J. MORRIS

Cranfield UNIVERSITY

Wet Fens For The Future

Feasibility Study Phase 2 - A Study of the Economic and Social Implications of Creating New Wetlands in Fenland

Final Draft Report

Silsoe College

November 1996

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School of Agriculture Food and Environment
Cranfield University
Silsoe
Bedford MK45 4DT
UK
Tl 01525 863000
Fx 01525 863344

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WET FENS FOR THE FUTURE
ECONOMIC AND SOIL IMPLICATIONS OF CREATING NEW WETLAND IN FENLAND
EXECUTIVE SUMMARY

Background

The Fens comprise a low-lying area of 3,700 square kilometres in central, east England. Reclaimed over centuries from swamps, bogs and open carr, the area is now served by a sophisticated system of dykes and drains which support some of the most intensive and productive farming in Britain. Indeed, the closely integrated processes of reclamation, drainage, settlement and agriculture give the Fens their unique character. Within this managed environment, there are a few areas which retain the hydrological and ecological properties of the original wet fen. There is concern that, without action to protect and add to these wet fens, the uniqueness of these natural features could be irreversibly lost.

The Fens also face a number of social and economic challenges associated with dependency on agriculture, relative geographic isolation, and consequent economic stagnation. Furthermore, intensive farming practices have resulted in a deterioration of land and water resources in the Fens which questions whether existing methods are sustainable into the future. Simultaneously, the reform of the Common Agricultural Policy and reduced levels of production support could threaten local economies which are agriculture dependent.

Given concern about the social, economic and environmental issues in the Fens, a strategy for the re-creation of wet fens is one of a number of initiatives in the search for a sustainable future for the Fens. Although environmental conservation and economic development (especially agricultural) interests in the Fens have been perceived in direct conflict in the past, Wet Fens for the Future initiative aims to bring together the various parties involved in the Fens to seek common interests and to explore practical and achievable means of promoting the wet fen programme.

Study Aim

In this context, the study reported here is Phase II of the Wet Fens for the Future Project. Phase I identified the general feasibility of the project. Phase II addresses two management topics relating to:

- the financial and economic feasibility of alternative wet fen land uses; and,
- the feasibility, from a soil management perspective, of returning land from re-created wet fen to arable farming should the strategic need arise.

Financial and Economic Analysis of Fenland Crop and Livestock Systems

The study defined the hydrological conditions necessary for the creation of wet fen and wet grassland. These conditions were used to determine agricultural and non-agricultural land use and practices suited to wet fen conditions. A number of scenarios were compiled to represent selected policy options and related farming systems. These provided a framework for a financial and economic analysis of land use alternatives in the Fens, ranging from existing arable farming systems to livestock rearing and fattening systems of varying intensity.

The analysis shows that, as far as agriculture is concerned, there are considerable financial and economic costs associated with a switch out of existing arable systems, especially given the area's comparative advantage in intensive non-cereal cropping. Sizeable incentives are likely to be needed to encourage farmers to revert to wet fen. Farming performance and prosperity, however, are not uniform throughout the fens, and evidence of soil degradation threatens the sustainability of intensive practices. The analysis suggests that the creation of wet fens could beneficially focus on areas of marginal agricultural productivity, on farms where particular proprietor circumstances favour change, or where the creation of wet fens in generally farmed areas can ease the pressure of intensive agriculture on natural resources and the environment.

Alternative Fen Enterprises

The study reviewed selected non-agricultural activities suited to wet fen conditions. Reedbeds and willow coppicing appear to offer the greatest scope for generating income from non agricultural wetlands. The financial viability of these enterprises is however dependent on grants and allowances, especially during the early years before plantations reach full harvest potential. Smaller-scale activities such as trout fisheries, and cricket-bat willow may be viable if run in conjunction with an existing arable enterprises, but are unlikely to provide the basis for a whole-farm enterprise on their own.

The net incomes per ha from non-agricultural activities appear substantially less than those produced from arable fenland farms. Alternative systems are unlikely in themselves, without substantial and targeted incentives, to be sufficiently attractive to encourage a switch out of arable farming on any significant scale. Furthermore, local and regional market constraints may limit the scale to which any one non-farming activity can offer a realistic option to agriculture. Nevertheless, they represent activities which can be promoted and encouraged as part of a strategy which seeks the establishment of sustainable land and water use in the Fens

Socio-Economic Impacts of Wet Fens

The study reviewed the socio-economic character of the study area in the context of sustainable development, and examined the likely social and economic impacts of the Wet Fen for the Future Initiative. The review revealed a local economy made vulnerable by its overwhelming dependency on the farming and municipal sectors and related industries. These sectors are experiencing considerable change and structural adjustment. Whilst there is a call for greater and more diverse economic development, there is a simultaneous commitment to secure the intrinsic characteristics of the Fens and their communities: reconciling economic development and environmental quality. Wet fens could have a role in this process.

From a socio-economic viewpoint, wet fens provide many functions of value to human society. As a supplier of resources, they can support income generating and wealth creating activities, whether this involves modern arable farming or traditional wet fen activities. They can provide a sink for wastes of various kinds which arise from economic activities. They also provide the medium for living organisms and are therefore an essential part of the natural system which supports human existence.

The study identified and assessed the contribution of wet fens in terms of ecological and environmental regulatory functions (such as the maintenance of soil and water quality and flood defences), carrier and production functions (such as food, agro-industrial commodities, tourism, countryside access and recreation, and nature conservation), and interpretative functions (such as heritage, landscape, amenity and knowledge accumulation) which support the human consciousness. These functions are elementary to the definition of the quality of human life. They are also critical to the achievement of sustainable development, especially as they allow the reconciliation of the otherwise competing demands of economic growth and environmental quality.

The study identified methods which could be engaged to place monetary values on these functions in order to judge the value to society of an increase or decrease in their provision. The estimation of actual values, however, went beyond the scope of the present study, particularly as their application would need to be site specific.

The diversity of functions and attributes of the fens is reflected in the range of stakeholders who have an interest in the Fens. A preliminary stakeholder analysis linked the features and functions of wet fens with the objectives and interests of the main 'actors' who might exert influence on future wet fen initiatives. These include Central Government Ministries and Local Government Authorities which have varied and sometimes conflicting interests in natural resource management, income generation, employment creation, economic and business

development and nature conservation. Farmers and their representatives have an obvious interest in the Fens, both with respect to conventional farming as it supports the predominantly agriculture based fenland economy, but also with respect to potentially viable alternatives and the rural enterprises that these might support. Numerous parties have interests in the ways that wet fens could add to, or relieve pressure on natural resources, especially regarding soil quality and water resources. These include farmers, water supply companies and the Environment Agency. Many groups and organisations have interests in protecting and enhancing the natural and historic man-made features of the fens, especially as they relate to informal and formal outdoor recreation, tourism, educational and scientific pursuits. Some organisations are particularly concerned with increasing access to the countryside, others with preservation of protected areas.

The success of any initiative in the Fens will hinge on the commitment and participation of the local communities and their representatives. Whilst for the most part members of the local community stand to gain, there are also localised social risks, such as those associated with increased visitors and traffic to the area, as well as possible change in employment opportunities. Given the diversity of interest in the wet fen proposal, it is important that the programme adopts a partnership approach which brings together the various stakeholders.

Soil Management Issues

The study examined two issues relating to soil management, namely the existing extent and quality of fen peats, and the feasibility of reverting wet fens back to arable agriculture should the need arise.

The study showed that the maximum extent of peat within the Fens in 17th century was 1480 km^2. This area has degraded to 16% of the original to 240 km^2 over 300 years. Of the remaining peat over half are below 1m in thickness. It takes 100 years for a peat soil to pass through the skirt stage to become mineral topsoil. With continuous degradation, the ALC grade for peat soils will decline as soils experience problems of droughtiness, workability, a reduction in the range of crops grown and a greater need for irrigation.

Further decline of peat soils and organic matter levels is inevitable without fundamental changes in the farming system. The reversion from arable to wet grassland with raised water-tables would slow the decline but not halt it completely. Frequent inundation and permanent waterlogging would help maintain or possibly increase soil organic matter, but this reduces the options for commercial land use.

This study reviewed the research evidence relating to the risk of build up of acid sulphates in soils and possible damage to soil structure in re-created fens subject to inundation and waterlogging. These could cause soil management problems in the event of returning wet fen land back into arable farming should the need arise. The conclusion is that whilst amelioration actions might be required to address possible build up of acid sulphates or structural change under wetland conditions, the wet fen creation is not irreversible. In this respect, options to re-use the fens for agriculture remain open. This is important from the viewpoint of strategic resource management.

Epilogue

In summary, the study provides a strategic overview of the wet fen creation with particular reference to farming systems, alternative land use, socio-economic impacts and selected soil management issues. The study confirms that the Wet Fen for the Future programme has potential to deliver a broad range of socio-economic and welfare benefits through the functions of a healthy and accessible environment. Simultaneously, there is a broad church of stakeholders with potential interests in the wet fen proposal, members of which stand to gain or lose to varying degrees according to the way the initiative is designed and managed. The Programme should be progressed by drawing on this partnership of interest, possibly with a view to identify particular sites for detailed appraisal..

1. INTRODUCTION

1.1. Background

The Fens, a lowlying area of 3,700 square kilometres in central, east England, are unique in character in the UK, comparable only with The Netherlands in Europe. Over 70% of the area is farmland, criss-crossed by dykes and drains. The Fens are significant in terms of their integration of land use, economic activity, wildlife and scenic value, and are internationally important for their biodiversity. The Fens also contain some of the most fertile, high value agricultural land in Britain.

The Fenland area is, however, facing challenges associated with its dependency on agriculture, its relative geographic isolation, and economic stagnation. Furthermore, intensive farming practices have resulted in a deterioration of land and water resources in the Fens which questions whether existing methods are sustainable into the future. Simultaneously, the reform of the Common Agricultural Policy and reduced levels of production support could threaten local economies which are agriculture dependent.

In the context of concern about the social, economic and environmental sustainability of the Fens, a strategy is being promoted by various organisations for the re-creation of wet fens as one of a number of initiatives for a sustainable future for the Fens. Although environmental conservation and economic development (especially agricultural) interests in the Fens have been perceived in direct conflict in the past, Wet Fens for the Future initiative aims to bring together the various parties involved in the Fens to seek common interests and to explore practical and achievable means of promoting the wet fen programme.

Cambridge County Council is the Lead Client for this feasibility study acting on behalf of a Steering Group comprising Countryside Commission, English Nature, Lincolnshire County Council, Environment Agency, Royal Society for the Protection of Birds and Wildfowl and Wetlands Trust.

1.2. Aims and Objectives

The aim of the study is to examine the economic and social implications of creating sustainably managed wet fens within the Fenland. This strategic overview will draw together existing information on agriculture, land use policy and social and economic factors in order to understand the potential impact of wetland creation on the area.

1.3 Report Structure

Section 2 of the report outlines the hydrological conditions required to create a range of wetlands. This assists in prescribing the conditions within which agriculture and other land use activities must operate. A financial and economic analysis identifies the changes in farm income associated with a switch from arable to livestock production on progressively wetter grassland. Five broad scenarios for potential future agricultural policy are used in the analysis.

Section 3 explores the opportunities for alternative non-agricultural wetland activities on fenland, such as bio-fuels, timber, and related agro-industry, as well as enterprises associated with traditional fenland management such as reed. Tourism, outdoor recreation and countryside sports are also considered. Changes in farm incomes associated with a switch from arable production to energy coppice or reedbeds are identified.

Section 4 assesses the socio-economic constraints, opportunities and effects of introducing alternative non-agricultural wetland activities. These are considered in terms of current policy, particularly in the context of sustainable development

Section 5 assesses the current extent of peat wastage in the Fens and predicts the likely future impact on agricultural land quality.

