9.0		67.5	**76.5**
Restored	7.8		39.1	**47.0**
Scrub	132.7		0.1	**132.8**
Wasted	115.0		2858.1	**2973.1**
Wooded	453.7	0.0	92.5	**546.3**
Semi-natural non peat forming	1.6		172.0	**173.7**
Total	759.3	2.5	2858.1	**3619.9**
Somerset Levels				
Afforested	4.7	1.2	7.4	**13.3**
Cultivated	160.2	603.6	612.8	**1376.6**
Extracted	675.8	59.5	0.0	**735.3**
Improved	531.1	3904.4	4004.9	**8440.4**

Overgrazed				
Peat Cutting	865.4	46.7		**912.1**
Polluted	2523.4	2016.6	2.4	**4542.4**
Pristine	1.3	5.9		**7.2**
Removed	37.4	72.7	82.6	**192.6**
Restored	141.8	1018.2		**1160.0**
Scrub	1.6	2.7	0.1	**4.3**
Wasted	0.0		5184.4	**5184.5**
Wooded	144.9	31.9	8.4	**185.2**
Semi-natural non peat forming	692.9	3314.0	24.2	**4031.2**
Total	2523.4	8419.0	5184.4	**16126.8**

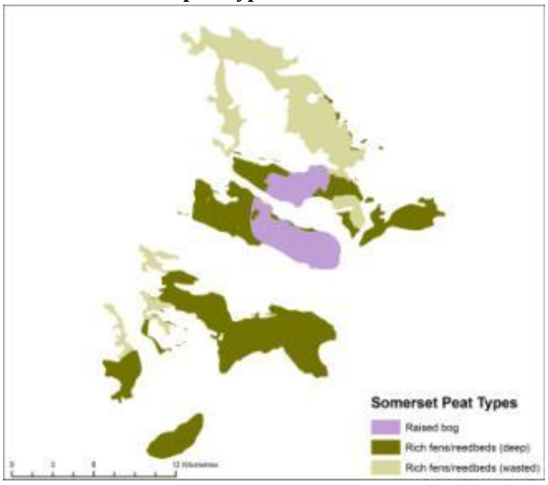
a: Lyth Valley peat type



b: Humberhead Levels peat type



d: Somerset Levels peat type



c: East Anglian Fens peat type

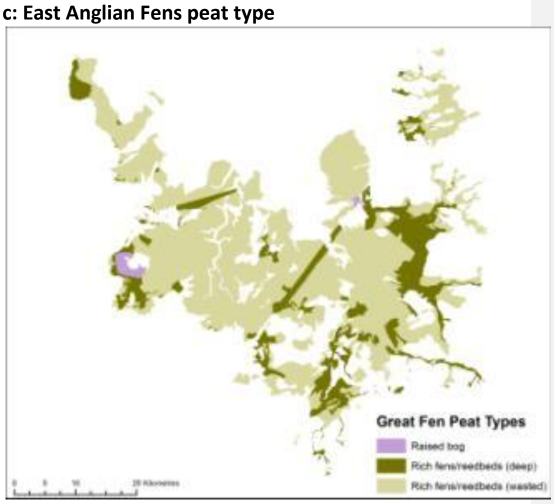
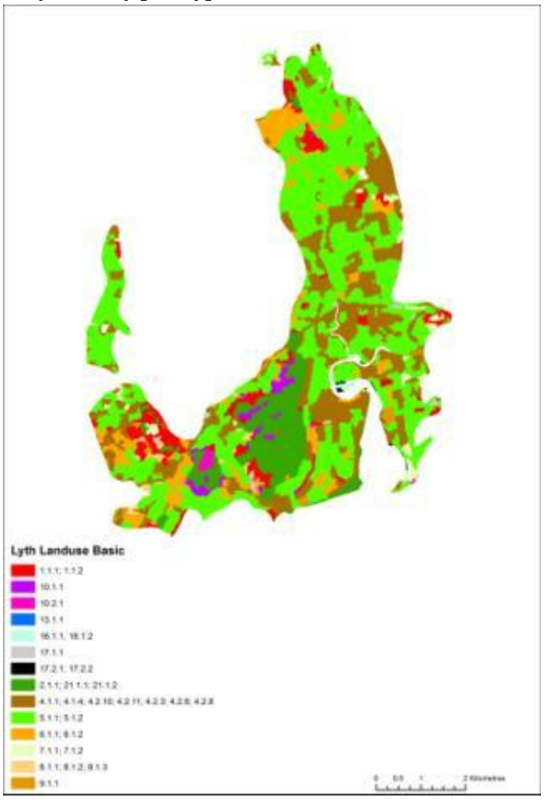
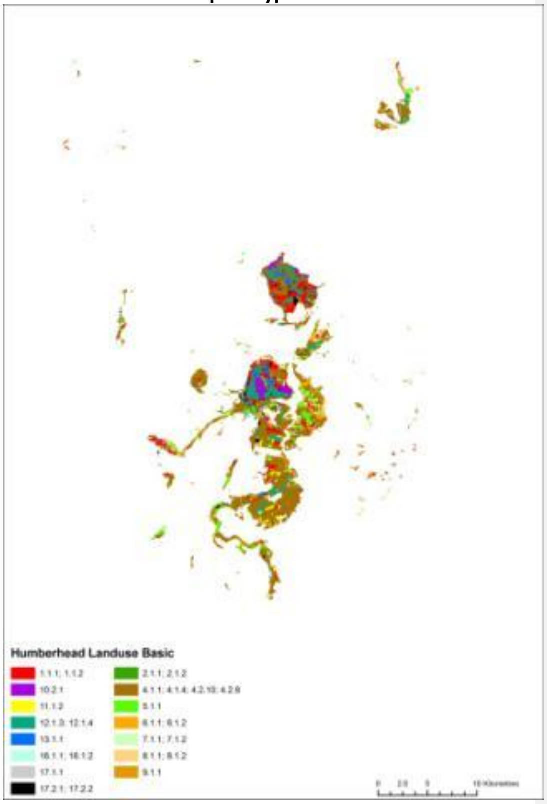


Figure A6. 5: Location of different peatland types (Source: Natural England)

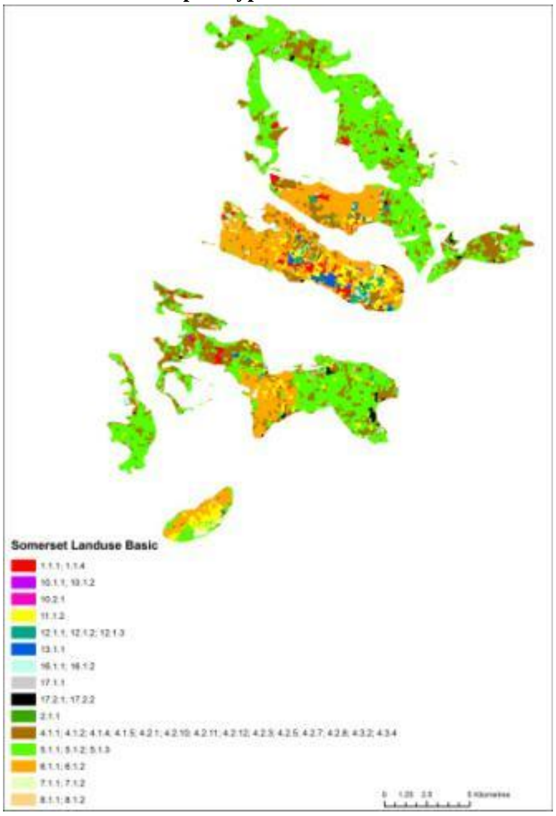
a: Lyth Valley peat type



b: Humberhead Levels peat type



d: Somerset Levels peat type



c: Great Fen peat type

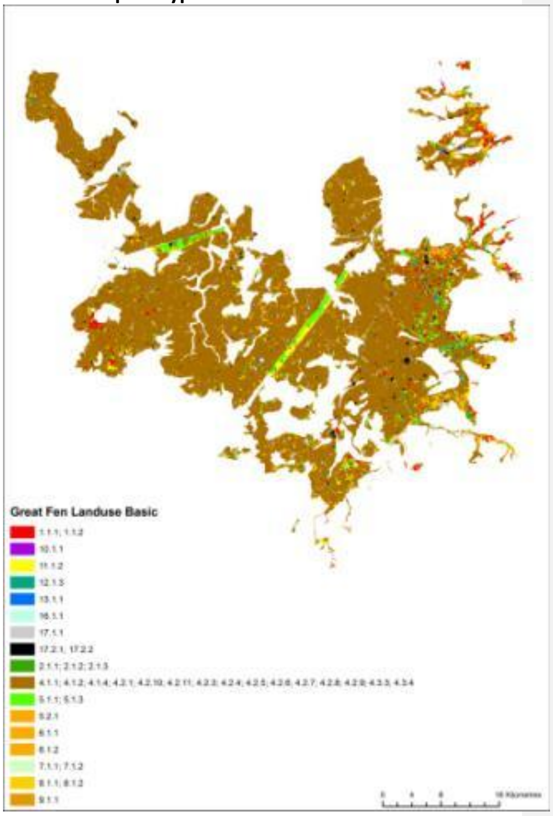


Figure A6. 6: Landuse on peatland areas (lcm 2000)