Section 6 consider whether wetland creation results in the irreversible loss of agricultural land with respect to acid sulphate and silt soils in the Fens.

The report is supported by References to the Literature and by Appendices.

2. ECONOMIC ANALYSIS OF FENLAND AGRICULTURAL SYSTEMS

The aim of this section is to identify the hydrological requirements for different wet fen habitats and examine the economic consequences associated with changes in agricultural activity. It reviews the existing agricultural conditions in the Fens and identifies the dominant farming systems. It also considers a change in farm income associated with a switch from typical fen agriculture to livestock production on progressively wetter grassland and looks at changes in agricultural activity with the introduction of different policy scenarios. The final part provides a review of payment schemes which could be used to encourage wet fen creation.

2.1. Hydrological conditions necessary for the creation of a range of wet fen and grassland habitats

This section identifies the hydrological conditions required for different habitats within the wet fens, describing the vegetation and habitats associated with particular water regimes. This will assist in defining conditions for possible agricultural and non-agricultural land use.

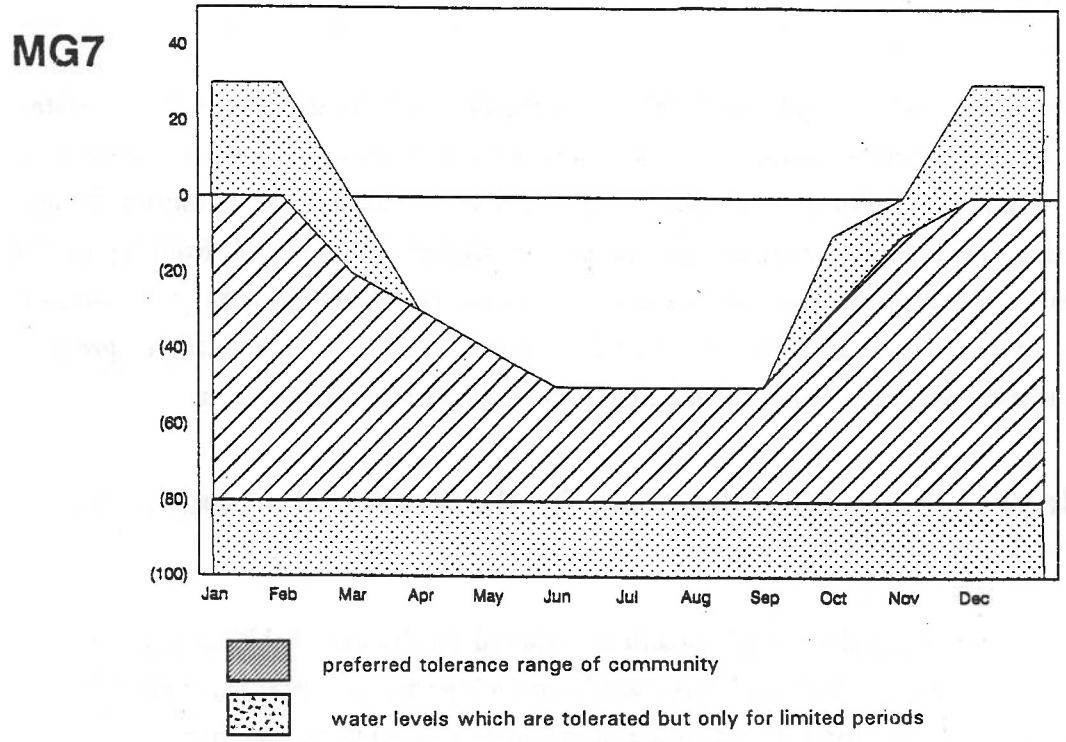
Table 2.1 and Figures 2.1a to 2.1f summarise the water regime requirements of six plant communities as defined by the National Vegetation Classification (Rodwell, 1991 *et seq*).

Table 2.1: Water regime requirements for MG7 plant community

Water-table depths	MG7		MG8		MG13		W2		S4		S24	
(cm)	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
January	10*	D	10*	30	0/F	60	0	30	F**	30	0/F	10
February	10*	D	10*	20	0/F	20	0	20	F**	30	0/F	0
March	20	D	10*	30	10*	30	0	20	F	10	0	10
April	40	D	10	30	10*	30	10*	30	F	0	0	20
May	50	D	20	40	10*	30	20*	40	F	0	20	40
June	50	D	30	50	10	40	20*	50	0	20	30	50
July	60	D	30	50	20	40	30	60	10	40	40	60
August	60	D	30	60	30	60	30	80	20	60	50	80
September	40	D	30	70	30	80	30	D	30	80	50	80
October	40	D	20	70	20	D	20*	D	30	60	30	60
November	30	D	10*	50	10	D	20*	D	10	40	10	40
December	10*	D	10*	40	0/F	80	10*	40	F**	20	0	20

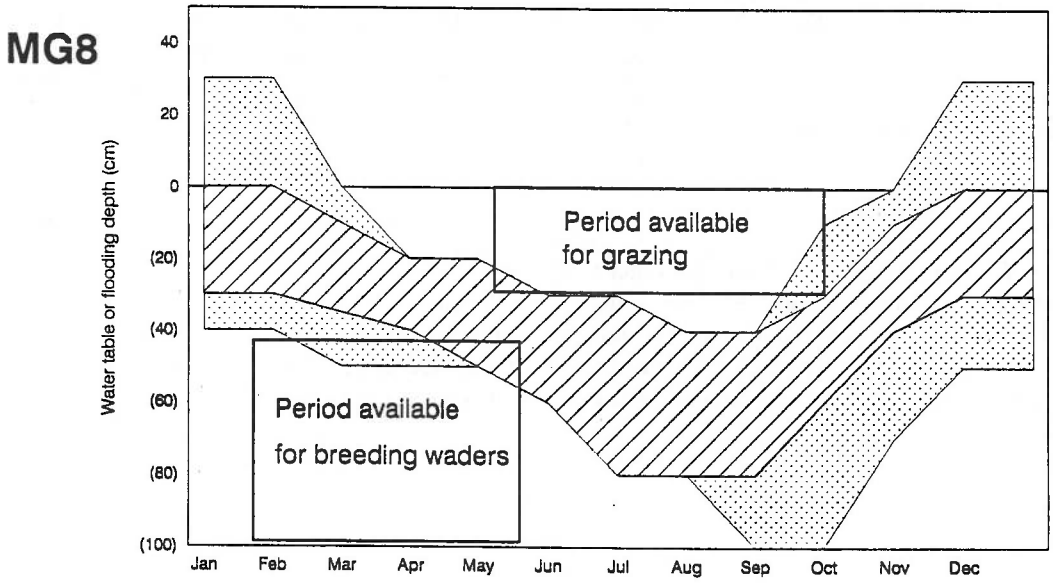
D = Soil freely draining - i.e. the presence of a water table not essential
F = Area flooded - exact depth usually not critical in range 0-100 cm
0 = Water table at surface or standing water on surface, but not above vegetation
* = Periods of inundation to a depth of 30 cm can be tolerated if not usually more than 7 days in duration
** = A facility to drain the area occasionally for management is required
Notes
All the above assume the climate of Eastern England and a permeable open-structured soil such as a peat.

Figure 2.1a: Water regime requirements for MG7 plant community



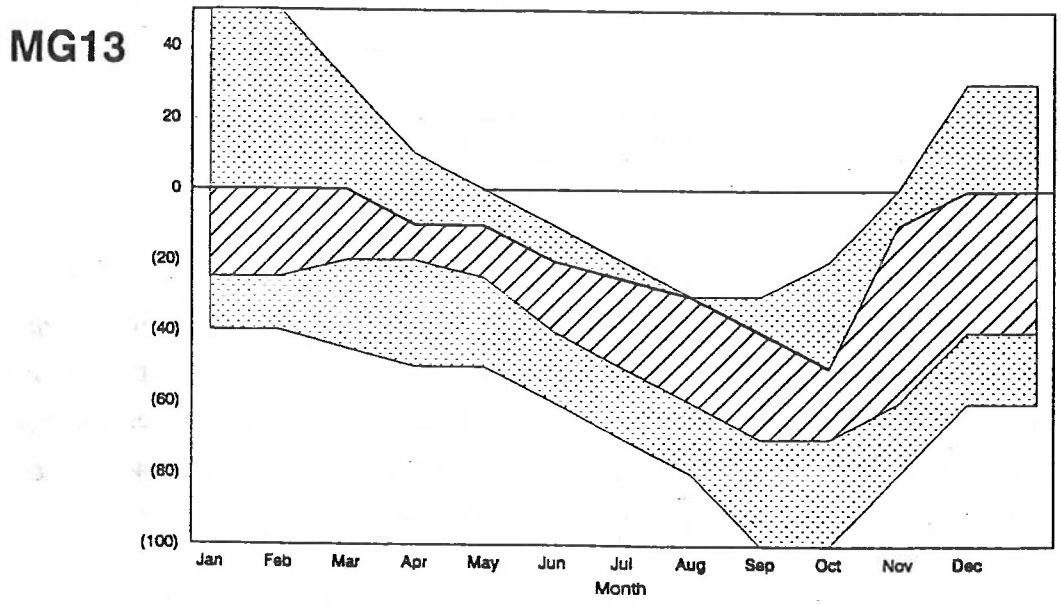
MG7 is a productive grassland dominated by perennial ryegrass. This grassland habitat corresponds to the conditions described for the livestock enterprise under Scenario 3 in the proceeding economic analysis. A water regime at the wet end of the spectrum given would result in sub-community 7B. Community 7A is the best agriculturally and would require best drainage. Management is usually intensive grazing through most of year with annual addition of nutrient, mainly nitrogen. No additional water necessary, though yields are increased if summer drought can be avoided. This is commonly found throughout the country where cattle are grazed on improved permanent pastures.

Figure 2.1b: Water regime requirements for MG8 plant community



MG8 is a flood pasture or water meadow with very species-rich flora. In the following economic analysis this habitat is associated with the livestock regime identified in Scenario 4. It is of high conservation value and requires water tables to be managed artificially usually with a dense ditch network and an external supply of water. Management is by summer grazing or hay-cut in June with some aftermath grazing. This is a scarce community found on some chalk streams in S England and on peat in the Somerset levels. It is the target of a habitat creation initiative at Wicken Fen, Cambridgeshire. For illustrative purposes, boxes have been drawn on the figure above to indicate the periods suitable for grazing and breeding waders.