Table A6. 5: Landuse on peatland areas (lcm 2000)

LCM2000 Target classes, Subclasses, Variants and their codes

LCM Target class	LCM Subclasses (Level-2)	Number	Variants (Level-3)	Number	Alpha-code
Sea / Estuary	Sea / Estuary	22.1	sea	22.1.1	We
Water (inland)	Water (inland)	13.1	water (inland)	13.1.1	W
Littoral rock and sediment	Littoral rock	20.1	rock	20.1.1	Lr
			rock with algae	20.1.2	Lra
	Littoral sediment	21.1	mud	21.1.1	Lm
			sand	21.1.2	Ls
			sand with algae	21.1.3	Lsa
	Saltmarsh	21.2	saltmarsh	21.2.1	Lsm
			saltmarsh (grazed)	21.2.2	Lsg
Supra-littoral rock and sediment	Supra-littoral rock	18.1	rock	18.1.1	Sr
	Supra-littoral sediment	19.1	shingle (vegetated)	19.1.1	Sh
			shingle	19.1.2	Shv
			dune	19.1.3	Sd
			dune shrubs	19.1.4	Sds
Bog	Bogs (deep peat)	12.1	bog (shrub)	12.1.1	Bh
			bog (grass/shrub)	12.1.2	Bhg
			bog (grass/herb)	12.1.3	Bg
			bog (undifferentiated)	12.1.4	Bo
Dwarf shrub heath (wet / dry)	Dense dwarf shrub heath	10.1	dense (ericaceous)	10.1.1	H
			gorse	10.1.2	Hg
	Open dwarf shrub heath	10.2	open	10.2.1	Hga
Montane habitats	Montane habitats	15.1	montane	15.1.1	Z
Broad leaved / mixed woodland	Broad leaved / mixed woodland	1.1	deciduous	1.1.1	D
			mixed	1.1.2	Dm
			open birch	1.1.3	Db
			scrub	1.1.4	Ds
Coniferous woodland	Coniferous woodland	2.1	conifers	2.1.1	C
			felled	2.1.2	Cf
			new plantation	2.1.3	Cn
Arable and horticultural	Arable cereals	4.1	barley	4.1.1	Ab
			maize	4.1.2	Am
			oats	4.1.3	Ao
			wheat	4.1.4	Aw
			cereal (spring)	4.1.5	Acs
			cereal (winter)	4.1.6	Acw
	Arable horticulture	4.2	arable bare ground	4.2.1	Aba
			carrots	4.2.2	Ac
			field beans	4.2.3	Af
			horticulture	4.2.4	Ah
			linseed	4.2.5	Al
			potatoes	4.2.6	Ap
			peas	4.2.7	Aq
			oilseed rape	4.2.8	Ar
			sugar beet	4.2.9	As
			unknown	4.2.10	Au
			mustard	4.2.11	Ax
			non-cereal (spring)	4.2.12	Ans
	Non-rotational arable and horticulture	4.3	orchard	4.3.1	Ado
			arable grass (ley)	4.3.2	Agl
			setaside (bare)	4.3.3	Asb
			setaside (undifferentiated)	4.3.4	Ase
Improved grassland	Improved grassland	5.1	intensive	5.1.1	Gi
			grass (hay/ silage cut)	5.1.2	Gih
			grazing marsh	5.1.3	Gim
Rough and semi-natural neutral and calcareous grasslands	Setaside grass	5.2	grass setaside	5.2.1	Gis
	Neutral grass	6.1	neutral grass (rough)	6.1.1	Grn
			neutral grass (grazed)	6.1.2	Gn
	Calcareous grass	7.1	calcareous (rough)	7.1.1	Gc
			calcareous (grazed)	7.1.2	Grc
Acid grass and bracken	Acid grass	8.1	acid	8.1.1	Ga
			acid (rough)	8.1.2	Gra
			acid with *Juncus*	8.1.3	Gaj
			acid *Nardus/Festuca/Molinia*	8.1.4	Gam
	Bracken	9.1	bracken	9.1.1	Gbr
11. Fen, marsh and swamp	11. Fen, marsh and swamp	11.1	swamp	11.1.1	Fs
			fen/marsh	11.1.2	Fm
			fen willow	11.1.3	Fw
Built up areas, gardens	Suburban/rural developed	17.1	suburban/rural developed	17.1.1	Us
	Continuous Urban	17.2	urban residential/commercial	17.2.1	U
			urban industrial	17.2.2	Ui
Inland Bare Ground	Inland Bare Ground	16.1	despoiled	16.1.2	Id
			semi-natural	16.1.1	Ib
16 target classes	26 target/subclasses		72 target/subclasses/variants		

Notes: 25/01/2002

Hard lines between classes denote generally reliable distinctions; dotted lines identify situations where spectral distinction is more difficult and where external data do not fully supply the separation

The read-across from BHs to Target class shows possible mismatches in their distinction; mismatches may apply to each Subclass (e.g. the *Bog* BH may be confused with Dense or Open Dwarf shrub heaths)

The colouring denotes (approximately) the map display colour; it aggregates BHs where distinctions are less reliable; but it may distinguish Subclasses which are soundly based and of wider user interest

The map display classes relate to the adopted colouring and represent an abridged class name used on hard-copy maps

r1.1

Table A6. 6: Designations on peatland case study sites (Source: Natural England)

Layer	Great Fen	Humberhead	Lyth Valley	Somerset Levels
Coastal floodplain BAP	4208.5	667.6	2572.8	13765.7
Reedbed	785.0	210.0	1.0	26.1
FEN BAP	586.2	3572.5	521.2	1782.3
Lowland meadows BAP	2780.6	0.8	0.6	732.1
Lowland raised bog BAP	0.0	3091.4	543.5	387.2
total BAP area	8360.4	7542.6	3639.9	16694.4
Countryside Stewardship agreement	13808.0	1088.6	27.7	150.7
ESA	5345.2	0.0	1761.8	12714.6
Environmental stewardship	68325.3	6401.1	1557.9	3016.5
total agri-env area	87478.5	7489.7	3347.4	15881.9
percentage of total area agri-env	0.7	0.5	0.9	1.0
RAMSAR sites	3219.1	0.0	122.0	4218.4
RSPB reserves	3151.2	0.0	5.2	1432.7
SSSI	4889.0	3703.0	623.7	4689.6
Special areas of conservation	1148.1	3252.0	608.6	0.5

Table A6. 7: Target area on peatland case study sites (Source: Natural England)

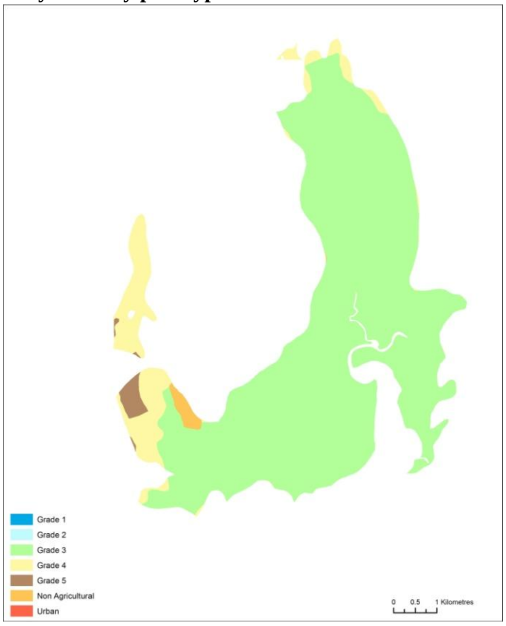
Area	Layer	Total_area	Area_in_peat
Lyth	Lyth _BAP_TA	1283.855	671.5407
Great Fen	opportunities	34562.1	18257.56
Great Fen	B&T Fen Area_region	7071.86	2426.028
Great Fen	area 2013_region	1447.18	1075.18
Great Fen	100 year vision area4_Region	5600.5	2879.561
Humber	Target Area_region	673.0311	363.5544
Somerset	Middle_Parrett_Floodplain	11522.64	7425.092
Somerset	new brue boun	12473.58	6119.629

Table A6. 8: Area of different peat types classified as different land types (Source: Natural England)