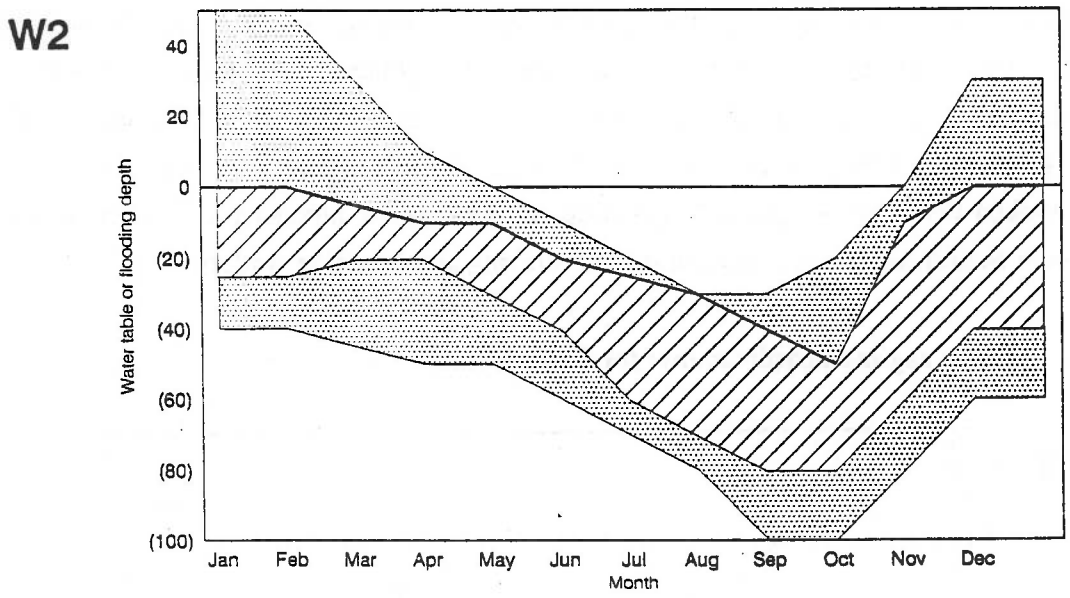
Figure 2.1c: Water regime requirements for MG13 plant community



MG13 is a species-poor inundation grassland dominated by creeping bent. The livestock regime associated with this grassland habitat relates to Scenario 5 in the economic analysis. It has little botanical value but can provide good conditions for breeding waders and wintering wildfowl. No fine control of water levels required. Depends on inundation from flood events in spring. Management consists of cattle grazing whenever soil is firm enough to support them. It can be found extensively on the Ouse Washes.

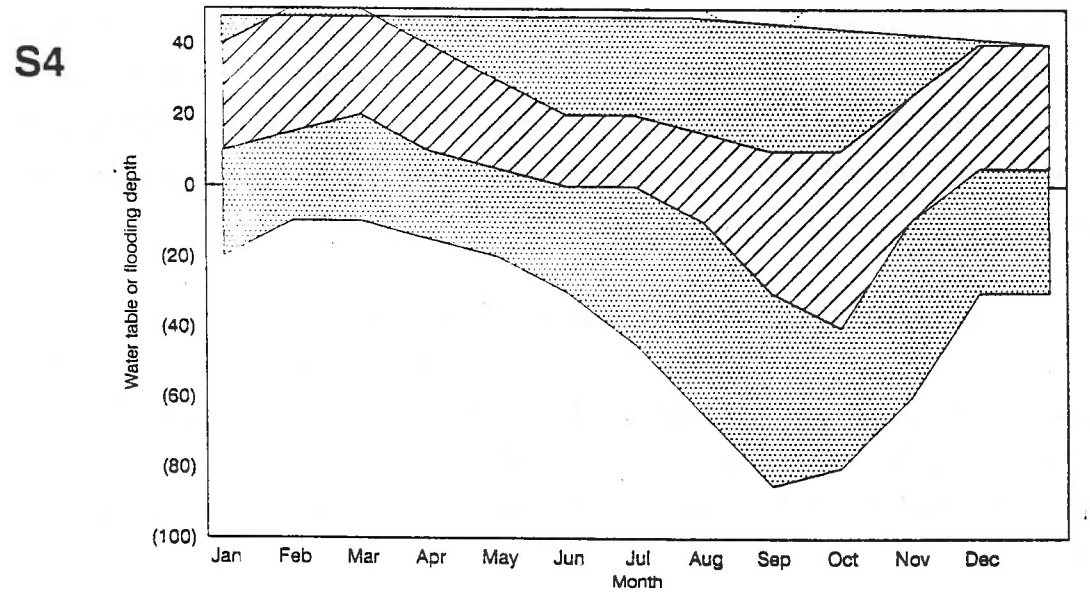
W2 is a wet woodland, primarily of willow species and is the habitat considered when looking at the economics of energy coppice. It demands high soil moisture in spring, but does not have exacting requirements in late summer/autumn. Little management required, would tolerate regular coppicing happily. No water management infrastructure necessary. Found around margins of many wetland sites in E England. It is often removed from former reedbeds to re-instate them.

Figure 2.1d: Water regime requirements for W2 plant community



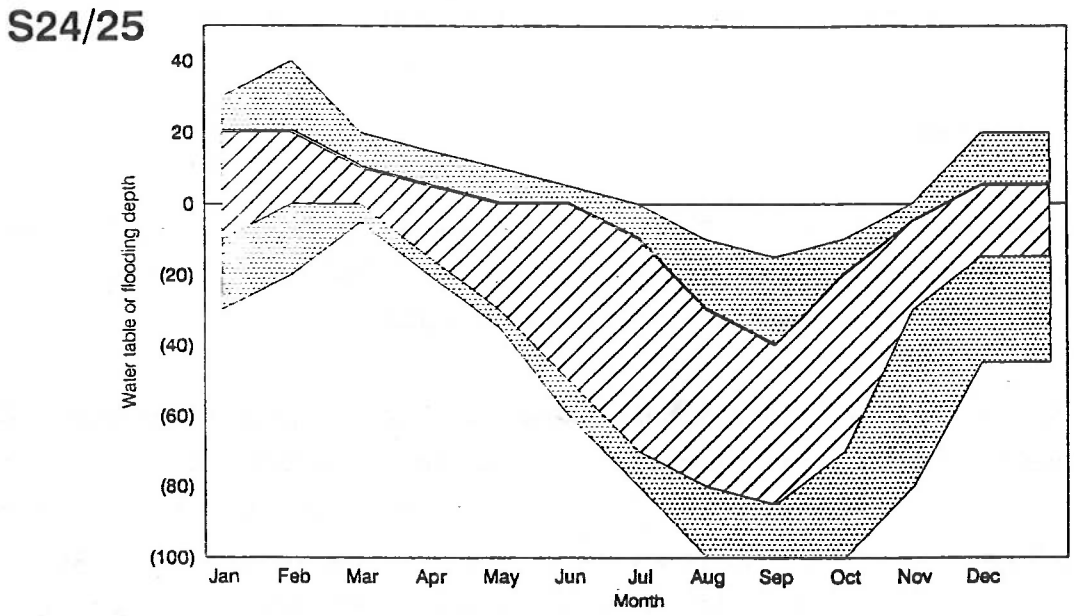
S4 is a swamp dominated by the Common Reed. It is usually found in association with areas of open water. Indeed its nature conservation interest is greatest where there is abundant interface between reedbed and water. It needs a plentiful supply of water year round and therefore is mainly found in river systems. It requires harvesting during late winter every few years to prevent a succession to scrub. It is widely scattered as small stands. Easton Valley and Minsmere in Suffolk are two good examples of extensive reedbed.

Figure 2.1e: Water regime requirements for S4 plant community



S24 is the classic tall fen vegetation. In Eastern England it typifies what botanists refer to as rich fen habitat. It has very high conservation interest but is not easily re-creatable. It would require an external supply of water in summer and a ditch system to distribute it. It requires cutting every two or three years. It is not tolerant of grazing. It can be found on Wicken Fen and at numerous sites in the Norfolk Broads.

Figure 2.1f: Water regime requirements for S24/25 plant community



2.2 Economics of Alternative Farming Systems

The aim of this section is to assess the financial and economic feasibility and consequences of a move from existing agricultural land use and farming systems to that based on a wet fens environment. In order to do this, current practices for a range of typical fen farms are compared with those for various alternative wet fen farming systems. The impact on farm income and added-value to the national economy are assessed. The likely magnitude of incentives required to encourage a switch to wet fen systems are identified, together with the circumstances which might favour farmer participation in a wet fen programme.

2.2.1 Policy Scenarios

This study identifies and examines a number of policy alternatives and related farming systems designed to deliver the environmental good of the wet fen. These policy options are based upon a review of possible changes to current agricultural policy.

In response to growing public concern and commitment to the concept of sustainability, policy makers have found it necessary to consider the production of non-marketable environmental goods, as well as agricultural output. It is now the case that agricultural and environmental policy are inextricably linked. The policy signals emerging from all the major stakeholders suggest that radical reform of the CAP is necessary to address environmental issues in harmony with agricultural issues.

There has been a clearly recognisable shift in agricultural policy over the last decade involving a more radical approach, which is set to continue (MAFF CAP Review Group, 1995). This recognises the complex interaction between agriculture and the environment and a realisation that less intensive farming on some land would not diminish the ability to feed the population. This shift can be evidenced by the emergence of a number of policy options which seek to control or redress environmental change, given the economic pressures of modern agriculture. Agricultural policy now consists of controls and incentives to induce provision of environmental goods, alongside the more traditional agricultural supports. These options for 'agri-environmental' policy include individually negotiated management agreements, standard area-based payments for environmentally positive activities and cost-sharing grants for conservation investment.

At present, the indications are that agri-environmental policy designed to deliver environmental goods in conjunction with agricultural output will be of a 'twin-track' approach (DOE, 1995). On the one hand, the notion of cross-compliance can be used to support a level of protection

and enhancement. A cross-compliance system requires that if farmers are to benefit from agricultural price supports, they must undertake specified environmentally positive activities. As currently implemented in the European Union (EU), farmers who benefit under the CAP must set aside a proportion of their land (arable farmers) or comply with maximum stocking rates (livestock farming). To qualify for support, environmental terms and conditions must be complied with. The making of payments to farmers for adopting farming practices that enhance environmental quality, or indeed reverse the trends of intensive agricultural systems, through management agreements, constitutes the second approach and clearly represent a positive incentives-based approach to this policy system. The Environmentally Sensitive Areas (ESAs) and Nitrate Sensitive Areas (NSAs) schemes are examples already in existence. The introduction of tiers or scales to such management agreements indicates that appropriate compensation for loss of agricultural goods in return for provision of specified environmental goods is the methodology of assessment that should be used in the initial appraisal of the recreation of wet fens.

2.2.2 Policy Change Scenarios

Scenario analysis is used to examine the financial and economic impact of land use change in the Fens. Five Scenarios which reflect different combinations of policy conditions and farming systems are identified.

- **Scenario 1:** Arable Farming operating under the current Common Agricultural Policy framework. Three subsidiary scenarios (Scenarios 1a, 1b and 1c) are used to represent the dominant types of existing arable farming circumstances and practices.

- **Scenario 2:** Arable Farming, Free Market. As for Scenario 1 but with market prices adjusted to reflect free market conditions and the removal of government support and protection to agriculture.

- **Scenario 3:** Moderately intensive Grassland Farming based on Cross Compliance with environmental policy objectives. Producers qualify for support payments for grassland enterprises, such as, livestock headage payments, in return for practising agriculture that delivers associated environmental goods. This 'cross-compliant' policy contains a compulsory element. This scenario is consistent with grassland type MG7 as given in Section 2.1.

- **Scenario 4:** Extensive Grassland based on an Environmentally Sensitive Area (ESA) type Management Agreement Tier 1 - producers will practice wet fen agriculture, qualifying for

compensation in respect of the loss of income due to less intensive agricultural systems. This system will maintain and protect a base level of environmental goods delivered from wet fen agriculture and is consistent with grassland type MG8.

- **Scenario 5**: Extensive Grassland based on ESA type Management Agreement Tier 2 - producers will deliver wet fen environmental goods, induced by compensation and positive incentives (standard payments and cost-sharing capital grants). This system will include provision and enhancement of environmental goods, as well as maintenance of the base level. It is consistent with grassland type MG13.

Scenarios 3, 4 and 5 draw on the type of management agreements set up under Tiers 1, 2 and 3 respectively, of the Norfolk Broads ESA (MAFF, 1992). The scenarios reflect decreasing intensity of land use as grassland becomes wetter and moves towards a wet fen environment. Further information on each tier is given Section 2.2.4.

2.2.3 Current Situation (Scenario 1)

The dominant agricultural system of the Fen area represents a distinct type of farming based on intensive cash cropping. The majority of land in the fen area is classified as Grade 1 or 2 and the highly productive capacity for a broad spectrum of enterprises is reflected in the high agricultural land prices. Average farm sizes are increasing due to farm consolidation in order to obtain economies of scale and maintain farm viability. At present, the average size of a Fen farm is 130 ha (Murphy, 1996).

The study area consists of two major agricultural districts: District 10, the Isle of Ely and District 11, the Lincolnshire Silts (Murphy, 1996). The dominant farm type in these two districts is classed as Type 7: Fen Arable. However, due to the observed variability in farm size and productivity across the Fens, three farms have been identified which represent the range of arable enterprises and which reflect the varying intensity of production.

Typical fen arable farms

Data for Fen arable farms (Type 7, Murphy, 1996), taken from a survey of 46 farms have been used to determine current enterprises, expenditure and income for an averaged size Fen arable farm covering 130 ha. Following discussions with the Farm Business Survey (FBS), Department of Land Economy, Cambridge, two other typical farm models have been identified,

which reflect farms of differing size, structure, enterprise combination and hence differing productivity. These three farms models are identified as Scenario 1a, 1b and 1c respectively.

Scenario 1a

The average Fen arable farm model is 130 ha in size, following a typical rotation of winter wheat, oil seed rape, maincrop potatoes, sugar beet, field beans and set aside. The percentage area given to each of these enterprises is shown in Figure 2.2. These percentages, and relevant farm management data, have been drawn from the secondary sources, especially Murphy (1996) and the regional FBS.

Scenario 1b

This farm model represents smaller farms with relatively lower land use intensity and profitability. This farm is typical of those on the poorer skirt soils for which profit is relatively low and variable. Average yields are lower than under Scenario 1a. Typical rotations are based on winter wheat, combine peas, sugar beet and set aside (Figure 2.2).

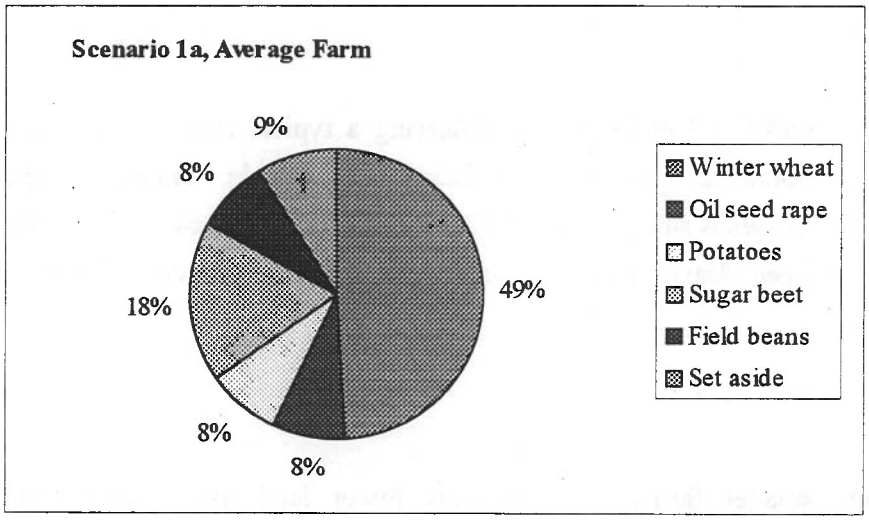
Scenario 1c

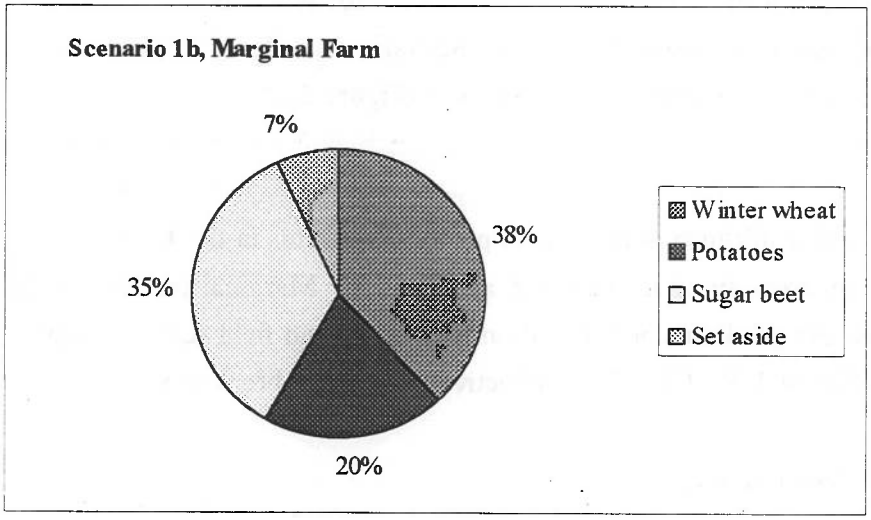
This farm model is representative of those in the top 10 performing farms in the Fens. Profits are consistently high with the majority of land classed as Grade 1. Marginal land is usually down to set-aside. Rotations are predominantly based on root crops and field scale vegetables such as carrots and onions (Figure 2.2). Cereals are effectively used as a break crop.

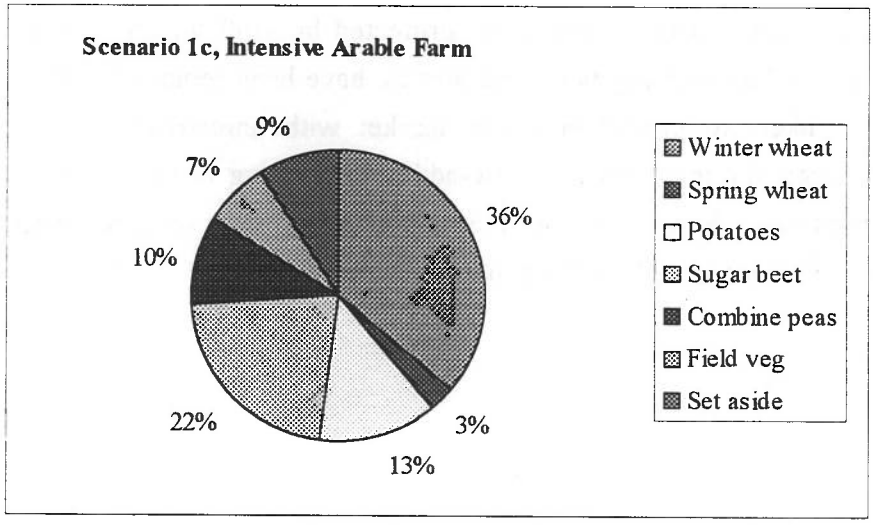
2.2.4 Free Market (Scenario 2)

Under Scenario 2, agricultural commodities are no longer protected by artificial price levels. All government price support, such as area payments and quotas, have been removed. Prices have been adjusted to those likely to prevail in a free market with unrestricted trading throughout the world. The scenario considers the value-added by existing farming systems under these revised price conditions. In practice, however, a change in prices towards world market levels is likely to result in changes in the pattern and structure of farming.

Figure 2.2: Agricultural production for three typical fen farms







2.2.5 Scenarios for Wet Grassland

Scenario 3

The Tier 1 policy of the Norfolk Broads ESA agreement has been used as a basis for determining land use under Scenario 3. The grassland is grazed intensively by sheep and beef and grass conservation takes place. However, the following compliance restrictions apply:

- land use must be permanent grassland;
- good drainage (watertable > 0.5 m from ground surface for > 80 % of time);
- no poaching (damage to soil structure and destruction of grass sward by livestock);
- 1 cut of silage (usually on half the area);
- maximum nitrogen application rate of 125 kg/ha (100 kgN/ha is assumed);
- beef cows and sucklers (spring calving);
- overwintered and grass finished beef;
- sheep and fat lambs - high lambing rate;
- graze from mid/late March to mid/late November; and,
- suckler cow, beef and sheep premia apply subject to overall maximum stocking rate of 2.0 livestock units/ha. Headage quota are available from national reserve as part of arable reversion scheme.

Scenario 4

Under Scenario 4, the intensity of grassland usage decreases. The management agreement set out under Tier 1 applies, in addition to the following restrictions:

- no grazing 31 October to 1 April;
- 1 cut of hay (usually on half the area);
- maximum nitrogen application rate of 44 kg/ha; and
- poaching risk avoided by restricted grazing.

The following assumptions have also been made regarding intensity of land use:

- drainage status is assumed to have deteriorated to a bad condition with no poaching (watertable > 0.3 m from ground surface for > 50 % time and > 0.5 m for < 80 % time);
- sheep and fat lambs - medium lambing rate;
- beef cows and sucklers (spring calving);
- grazing season - early/mid April to mid/late October;
- beef suckler and ewe premia are available as Scenario 3; and,
- extensification premia for suckler cows subject to stocking rates of below 1.4 livestock units per ha.

Scenario 5

Under Scenario 5, the intensity of grassland usage has been further decreased as the grassland is very wet throughout much of the year. Land use is restricted to the summer grazing of store cattle. The management agreements set out under Tier 1 and 2 still apply, in addition to the following restrictions:

- no fertiliser is applied;
- no grazing 1 Nov. to 15 May; and,
- poaching risk avoided by restricted grazing.

The following assumptions have also been made regarding intensity of land use:

- drainage status is assumed to have deteriorated to a very bad condition (watertable depth < 0.3 m from ground surface for > 50 % of time);
- no reliable grass conservation;
- medium store cattle;
- beef cows and sucklers (spring calving); and,
- grazing season - early/mid May to early/mid October.

2.3 Financial and Economic Analysis of Agricultural Systems

2.3.1. Budgeting and Pricing Methodology

The comparative analysis of the financial and economic performance of each of the aforementioned scenarios follows a common format. Two farm perspectives and two pricing perspectives are taken. With respect to the former:

- A whole farm budget is compiled for each of the scenarios showing the average annual income and expenditure and net return per ha (defined as management and investment income (MII) in accordance with farm management accounting convention). The whole farm budget shows the average net returns per ha which would be gained or lost in the event of a switch into or out of the farming system concerned respectively. Variable costs are based on standard estimates which reflect local yield performance, checked against regional statistics for consistency. Fixed costs are based on regional farm management survey sources. In the case of arable farms, fixed costs are based on data for fen farms, whereas for livestock, fixed cost data are drawn from livestock rearing and fattening farms in various parts of the country. Estimates are based on a range of data sources which include the published results of the Regional Farm Business Surveys, especially Farming in

the Eastern Counties (Murphy 1996), and farm management source books such as Nix (1996) and ABC (1996).

- A partial budget is compiled for each of the scenarios showing the extra income and expenditure and net margin per ha associated with substitution of farming activities at the margin, without changing the predominant farming system. There are some changes in labour requirements and operating costs of machinery but the majority of fixed costs on the farm remain unchanged.

With respect to prices, two perspectives are taken for farm outputs:

- Financial prices are used to reflect the prices paid and received by farmers, including relevant taxes and subsidies, such as area payments and livestock premia. !996 prices are used throughout. The financial analysis uses estimates of short term (year 2000) prices. These are lower than recent and present prices which are considered high relative to the long term trend of declining real prices for farm output. For example wheat prices averaged £115 to £120/t in 1995/6, whereas the short term prediction (1 to 3 years) is about £105/t. The medium term prediction (3 to 5 years), given the commitment to move prices to world market levels, is about £90/t. The latter is used in the economic analysis (see below). The market in livestock products has recently been upset by the impact of BSE. The financial analysis adopts pre BSE prices (based on 1994 to 1995 levels).