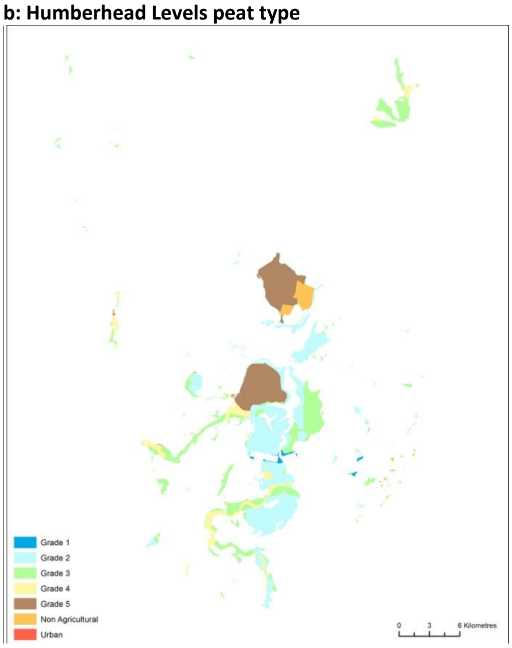
	Area (ha)	Proportion total area (%)
Great Fen	***132131.3***	***100.0%***
Raised bog	*1492.8*	*1.1%*
GRADE 1	1128.9	0.9%
GRADE 2	105.7	0.1%
GRADE 3	0.1	0.0%
NON AGRICULTURAL	258.0	0.2%
URBAN	0.0	0.0%
Rich fens/reedbeds (deep)	*26518.9*	*20.1%*
GRADE 1	12149.6	9.2%
GRADE 2	6842.6	5.2%
GRADE 3	3325.2	2.5%
GRADE 4	3092.6	2.3%
GRADE 5	55.4	0.0%
NON AGRICULTURAL	973.2	0.7%
URBAN	80.4	0.1%
Rich fens/reedbeds (wasted)	*104119.5*	*78.8%*
GRADE 1	50560.7	38.3%
GRADE 2	36309.0	27.5%
GRADE 3	10627.4	8.0%
GRADE 4	4902.8	3.7%
GRADE 5	15.3	0.0%
NON AGRICULTURAL	1566.5	1.2%
URBAN	137.8	0.1%
Humberhead Levels	***14234.2***	***100.0%***
Raised bog	*3677.7*	*25.8%*
GRADE 2	190.9	1.3%
GRADE 3	75.2	0.5%
GRADE 4	0.2	0.0%
GRADE 5	2922.8	20.5%
NON AGRICULTURAL	488.6	3.4%
Rich fens/reedbeds (deep)	*4481.2*	*31.5%*
GRADE 1	52.0	0.4%
GRADE 2	1631.8	11.5%
GRADE 3	1816.2	12.8%
GRADE 4	886.0	6.2%
GRADE 5	28.5	0.2%
NON AGRICULTURAL	55.7	0.4%
URBAN	11.0	0.1%
Rich fens/reedbeds (wasted)	*6075.3*	*42.7%*
GRADE 1	54.9	0.4%
GRADE 2	3738.4	26.3%
GRADE 3	1940.2	13.6%
GRADE 4	272.3	1.9%
GRADE 5	68.8	0.5%
NON AGRICULTURAL	0.6	0.0%
Lyth Valley	***3561.0***	***100.0%***
Raised bog	*759.3*	*21.3%*
GRADE 3	695.1	19.5%
GRADE 4	32.7	0.9%
NON AGRICULTURAL	31.5	0.9%
Rich fens/reedbeds (deep)	*2.5*	*0.1%*
GRADE 3	0.0	0.0%

GRADE 4	2.5	0.1%
Rich fens/reedbeds (wasted)	*2799.2*	*78.6%*
GRADE 3	2417.9	67.9%
GRADE 4	337.1	9.5%
GRADE 5	42.7	1.2%
NON AGRICULTURAL	1.5	0.0%
Somerset Levels	***16126.8***	***100.0%***
Raised bog	*2523.4*	*15.6%*
GRADE 2	1006.6	6.2%
GRADE 3	46.5	0.3%
GRADE 4	1470.3	9.1%
Rich fens/reedbeds (deep)	*8419.0*	*52.2%*
GRADE 1	102.5	0.6%
GRADE 2	6636.2	41.2%
GRADE 3	1182.9	7.3%
GRADE 4	497.4	3.1%
Rich fens/reedbeds (wasted)	*5184.4*	*32.1%*
GRADE 1	71.8	0.4%
GRADE 2	666.7	4.1%
GRADE 3	2333.9	14.5%
GRADE 4	2078.9	12.9%
GRADE 5	1.2	0.0%
URBAN	31.9	0.2%