- Economic prices are used to reflect the value of agricultural inputs and outputs to the national economy once the costs of support have been taken out. The value of internationally traded commodities, for example should reflect international , i.e. world market, prices. For this reason, the economic price of wheat at £90/t reflects a medium term international price prediction. Further adjustments to take out Government subsidies follow the methods advised by MAFF (1993) for the appraisal of flood defence projects. This involves reducing the financial value of output to farmers (inclusive of subsidies) by specified percentages (e.g. 10% in the case of wheat, 25% in the case of beef) to reflect the cost of subsidies provided by the Government. These methods are open to some debate. They tend to reflect the net costs to the Exchequer after reimbursement of some the costs of support, such as set aside payments, from the EU, rather than the economic resource costs involved in supporting the sector. The methods, whilst still in place, are reportedly under review by MAFF. The estimates of economic performance must be used very cautiously.

For the purpose of analysis, data from the sources referred to above, were used to compile standard crop and livestock budgets which reflect local circumstances. These which were fed into a spreadsheet routine using methods drawn from the SCADE (Silsoe College Agricultural Land Drainage Evaluation) Model. This model, as the name suggests, was designed to appraise the impact of changes in farming system associated with changes in land drainage. The model is particularly useful for determining the productivity of grassland systems under wet fen regimes. The features of the model are described in Appendix I.

Appendix II contains details of the financial and economic analysis of the selected scenarios, together with a glossary of the terms used.

2.4 Whole Farm Analysis

2.4.1. Financial Analysis of Scenarios

Table 2.2 contains the whole farm budgets associated with each scenario. It shows the financial gross output, variable costs, gross margins, fixed costs and management and investment income per ha accruing to farmers for each farming system/policy scenario. It also shows the economic value-added by each scenario.

Table 2.2 Whole farm budgets for fenland farming system/policy combinations

Scenario	Current Situation			Free Market			Cross-Compliance	Management Agreement	
								I	II
	1a	1b	1c	2a	2b	2c	3	4	5
Financial Prices (£/ha)									
Gross output	1297	1059	1856	1039	800	1653	900	412	176
Variable costs	405	315	574	429	333	598	241	147	94
Gross margin	892	744	1282	610	467	1055	659	265	82
Total fixed costs	717	689	1042	717	689	1042	595	420	300
Management & investment income	**175**	**55**	**240**	**-107**	**-222**	**13**	**64**	**-155**	**-218**
Difference compared to Scenario 1a							**-111**	**-330**	**-393**
Economic Prices (£/ha)									
Management & investment income	**76**	**0**	**116**	**76**	**0**	**116**	**-213**	**-271**	**-280**
Difference compared to Scenario 1a							**-289**	**-347**	**-356**

Figures subject to rounding. Fixed costs here assume charges for land in the form of rent and for family labour at prevailing wage rates.

Table 2.2 confirms the financial profitability of existing farming regimes under current policy arrangements (scenario 1) in the fens, but confirms that financial performance varies amongst farms according to enterprise combination and levels of intensity. For the assumptions made, MII for the typical fen farm is £175/ha, whereas the more intensive farms achieve MII of about £240. The less intensive, marginal farms achieve about £55/ha. In practice, of course, actual MII varies considerably from year to year in response to market and climatic conditions. The estimates here are expected average values for the medium term. The disposable income accruing to the farm family may be larger than indicated because the latter includes a charge for family labour which is an income source and for rents which may not be paid where occupiers are owners.

In general, most holdings within the Fen area report relatively high and reliable profits from current agricultural practices, despite annual fluctuations in output prices for enterprises such as potatoes. The financial viability of current agriculture is evident. It is those producing on the most marginal skirt soils on a smaller scale and with relatively high rents to pay that face possible fluctuations around the break-even point.

Table 2.2 also the estimates the value added of existing farming systems in the absence of Government support and the operation of free market conditions where prices approximate to world market prices (inclusive of transaction costs) (Scenario 2) The impact on farm incomes is apparent. There are substantial reductions relative to the current case (Scenario 1). MII is -£ 107, -£ 222 and £ 13 for Scenarios 2a, 2b and 2c respectively. These estimated returns are unlikely to prevail in practice. In the face of declining prices, farmers are likely to adjust their cropping patterns and to reduce inputs in an attempt to reduce costs. Current farming systems are dependent on Government support.

Table 2.2 shows the financial performance at whole farm level of Scenarios 3,4 and 5 all of which involve the rearing and fattening of livestock. The scenarios differ in terms of degree of wetness which in turn affects the productivity, carrying capacity and hence profitability of the farming systems (see Appendix II). Whilst increased wetness reduces farming profits, it is assumed to increase the delivery of wet fen environmental benefits.

Scenario 3 represents a moderately intensive livestock system on reasonably well drained land involving suckler beef, grass finished store cattle and lowland fat lamb production. The system is based on the practices associated with Tier 1 of ESA management agreements. In this respect, the Scenario involves 'cross-compliance'. Overall stocking rates are about 2 livestock units per ha. Headage payments are assumed to apply (see Section 2.3.1). Scenario 3 appears financially viable with an MII of £64/ha.

Scenario 4 represents a low input grassland system producing sucker calves and lambs. The system is indicative of Tier 2 arrangements. Overall stocking is about 1 livestock unit per ha and therefore additional extensification premia apply. For the assumptions made, revenues are insufficient to recover costs and financial MII is -£ 155/ha.

Scenario 5 is an extensive wet fen system. Beef cows and store cattle are summer grazed. It is too wet for sheep. Stocking rates are less than 1 livestock unit per ha. Revenues are insufficient to recover costs. Financial MII is -£218/ha.

2.4.2. Economic Analysis of Scenarios

Table 2.2 also shows the added value of agriculture expressed in economic prices using the methods prescribed by MAFF Flood Defence appraisal guidelines to remove the effect of subsidies. These have the effect of reducing the MII for Scenarios 1a, 1b and 1c to £76, £0 and £116 per ha respectively. The economic value of Scenario 2 is assumed to be the same as for Scenario 1 because the same farming system applies (but for Scenario 2 the returns to farmers of operating the current system under free market conditions is not the same as the economic value).

Table 2.2 estimates the economic returns from Scenarios 3, 4 and 5. This follows MAFF guidelines on the reductions of beef and sheep gross output to reflect headage payments. Economic value added is -£ 213/ha, -£ 271/ha and -£ 280/ha respectively. There appear to be significant net economic costs associated with livestock production. These reflect the high levels of support to the livestock sector as well as the rel

2.4.3. Comparative Whole Farm Analysis of Scenarios

Table 2.2 also consequences for farm income and economic benefits to the nation of a switch in land use and farming practice from existing to alternative scenarios. From a financial viewpoint, a switch in the whole farm from a typical fen arable system (Scenario 1a) to a moderately intensive grassland system (Scenario 3) would result in an average annual income loss of £111/ha. Switching to very extensive summer grazing (Scenario 5) would result in an annual loss of about £393/ha. From an economic perspective the losses are £289/ha and £356/ha respectively. Switching to livestock does require considerably more support to the sector under existing policy regimes.

The economic analysis indicates that in terms of agricultural production, the costs to the national economy associated with a switch from arable to livestock systems are as great as, if

not greater than, those to farmers. This is because of the relatively high levels of government support given to livestock farmers in the form of headage subsidies. These economic losses may be offset by savings in other directions, especially the subvention given by Government to flood defence and land drainage. The economic losses associated in Table 2.2 must also be compared with the economic value of the environmental benefits associated with wet fen creation as identified in Section 7 below.

The analysis assumes perfect substitutability between current arable enterprises and livestock enterprises. Livestock and livestock husbandry skills are no longer common in the fen lands such that many farmers would find the switch difficult. It also assumes that farmers can acquire headage quota from the national reserve under the arable reversion schemes. Otherwise, they will incur additional costs purchase or lease such quota.

2.5 Partial Budgets

2.5.1. Financial Analysis

Table 2.3 shows the impact on farm income of a unit hectare increase or decrease in size of a particular farming activity (defined in terms of Net Margin per ha, see Appendix II), assuming that the dominant features and therefore the fixed cost structure of the farm remain. This perspective is relevant where small areas on a farm might switch from one land use to another.

Table 2.3 shows that in financial terms to the farmer, all scenarios are financially viable at the margin. That is, net margins are positive: extra revenues exceed extra costs. The arable systems under Scenario 1 have very high net margins, ranging from £610 to £1060/ha depending on circumstances. These values are evident in practice when farmers pay high prices for extra land which they can farm without increasing their labour force or stock of buildings and machinery. Net margins remain high under the free market Scenario (2).

The net margins for the livestock scenarios are positive, but relatively small for the extensive systems (Scenarios 4 and 5).

2.5.2. Economic Analysis

The application of MAFF guidelines to derive economic estimates of net margins results in lower net margin values compared to the financial analysis. Table 2.3 shows that economic net margins per ha are positive for all arable scenarios. (Economic values for Scenario 2 are assumed the same as for Scenario 1). Scenarios 3, 4 and 5 all demonstrate negative net

margins, suggesting that, once the value of subsidies are taken out, the extra return from livestock do not recover the extra costs. Indeed the less intensive is the livestock system , the less is the economic loss.

2.5.3. Comparative Partial Budget Analysis of Scenarios

Table 2.3 shows the changes in income per ha associated with switching small parts of the farm from one land use to another. The switch from typical arable farming (Scenario 1a) to moderately intensive grassland Scenario 2) involves an estimated loss at the margin of about £350/ha. Switching to extensive grassland involves an estimate loss of over £650/ha. In economic terms, the losses at the margin associated with the switch from arable to grass are estimated at between £530 to £640/ha. In practice these estimates may overstate the real losses associated with a switch, especially when farms are transferring small, fragmented or less productive parts of the farm from arable to grassland.

Table 2.3: Partial budgets

Scenario	Current Situation			Free Market			Cross-Compliance	Management Agreement	
								I	II
	1a	1b	1c	2a	2b	2c	3	4	5
Financial Prices (£/ha)									
Gross output	1297	1059	1856	1039	800	1653	900	412	176
Variable costs	405	315	574	429	333	598	241	147	94
Gross margin	892	744	1282	610	467	1055	659	265	82
Semi fixed costs	166	134	222	179	145	236	287	207	37
Net Margin	**726**	**610**	**1060**	**431**	**322**	**820**	**372**	**58**	**45**
Difference compared to Scenario 1a							**-354**	**-668**	**-681**
Economic Prices (£/ha)									
Net Margin	**452**	**388**	**489**	**452**	**388**	**489**	**-184**	**-172**	**-78**
Difference compared to Scenario 1a							**-636**	**-624**	**-530**

NB: Figures are subject to rounding

2.6. Conclusions from Financial and Economic Analysis

The following conclusions can be drawn from the analysis of results presented in Tables 2.2 and 2.3:

- The financial and economic performance of existing arable farming systems in the fens is high relative to the region as a whole. There is considerable variation within the fens.

Specialist, often large scale root crop and field vegetable producers demonstrate high returns relative to the typical fenland farm whereas small farms, often occupying skirt (degraded peat) soils exhibit much lower returns.

- The removal of all government support to farms would undermine the profitability of existing arable systems. It is likely that farmers would adjust the type and intensity of arable farming practices in order to cope with free market conditions. Those intensive farmers producing unsupported commodities such as potatoes and field vegetables on contract will be less affected by the change to free market than those dependent on cereals, oil seeds and grain legumes.

- Existing arable farming systems in the fens appear economically viable when judged from a national viewpoint. This confirms the comparative advantage of the area for arable farming. There are concerns, however, about the sustainability of current farming practices, given evidence of deteriorating soil quality, contamination of water quality due to agro-chemicals, and over abstraction of surface and ground waters. These are real resources costs which at present go unrecorded. It is likely that in future farmers will need to comply with environmental requirements and this may, at least in the short to medium term, compromise the financial performance of their businesses. Revisited or new technologies such as integrated pest management, minimum tillage, or precision application systems could help to deliver sustainability.

- Whole farm conversion from arable to grassland systems would result in large income losses to farmers and is unlikely to occur without considerable incentives which compensate for loss of income. The exception is the possible switch from arable to moderately intensive grass on the small, marginal farms on poor soils.

- Where whole farm change does occur it is likely that other factors will be important, such as ownership change or impending farmer retirement. The whole farm switch to grassland is constrained by access to headage quota as well as a relative lack of livestock skills and supporting infrastructure in the region. This is compounded in 1996 by an emerging shortage of livestock due to BSE.

- The income losses of switching small areas of the farm from arable to grass are high, unless there are concomitant savings in fixed costs for the whole farm. For the typical fen farm land is often perceived as the major constraint, especially as farmers pursue economies of scale in the operation of mechanised farming systems. Giving up land in any quantity is

not popular, unless it is problematic due to limited access or low productivity, or can serve interests such as game cover.

- There may be opportunities to encourage wet fen creation on some of the relatively unproductive areas of the larger farms. These areas are most likely down to non-rotational set aside. With the further reduction in set aside area, the switch may provide a viable alternative to farmers.

- The analysis suggests that the focus of attention should be towards:

  farmers on marginal soils achieving low and variable profitability under existing arable practice;
  parts of larger farms regarded as marginal to the dominant farm business, such as relatively unproductive areas or those which for a variety of reasons are difficult to farm;
  parts of larger farms where reverting land to wet fen could serve other interests or demonstrate a commitment to environmental beneficial land and water use; and,
  situations where changes in land tenure and/or farmer circumstances favour the move to extensive farming and wet fen creation.

- It is likely that farm specific circumstances will dictate an interest in and the feasibility of a switch from conventional fen farming to wet fen grassland systems. Furthermore, site conditions are likely to determine the type of farming and the type of wet fen environment which can be supported. For this reason blanket prescriptions may not work particularly well. It may be more appropriate to determine targeted environmental management agreements which specify the wet fen conditions to be achieved and which incorporate a level of incentive/compensation which reflects income loss and expenses incurred.

2.7 Incentive Payments

Numerous conservation policies, grants and payments are available to support the conversion of intensive arable and grassland areas to less intensive land use which simultaneously delivers environmental enhancement. These schemes (Table 2.4) may be used to provide financial incentives to encourage farmers to participate in the creation of wet fen environments.

The Environmentally Sensitive Area policy (ESA) was introduced in 1987 in response to continued pressure on threatened landscapes, their associated farming practices and the absence of suitable measures of protection. The ESA scheme is designed to aid the conservation of areas of high landscape or wildlife value which are vulnerable to changes in

farming practice through offering payments to farmers who are willing to maintain or to introduce environmentally beneficial and/or traditional farming methods.

This voluntary programme originated in the Broads Grazing Marshes Conservation Scheme which was set up to reduce pressure to plough up the grazing marshes for arable crops. This provided the prototype of flat rate payments to farmers in return for compliance with a set of management prescriptions. European Union authorisation for similar, more refined schemes for environmental protection which could be implemented throughout the country was sought following introduction of this scheme and was finally given through Article 19 of the structures regulation (EC 797/85). This Article, which permits member states to pay farmers to follow environmentally acceptable practices, was implemented in the UK through Section 18 of the Agriculture Act 1986 which empowers Ministers to designate Environmentally Sensitive Areas. By 1995 22 ESA schemes had been designated in the UK.

The ESA schemes are divided into tiers according to the levels of management agreement imposed. For example, the Broads ESA scheme for the protection of lowland river valley grassland is composed of four tiers. These are:

Tier 1	To maintain the Broads ESA landscape and grassland
Tier 2	To enhance the ecological interest of grassland and dykes
Tier 3	Creation of wet winter and spring conditions on the grazing marshes
Tier 4	Reversion of arable land to permanent pasture to create land suitable for Tier 1, 2 or 3
Tier 4	Grassland margins

A wet fen tier for the Broads ESA scheme is presently under consideration for possible inclusion in 1997 at the present time. Published details are not available but it is believed that payments will be made to participants who convert land into a wet fen environment.

Payments vary between ESA schemes and according to the tier within the scheme. A list of payments for each tier under various ESA schemes is presented in Table 2.4. Under the Somerset Levels and Moors ESA scheme, the payments of £ 415 /ha/yr are made for the creation of wet grassland. This payment is comparable with the estimated difference in MII between the current situation (Scenario 1a) and that of the extensive wet grassland (Scenario 5) (£ 393).

Fen creation may qualify for payments under arable to grassland reversion schemes within the ESA structure. At present payments range from approximately £260 to £550 depending on

local circumstances and income opportunities foregone. These payments are of similar magnitude to the losses in MII incurred in the switch from Scenario 1a to Scenario 3, 4 or 5 and therefore may go some way towards providing incentive payments or compensation (as shown in Appendix II, Table II.9).

Agreements which are individually negotiated with the participant, similar to those for Sites of Special Scientific Interest (SSSI), could be used to encourage the creation of a wet fen environment. Schemes could be entered into for a number of years. In the case of the SSSIs, sites are designated by English Nature. Participants receive annual payments in accordance with the net profit which is foregone. Capital grants may also be individually negotiated.

The Wildlife Enhancement Initiative, also administered by English Nature, offers annual payments for positive management on SSSIs and land adjacent to them. In return for payments, farmers are required to follow guidelines on ditch water levels, stocking rates and land management.

Under the Countryside Stewardship Scheme, introduced in 1991 by the Countryside Commission but now administered by MAFF, creation of fen areas qualifies for annual payments. Restoration and conservation of existing fen and water meadows qualify for payments of £ 100 /ha/yr. The creation of reedbeds qualifies for a payment of £ 40 for five years under this scheme. Annual management payments of £ 100 are also made. These payments are unlikely in themselves to encourage change from profitable arable land uses, but they may be supplemented by additional sources of income arising from alternative land use.

The Habitat Scheme is a voluntary scheme which was launched in 1994 to encourage farmers to create or enhance wildlife habitats along the fringe of lakes and watercourses by taking arable or temporary grassland out of production for 20 years. This scheme awards annual payments for the creation of extensive grazing. If measures are taken to raise the water levels, the raised water level supplement (£ 40 /ha/yr) may be claimed in addition to the main payment.

Fen creation may qualify for payments under arable to grassland reversion schemes. At present, payments range from approximately £ 350 to £ 550 depending on local circumstances and income opportunities foregone.

One option for farmers moving out of arable land use and into a wet fen environment, is to establish woodland and alder or willow carr. Various schemes offer different levels of payment as incentives. The Countryside Stewardship scheme awards payments of £ 40 /ha/yr for the

creation of alder or willow carr. The Farm Woodland Premium and Woodland Grant schemes both offer capital grants of £ 1050 /ha for the planting of broad-leaved woodland. The Woodland Grant Scheme also offers capital grants for restocking of woodland and coppicing. An annual management grant of £ 35 /ha/yr is also paid.

Table 2.4: Payments indicative of those which may support creation of wet fen

Scheme	Payment
Environmentally Sensitive Areas (10 year management scheme) (1996 prices)	**£/ha/yr**
Range of payments according to ESA scheme and management tier	40 - 430
The Broads	
Tier 1 Permanent grassland	145
Tier 2 Enhance ecological interest of grassland & dykes	225
Tier 3 Wet grassland	300
Tier 4 Arable reversion to permanent grassland	260
Tier 4 Grassland margins	330
Suffolk River Valleys	
Tier 1 Permanent grassland	70
Tier 1 Arable reversion to permanent grassland	240
Tier 2 Wet grassland	180
Tier 2 Arable reversion to wet grassland	260
Tier 2a Marshland supplement (added to Tier 2 payment)	50
Hedgerow supplement (added to Tier payments)	8
Somerset Levels and Moors	
Tier I Permanent grassland	130
Tier IS Permanent grassland with water level supplement	210
Tier 2 Enhanced grassland	215
Tier 2S Enhanced grass with water level supplement	295
Tier 3 Wet grassland	415
Essex Coast	
Tier 1 Permanent grassland	70
Tier 2a Wet grassland	180
Tier 2b Wetter grassland	230
Tier 3 Arable reversion to wet grassland	260
Countryside Stewardship (1996 prices unless shown)	**£/ha/yr**
Reedbed creation (for 5 years)	40
Reedbed management	100
Creation of fen, willow or alder carr (for 5 years)	40
Restoration and conservation of existing fen	100
Restoration and conservation of ancient water meadows (1993 prices)	225
Water level management and water features	
Culvert	£ 40 each
Sluice	£ 140 - 400 each
Ditch/dyke restoration	£ 2 / m run

Scheme	Payment
Habitat Scheme - (Currently arable/temp grass) (1996 prices)	**£/ha/yr**
Water fringe - buffer zone	485
Water fringe - extensive grazing	435
Raised water level supplement	40
Nitrate Sensitive Area (1996 prices)	**£/ha/yr**
Premium arable A - conversion of arable to extensive grassland - no grazing or fertiliser	450 - 550
Premium arable B- with native rich grass species, no grazing or fertiliser	490 - 590
Premium arable C - arable reversion, no fertiliser, limited grazing	420 - 520
Premium arable D - arable reversion, limited fertiliser and grazing	340 - 440
Farm Woodland Premium Scheme (1996 prices)	**£/ha**
Planting (broad-leaved)	1050
Woodland Grant Scheme (1996 prices)	**£/ha**
Planting (broad-leaved)	1050
Short rotation coppice	525
Restocking	525
Livestock exclusion premium	£ 80 /ha /yr
Annual management grant	£ 35 /ha /yr
Sites of Special Scientific Interest (1 to 21 year contract)	**£/ha/yr**
Payments vary according to site	variable
Wildlife Enhancement Initiative - part of SSSI scheme	variable
Landscape and Nature Conservation Grants	**Rate of Grant**
To encourage creation of wildlife habitats	up to 50 %

2.9. Summary and Conclusions

This Section defined the hydrological conditions necessary for the creation of wet fen and wet grassland. These conditions were used to determine the agricultural land use and practices which could be sustained in the event of a reversion from arable to grassland systems in the Fens. A number of scenarios were compiled to represent selected policy options and related farming systems. These provided a framework for a financial and economic analysis of land use alternatives in the Fens, ranging from existing arable farming systems to livestock rearing and fattening systems of varying intensity.

The analysis shows that, as far as agriculture is concerned, there are considerable financial and economic costs associated with a switch out of existing arable systems, especially given the area's comparative advantage in intensive non-cereal cropping. Sizeable incentives are likely to be needed to encourage farmers to revert to wet fen. Farming performance and prosperity,

however, are not uniform throughout the fens, and there are signs that the degradation of soil quality questions the continued sustainability of intensive practices. The analysis suggests that the creation of wet fens could beneficially focus on areas of marginal agricultural productivity, on farms where particular proprietor circumstances favour change, or where the creation of wet fens in generally farmed areas can ease the pressure of intensive agriculture on natural resources and the environment.

3. NON-AGRICULTURAL WETLAND ACTIVITIES

This section identifies non-agricultural wetland activities as alternative enterprises to intensive agricultural production in the wet fens. It also considers the economic potential of each of the activities and estimates the change in farm income per hectare involved in a switch from agriculture to non-agricultural activities.

The farm budget of a typical arable fen farm, as identified in Section 2, will be compared with those produced for some of the non-agricultural wetland activities. This analysis will assist in identifying the grants and incentives that may be necessary to support viable enterprises and encourage farmer adoption.

The following enterprises have been identified as possible alternative wetland activities:

- Reedbeds
- Energy coppice
- Wood products
- Fibre crops
- Countryside sports
- Nature conservation
- Tourism

These are examined in turn.