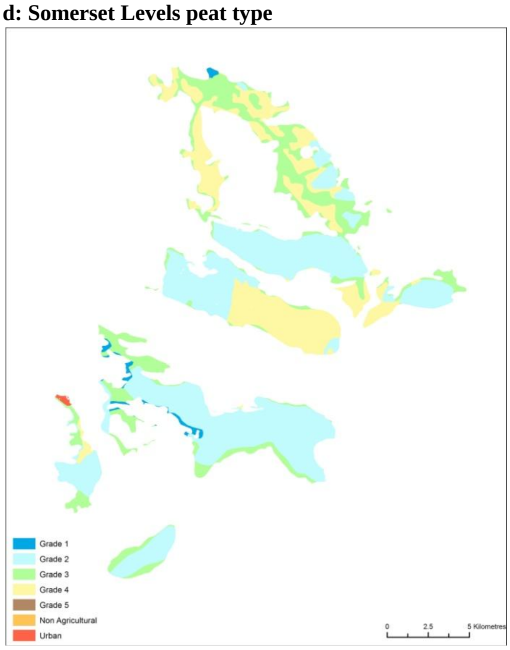
a: Lyth Valley peat type



b: Humberhead Levels peat type



d: Somerset Levels peat type



c: Great Fen peat type

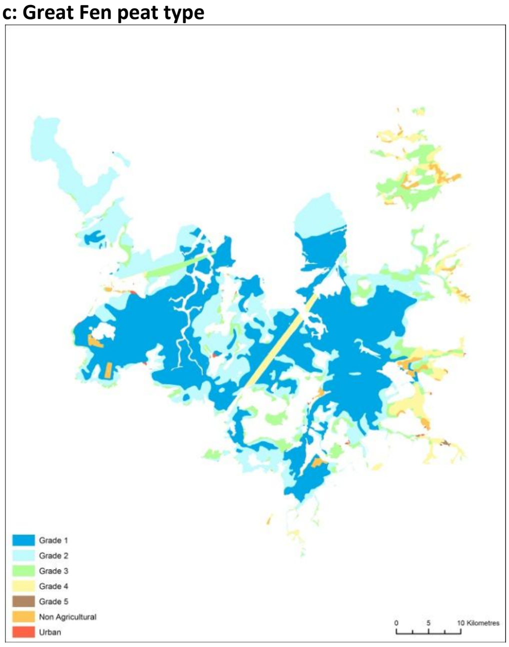
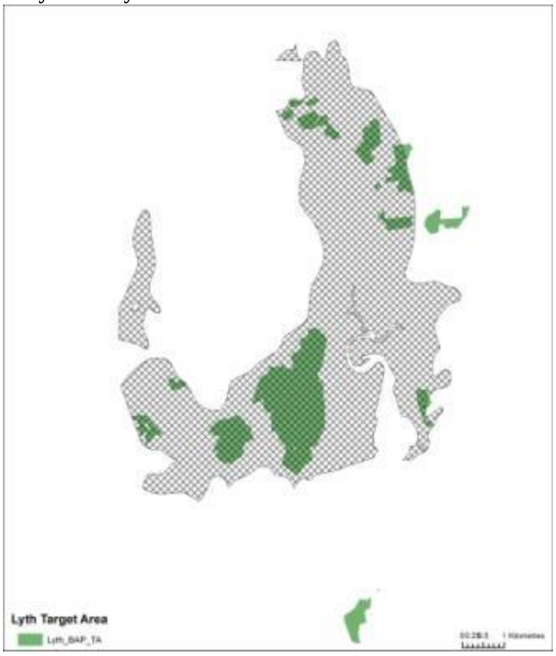


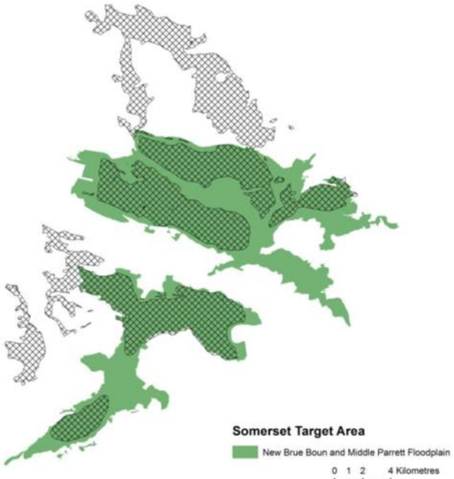
Figure A6. 7: Location of different land grades on the case study sites (Source: Natural England)

a: Lyth Valley



b: Humberhead Levels

d: Somerset Levels



c: East Anglian Fens

Figure A6. 8: The Target Areas (shaded) for peatland restoration within each of the regional study areas (hatched)

Table A6. 9: Lyth Valley target area objectives (rows) on peatland case study sites (columns) (Source: Natural England)