3.1 Reedbeds

Commercial reed production has been considered as a possible alternative use for land in the Fens.

3.1.1. Market Potential

Reeds are a traditional produce of Fenland with their main use for thatching. Although in recent decades the thatching industry has been in decline, there is some return to this type of roofing, which is particularly evident when the economy is prospering. Bateman *et al* (1990), in a study of the thatching industry, estimated that current commercial reed production in England is equivalent to 365 hectares of reedbed. Currently, Britain imports most of its thatching reed from Hungary, France, Romania and Poland which suggests there is a potential market within Britain for producing its own thatching reed. It has been estimated that there is a theoretical maximum of approximately one million hectares of agricultural land in UK which would be suitable for reed production (Bateman *et al*, 1990). There has been concern recently

about the quality of domestically grown thatching reed and the production of good quality reed will be important for the viability of any new enterprise.

Recently there has been a growing interest in the use of reedbeds for water quality improvement through assimilation of nutrients and toxins. Severn Trent Water have established reedbeds on the outfalls of over 100 sewage works and have found that reedbeds are effective at extracting secondary effluents of widely varying quality comparable with the best conventional treatment plants (Green 1993). Capital and maintenance costs are relatively low compared with standard water treatment works.

Other potential functions for reedbeds include flood defence through absorption and slow release of flood waters and as a source of bio-fuel for non fossil fuel power stations as "bio fuel".

3.1.2. Requirements for Reedbeds

Reeds grow best in fine soils, such as clays and silts (Haslam, 1972). Peat soils are not ideal for establishing reeds (Ekstam *et al*, 1992) and coarse soils such as gravels and sands are also less favoured by reed.

Reeds require a water level that is at or above ground level for 3 months during the February to April period when reed shoots emerge. Ideally water levels should rise with the growth of reed shoots as this protects against frost and competition from invasive plants. Water levels should be lowered by gravity or artificial means in the autumn/winter.

3.1.3. Establishment Costs

Establishment of reedbeds may involve a varying degree of land forming and construction of bunds and ditches, installation of water control structures and vegetation establishment, depending on the characteristics of the site. Establishment costs are variable depending on the amount of soil moving required, topography, and the method of reed establishment. Construction on slopes can be 3-4 times more expensive than on flat ground.

There are a number of possible techniques for vegetation establishment, including the use of direct seeding, rhizome transplantation, pot-grown seedlings and stem cuttings. Apart from natural expansion of existing reedbeds, direct seeding appears to be the most cost effective technique. Agricultural operations would be required to prepare a seedbed, followed by spray irrigation during germination. As shown in Table 3.1, if pot-grown reeds are planted the

establishment costs will considerably higher. Costs for bulk order emergent plants can vary from 24p/plant to 50p/plant.

Table 3.1: Reedbed establishment costs

Operations	£/ha *	£/ha **
Levelling	215	215
Bund construction assuming 87.5m/ha @ £19/m	1,663	1,663
Ditch construction 81.25m/ha @ £8/m	650	650
Direct seeding		
Harvesting and processing of reed panicles	85	
Cultivation to prepare seedbed	200	
Sowing by hand	25	
Herbicide	50	
Spray irrigation	150	
Total	510	
Pot-grown seedlings		
Seedlings - 10,000/ha @ 0.42 each		4,200
Total per hectare	3,038	6,728
Annualised costs over 25 years @ 6% interest	237	525

* direct seeding
** pot-grown reed seedlings

(Based on Hawke & Jose, 1996)

The figures presented in Table 3.1 show that initial establishment costs for reedbeds are high. Bateman at al (1991) suggested that first returns will be realised only 5 to 8 years after establishment. Therefore, a long term investment and financing plan will be required. They demonstrated that any infrastructure work should be kept to a minimum if a new reed bed is to be economically feasible. In fact, the conversion of land to reed growing only represents a viable option if the natural topography and groundwater conditions are already suitable for reeds.

Where reedbeds are intended for water treatment purposes additional construction costs include pipes, valves gravel, concrete, support medium, basin sealing with impermeable liner or membrane. The establishment costs of horizontal-flow sub-surface treatment systems in Severn Trent Water are £700-£1,600 *per capita* for secondary treatment systems and £40 *per capita* for 1,000 population equivalent sites to £100 *per capita* for 100 population equivalent sites for tertiary treatment systems (Green & Upton, 1994). Conventional treatment works of similar asset life and engineering standard designed to treat similar wastewater to achieve the

same effluent standards would cost was more than £2,000 *per capita* for an equivalent population size by Severn Trent Water (Green & Upton, 1994).

3.1.4 Sale Price, Yield and Production Costs

Reeds can be harvested for thatch on either a single wale (annual) or double wale (biannual) regime. Double wale cutting usually produces taller and thicker stems than the single wale. In 1995 the price for a standard bundle of UK reed (minimum 24" diameter at tie) was £1.60 - £1.75 and an average crop yield for reed is approximately 750-1,000 bundles per hectare (Hawke & Jose, 1996). However where reedbeds have been cut single wale for many years there may be a gradual decline in yield (Ward, 1992).

Variable costs are low as there are no requirements for re-seeding, fertiliser or herbicide. In owner-cutter regimes, the main expense is rope required for tying bundles, costing approximately £6/ha (Bateman *et al*, 1991).

Fixed costs are the main component of the production costs. In a number of case studies looked at by Bateman *et al* (1991), expenditure on labour was identified as one of the major components of fixed costs. The most labour-intensive operational element in reedbed management is the harvest, particularly the cleaning and dressing of the reed. This labour requirement is increased if a double swale cut is used, as more unwanted vegetation needs to be removed from the bundles. In addition to the harvest costs, reedbeds require some maintenance throughout the year, involving regular dyke clearance and scrub removal.

Reedbeds can be either be managed directly by the owner or can be licensed out to interested parties, such as professional reed-cutters, thatchers or conservation organisations. If an enterprise relies solely on its own labour resource then net margins, including annualised establishment costs using direct seeding, are estimated at £286, as shown in column (a) in Table 3.2. Column (b) shows a net income of £405 when an ESA grant for 50% of the reedbed establishment costs has been received. If the owner only cuts and stacks the reed and the cleaning and dressing are done by an outside thatcher in return for a discount bundle price, the net margins would be £125. This is shown in column (c) in Table 3.2. If the establishment of the reedbed is to be created through the planting of pot-grown seedlings then there is an increase in establishment costs and a subsequent decrease in net income as presented in column (d). If the landowner allows a contractor to cut the reed, then the two main factors which determine a reasonable return are crop yield and 'royalty' fee. Large enterprises will be able to spread fixed costs and thereby achieve some economies of scale.

Table 3.2: Net Income per annum for thatching reed

	(a)	(b)	(c)	(d)
OUTPUT (£/ha)				
Yield (bundles/ha)	750	750	750	750
Price per bundle	1.5	1.5	1.1	1.5
Gross Output	1,125	1,125	825	1,125
Establishment costs per hectare annualised over 25 years at 6% interest	237	118	237	525
Gross Output (after establishment costs)	888	1,007	588	600
VARIABLE COSTS				
Rope	6	6	0	6
Total Variable Costs	6	6	0	6
Gross Margin (£/ha)	882	1,001	588	594
FIXED COSTS				
Labour				
site supervision (£15,000/yr spread over 130 ha)	115	115	115	115
harvesting	265	265	133	265
Machinery				
harvesting	156	156	156	156
cutting edges - 125m/ha	20	20	20	20
ditch cleaning - 25m/yr	40	40	40	40
Total Fixed Costs	596	596	464	380
Net Income	286	405	125	214
Net Income (before establishment costs)	523	523	362	739

	(a)	(b)	(c)	(d)
Capital sum	-3548	-1,774	-3,548	-6728
Present value of net value before establishment costs (years 7 to 25)	4,485	4,074	3,132	5,890
Net present value at 6%	937	2,300	-416	-838
Equivalent annual net income (over 25 years) (annuity at 12.8)	73	180	-33	-65

(a) reedbeds established by direct seeding
(b) reedbed established by direct seeding, including ESA grant for 50% of establishment costs
(c) reedbed established by direct seeding and cleaning and dressing by outsider for royalty fee
(d) reedbeds established with pot grown seedlings

The net income for reedbeds without financial support may range from £125 to £286, with an average return of £208/ha. Such returns are comparable with net income for winter wheat grown on marginal quality land.

Reedbed water treatment systems have both lower construction and operating costs than conventional waste treatment options, particularly for populations up to 1,000. Annual

operating costs for surface-flow systems have been calculated at about £400-£600 per hectare, This includes pumping energy, mechanical maintenance and pest control

A report by Fife Regional Council (undated) compared the capital and revenue costs of activated sludge and reedbed water treatment systems

Table 3.3: Costs of alternative water treatment systems

Discounted cash flow (net present values) projects for the two options over thirty years discounted at a discount rate of 6%			
	Cost (£)	cost/person (£)	cost/person/year (£)
Reedbed	2,652,000	226	8
Activated sludge	4,245,000	309	10
Reedbed saving	1,593,000	83	2

(Source: Sheffield, undated)

Table 3.3 suggest that constructed wetlands are a cost-effective means of sewage treatment for a population of about 12,000 in this case. There may also be commercial potential to reuse some of the water treatment system products, for example, compost for horticulture and biofuel. However, the reeds grown in wastewater are unlikely to be useful for thatching because the excess nitrogen makes the reeds soft.

3.1.5 Financial incentives

There are financial incentives for creating and managing reedbeds within the following schemes: Environmentally Sensitive Areas, Countryside Stewardship, Habitat Scheme and local conservation grants.

In Environmentally Sensitive Areas (ESAs) farmers can enter 10-year agreements to adopt environmentally beneficial practices and grants are available for establishing reedbeds as part of a Farm Conservation Plan. The payments range from £8 - £400/ha/year depending on the particular ESA and the income opportunities foregone. The Countryside Stewardship scheme offers a 10 year management agreement with payment of £40/ha for 5 years for reedbed creation and £100/ha for reedbed management. The Habitat Scheme contain a Water Fringe option which encourages the establishment or enhancement of water fringe habitats alongside lakes and watercourses. This is currently limited to 6 designated pilot areas. Payments range from £125/ha to £360/ha depending on local circumstances. Since July 1995 it has also been possible to count eligible arable land entered into Habitat Schemes as part of the set-aside obligation. There is also an additional "raised water level" annual supplement under the Water Fringe option of £40 per hectare. In addition, there are a wide range of projects which

encourage the conservation and creation of landscapes, wildlife and habitats. These include agreements for management of SSSIs and ASSIs. These payments cover part of the management costs and capital costs (usually up to 50%) (Hawke & Jose, 1996). MAFF have made available for reedbed treatment systems a 50% grant under the Farm and Conservation Grant Scheme

In the future, under the new Agri-environment regulation, reeds could be defined as a 'non-food crop' which would enable them to be grown and harvested on set-aside land.

3.2. Energy Coppice

Energy coppice is the production of fast growing hardwood trees which are harvested to produce biomass for energy.

3.2.1 Market Potential

Over the last two decades there has been a growing interest in use of energy coppice, originally initiated by the oil price shocks of the 1970s which caused a reappraisal of the potential for alternative fuels. There are currently about 200 ha of coppice for biomass planted in the UK. Future prospects will depend to a great extent on the price of fossil fuel, which in turn will partly depend on Government energy policies.