	Raised bog	Rich fens/reedbeds (deep)	Rich fens/reedbeds (wasted)	Grand Total
CFPGM			124.1	124.1
maintain			3.3	3.3
restore			120.8	120.8
Fen	20.9		47.4	68.3
create	15.4		7.8	23.2
recreate			34.7	34.7
restore	5.4		4.9	10.4
Raised Mire	148.8		3.6	152.4
restore	148.8		3.6	152.4
Reedbed	1.3		16.9	18.3
create	1.3		16.9	18.3
Unspecified	233.1		16.2	249.2
Non Target Areas	356.7	2.5	2649.3	3008.6
Grand Total	760.8	2.5	2857.5	3620.9

Table A6. 10: Humberhead Levels target area objectives (rows) on peatland case study sites (columns) (Source: Natural England)

Row Labels	Raised bog	Rich fens/reedbeds (deep)	Rich fens/reedbeds (wasted)	Grand Total
20	2.3	0.5		2.9
21	24.0	1.7		25.7
23	0.4	0.1		0.5
27		1.1		1.1
28		0.2		0.2
29	0.1			0.1
40	195.0	0.3		195.3
41	5.8			5.8
42	16.7	0.1		16.8
43	29.2	12.0	45.1	86.3
12b	13.2			13.2
18b	2.0			2.0
Non-target area	3388.9	4544.0	6169.1	14102.0
Grand Total	3677.7	4559.9	6214.2	14451.8

Table A6. 11: Somerset Levels target area objectives (rows) on peatland case study sites (columns) (Source: Natural England)

Row Labels	Raised bog	Rich fens/reedbeds (deep)	Rich fens/reedbeds (wasted)	Grand Total
Greylake RSPB		108.3		108.3
High Priority target area for		960.5		960.5
Huish Moor RSPB		12.0		12.0
Kings Sedgemoor SSSI		820.4		820.4
Moorlinch SSSI		157.5		157.5
RWLA Greylake		108.3		108.3
RWLA Sutton		77.7		77.7
RWLA Walton		35.6		35.6

West Sedgemoor RSPB		444.1		444.1
West Sedgemoor SSSI		672.5		672.5
Whole area		4028.2		4028.2
Non Target Areas	2523.4	4390.8	5184.4	12098.6
Grand Total	2523.4	11815.9	5184.4	19523.7

Table A6. 12: Great Fen target area objectives (rows) on peatland case study sites (columns) (Source: Natural England)

Row Labels	Raised bog	Rich fens/reedbeds (deep)	Rich fens/reedbeds (wasted)	Grand Total
Fens	636.5	6688.2	10505.5	17830.3
Barton Mill		130.5	275.0	405.5
Broadpool		0.2	608.2	608.4
Chippenham Fen		67.8		67.8
Ely Pits and Meadows		23.5	134.0	157.5
Great Fen	636.5	1157.1	985.8	2779.4
Kingfisher Bridge		33.9		33.9
Landwade		18.8		18.8
Little Wilbraham		139.8		139.8
Mereham		71.8	885.9	957.7
Narborough		104.3	1160.8	1265.0
Nene Washes	0.0	1135.3	2155.5	3290.9
Northwold Fen		574.3	241.7	816.0
Pashford and Lakenheath		1329.6	1599.7	2929.3
River Wissey Northwold			322.8	322.8
River Wissey Wissington		237.4	309.3	546.6
Soham Fen		4.5	437.4	441.9
Wicken Fen		1659.3	1389.6	3049.0
Hilgay		175.3	33.9	209.2
Hilgay Area 1		39.9	33.9	73.8
Hilgay Area 2		135.4		135.4
Lakenheath		80.7		80.7
Lakenheath		80.7		80.7
Middle Level Barrier Banks			20.2	20.2
Middle Level Barrier Banks potential comp habitat			20.2	20.2
Welney			117.2	117.2
Welney			79.2	79.2
Welney (Kisby)			38.0	38.0
Grand Total	636.5	6944.2	10676.8	18257.6

Row Labels	Raised bog	Rich fens/reedbeds (deep)	Rich fens/reedbeds (wasted)	Grand Total
S Warrington		1558.5	1321.1	2879.6
Grand Total		1558.5	1321.1	2879.6

Row Labels	Raised bog	Rich fens/reedbeds (deep)	Rich fens/reedbeds (wasted)	Grand Total
B & T FEN AREA		892.9	1533.2	2426.0
Grand Total		892.9	1533.2	2426.0

Table A6. 13: All England land use and attributes on lowlands (Source: Natural England)

Row Labels	Attribute	Raised bog	Rich fens/reedbeds (deep)	Rich fens/reedbeds (wasted)	Grand Total
AFF	Afforested	6159	1086	2321	9566
BUR	Burnt	196	1		196
CUL	Cultivated	8749	37369	115033	161151
ERO	Eroded	11			11
EXT	Extracted	5550	112	0	5662
GRP	Gripped	290	19		309
IMP	Improved	5286	21208	26605	53099
OVG	Overgrazed	14	63	170	246
PCT	Peat Cutting	4988	2763	202	7953
POL	Polluted	35720	6615	1045	43380
PRS	Pristine	338	572	341	1251
REM	Removed	791	3105	5213	9110
RST	Restored	1687	3804	1379	6870
SCB	Scrub	802	830	140	1773
WST	Wasted	198		192205	192403
BAR	Bare	19	13	9	41
WOD	Wooded	3631	6882	6959	17472
SNN	Semi-natural non peat forming	5233	11164	6599	22995
MOL	Molinia	21	1	0	22
Total		**35721**	**95804**	**192205**	**323730**

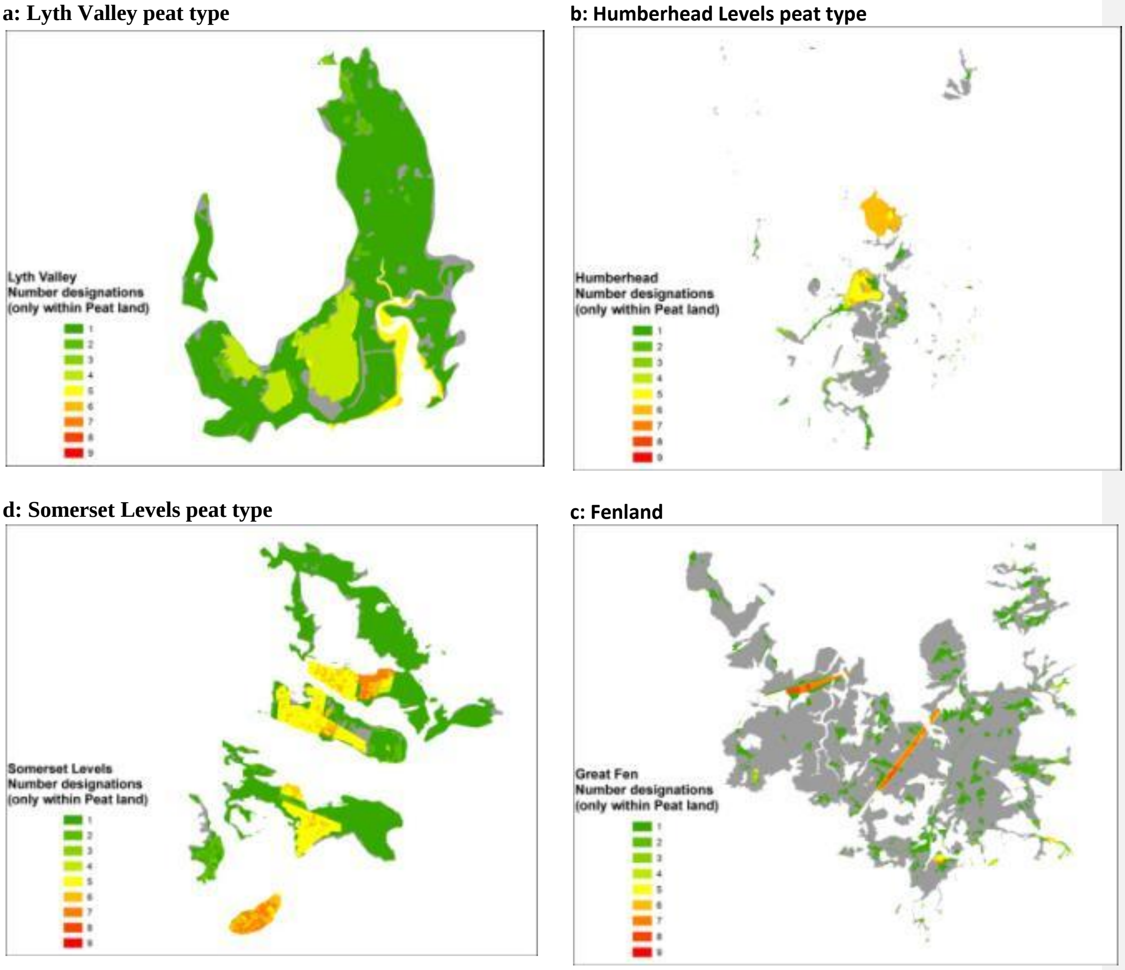


Figure A6. 9: Number of designations on Peatland Regional study areas

Appendix 7 : Summary of economic assessments and selected LCA Environmental Emissions by Scenario and Target Areas

This is provided separately as a pdf file