There are two market segments for energy coppice: small scale use for domestic heating and greenhouses and large scale use for electricity generation, community or industry heat or power. This latter segment includes the supply of electricity to the National Grid. Current legislation requires privatised Regional Power Companies to obtain a proportion of their electricity requirements from renewable resources. These companies are entering into 15 year contracts with farmers to provide wood chips for bio-fuelled power stations. The Government aims to derive 200 megawatts from energy crop and forest residues by the year 2000. (Macpherson, 1995). The Department of Trade and Industry is expected to devote some £1-2 million per year on support activities for coppice cropping. There will also be money available from the EU for the development of renewable energy. There is the potential within the Fens for energy coppice to provide heating for glasshouses in the flower industry.

3.2.2. Requirements for Energy Coppice

Willow is the best species to use for energy coppice as it is easy to propagate, fast growing, and produces high biomass. Willows can be grown on soils between pH 5.5-7.5 in most areas

of the UK, although there is less certainty about its growth on peat (Whinney, 1994). Willows are planted by machines using unrooted cuttings at the rate of 10,000 per hectare. At the end of the fourth year, having reached a height of 6-7.5 m and thereafter every third year, the crop can be cut with an adapted maize forage harvester. The overall duration of a plantation is 25-30 years. Herbicides are required to control weeds during the early stages of growth. Fertiliser requirements are relatively low. Due to the bulky nature of the fuel it is essential that energy coppice plantations are close to a market for chips, preferably within 50 km.

3.2.3 Establishment Costs

Table 3.4 presents the establishment costs for a typical energy coppice plantation. There is a high initial investment cost of £1,696/ha of which £1,000/ha are for planting materials. An equivalent annual cost of establishment of £132 before grants has been derived by calculating an annuity over a 25 year period at a real interest rate of 6%

Table 3.4: Establishment Costs for Energy Coppice (£/ha)

Operations	(a)	(b)	(c)
Deep ploughing	35	35	35
Power harrowing	30	30	30
Planting	200	200	200
Cuttings	1,000	1,000	1,000
Herbicide	70	70	70
Herbicide Application	36	36	36
Weeding	45	45	45
Fencing	280	280	280
Grants and payments			
Annual area payment of £345/ha/yr discounted to present value over 5 years at 6%		1,453	
One-off Woodland Grant Scheme		400	600
TOTAL PER HECTARE	**1,696**	**-157**	**1,096**
Annualised costs over 25 yrs @ 6%	132	-12	85

a) establishment without grants
b) establishment with woodland grant aid on set-aside land
c) establishment with woodland grant aid on land outside arable areas payment scheme

(Adapted from Whinney, 1994)

There are grants available which will assist with establishment costs. Energy coppice qualifies for a single payment of £400/ha for Woodland Grant Scheme and may qualify for a set-aside payment of £345 per hectare per annum over five years. In Table 3.4 the area payment has been included as an annual figure discounted to the present value over 5 years at 6% interest rate. If the land is outside the arable payments scheme the single Woodland Grant Scheme payment of £600 is available.

Although these initial establishment costs are high, it is predicted that by 2015 establishment costs in real terms will be a quarter of what they are today as more suppliers of cuttings enter the market place. There may be a fall in establishment costs by as much as £400-500/ha (Swindells 1995)

3.2.4. Production Costs

Table 3.5 presents the net income per hectare per annum for energy coppice assuming different prices and varying degrees of financial support for establishment costs. The Fixed Costs are based on the assumption that a Class harvester is used, with harvesting costs of £11/dry tonne (Macpherson, 1995) and annual weeding costs are estimated for the use of a harrow or cultivator with spaced tines.

Table 3.5: Net margins per hectare per annum for energy coppice

	(a)		(b)	(c)
OUTPUT	High	Low		
Yield (DT/ha)	12.5	12.5	12.5	12.5
Price received per dry tonne	40	30	40	40
Gross output	500	375	500	500
Annualised establishment costs	132	132	-12	85
Gross Output (after establishment costs)	368	243	512	415
VARIABLE COSTS				
Annual herbicide after harvest every 3 years @ £60/ha	20	20	20	20
Annual fertiliser after 3 year harvest	8	8	8	8
Total variable costs	28	28	28	28
GROSS MARGIN	340	215	484	387
FIXED COSTS				
Labour	87	87	87	87
Machinery				
Harvesting	138	138	138	138
Weeding	45	45	45	45
Total Fixed Costs	270	270	270	270
NET INCOME	70	-55	214	117
NET INCOME (before establishment costs)	202	77	202	202

	(a)	(b)	(c)
Capital sum	-1696	157	-1096
Present Value of net income before establishment costs (years 5 to 25) at 6%	1835	1835	1835
Net Present Value at 6%	139	1992	739
Equivalent annual net income (over 25 years)	11	156	58

(a) establishment without grants
(b) establishment with woodland grant aid on set-aside land
(c) establishment with woodland grant aid on land outside arable areas payment scheme

(Adapted from Macpherson, 1995)

These net incomes have been estimated at £70 for a high price of £40 per dry tonne of output and £55 for a low price of £30 per dry tonne. Net incomes when grant payments for establishment costs are included range between £117 to £214. The Scottish Agricultural College and John Seed (1993) carried out a similar analysis and have suggested energy coppice produces a gross margin of £320/ha. This is comparable to the findings above where gross margins range between £214/ha to £484/ha depending on price, output and establishment costs.

3.3. Comparison of farm budgets for arable, reedbeds and energy coppice

Table 3.6 compares the farm budgets for energy coppice and reedbeds with the typical arable system in order to determine the net benefits and costs associated with a switch from the current situation to either of these two enterprises. Energy coppice has been calculated as a proportion of a wet grassland enterprise. The farm budgets under Case 1 for reedbeds and energy coppice represent a situation where no grants or subsidies are available. Under Case 2, for reedbeds it is assumed that 50% of the reedbed establishment costs are met by an ESA payment. Under Case 2 for energy coppice it is assumed that the woodland grant aid and set-aside payment are available.

3.4. Wood products

Willows have traditionally been grown on Fenlands for use as stakes for river bank protection and basket-making. Although this market has declined, pollard poles are increasingly in demand particularly for use in cardboard box manufacture, where a hardwood pulp with a short fibre length is useful for the corrugated section. Purseglove (1988) states that "timber merchants predict there will always be a demand for pollard poles, and are developing on-site chipping machines which will harvest a whole crop of poles and chip them on the river bank."

Table 3.6: Comparison of budgets for arable, reedbeds and energy coppice, excluding land costs and general expenses

	Arable	Reedbeds		Energy Coppice	
Element	Scenario 1a £/ha	Case 1 £/ha	Case 2 £/ha	Case 1 £/ha	Case 2 £/ha
Gross output	1,296	888	1007	368	512
Gross margin	892	882	1001	340	484
Fixed costs					
- Regular labour	169	380	380	87	87
- Machinery/power	299	216	216	183	183
Total fixed costs	468	596	596	270	270
Net Income at full development *	424	286	405	70	214
Equivalent Annual Net Income adjusted for delay to harvest plantation	424	73	180	11	58

* Net Income before land charges and general expenses

Case 1 represents current situation with no grant or subsides
Case 2 for reedbeds includes ESA grant for 50% of establishment costs
Case 2 for energy coppice includes area payment and Woodland Grant payment for establishment costs

3.4.1. Cricket Bat Willows

The willow *Salix alba coerulea* is the ideal species for cricket bat manufacture. It grows best on deep, permeable, alluvial loams or fertile boulder clays of high pH. It dislikes waterlogged and stagnant sites. The eastern counties of England, particularly Essex, Suffolk, the Thames Valley and Hampshire are the main growing areas (Hart, 1991) Cricket bat willow has a relatively short rotation of 15-20 years compared to other species and hence it is considered to be a viable commercial crop. The trees must be fenced against livestock and rabbits. The stems up to 3 m must be kept free of side shoots by disbudding each year in early spring, three times at least in the early years, the aim being to keep the bole unblemished and free from knots.

Table 3.7: Establishment and maintenance costs for Cricket bat willow (£/ha)

Operation	Year(s) of operation	Labour	Machinery	Materials	Total Costs/ha	Output	Net Profit
Output 70 trees/ha @ £50/tree						3,500	
Ground preparation	0	50	40		90		
Fencing and sleeving	0	500	50	500	1,050		
Sets and planting (£5 + £1 each)	0	75		350	425		
Protection	0			100	100		
Weeding	0 to 2	45		5	50		
Disbudding	1	25			26		
Disbudding	2 and 3	20			20		
General Maintenance (£10/ha/yr)	4 to 20	200			200		
Total					**1,961**	**3,500**	**1,539**

(Source: Hart. 1991)

In 1991 a mature cricket-bat willow was estimated to be worth £50-£65. A net margin for Cricket-bat willow has been estimated in Table 3.6 assuming that the willow will be planted at 12 m spacing giving approximately 70 trees per hectare and will be felled after 20 years.

3.4.2. Osier beds

"Osier" is a loose term covering a number of species of willow which are coppiced in some form. Traditionally every lowland settlement had osier beds used for basket work, eel traps, thatching spars, firewood fencing and many other uses. East Anglia was one of the centres of a well-developed local industry based on basket willow and specialised uses such as protective river-bank mats.

Today, the main market for use of osiers is basket making. The present basket market in the UK is dominated by imports from other countries such as Romania and Madeira This suggests that there is a potential market for osier beds in Britain to substitute for imports equivalent to an extra 1,000 hectares. Presently, British sources are dominated by one supplier with 40 hectares of commercial osier beds achieving an annual turnover of about £7,500 gross per annum per hectare (Purseglove, 1988).

According to Hart (1991) a processed rod cost about £14 per bundle to produce and retailed at about £17 per bundle; a bundle measures about 1 m in circumference at 5 cm from the base and weighs approximately 12 kg.

3.5 Fibre Crops

At present, small quantities of fibre crops are produced in Europe which represent only 2% of arable land use. This partly reflects the difficulty of growing the crops in northern climates. However, there is a growing interest in the use of fibre crops mainly as the result of environmental concerns, particularly those associated with deforestation.

The largest potential market for fibre crops is in the pulp, paper and board industries. At present these products are mostly derived from imported softwoods. As indicated in Table 3.8 there has been an increase in the UK consumption of wood and a number of forecasts (Forestry Industry Committee, 1987, Whiteman, 1991) predict that future demands for wood will increase, particularly in the pulp and paper industries. According to McDougall *et al* (1993), the costs of imported fibres "will continue to rise since there is a world shortage of suitable fibre for the pulp and paper industry".

Table 3.8: Wood imports, production and consumption (Mm^3) in the UK, 1982-1991

Year	Imports					UK production	Apparent consumption
	Wood	Pulp	Panel Products	Paper	Total imports		
1982	13.6	7.5	4.1	10.7	35.9	4.1	37.8
1983	14.5	8	4.8	9.1	36.4	3.9	38
1984	13.1	8.6	4.7	12.3	38.7	3.8	39.7
1985	12.3	8.1	4.7	12.4	37.5	4.7	39.9
1986	14.6	8.3	4.3	13	40.2	5.2	43
1987	19.1	8.5	4.5	15.4	47.6	5.4	49.4
1988	18.6	9.2	6.8	13.9	48.5	6	50.7
1989	18.6	8.9	6.1	14.4	48	6.4	50.3
1990	20.3	8.6	5.7	13.8	48.4	6.4	50.2
1991	16	8.7	4.9	13.6	43.2	6.5	44.7

Source: Adapted from Forestry Commission (1988, 1992)

Replacing man-made fibres composites, plastics and metal with composites incorporating fibres from crops represents a small but lucrative potential market (Carruthers *et al*, 1994).

Hemp is an example of a fibre crop that could be grown on wet land. Annual production of hemp in UK is estimated at around 1,140 tonnes from about 600 ha, with an average fibre yield of 1.9 tonnes per hectare per year (Carruthers *et al* 1994).

Hemp fibres could be used in the paper industry and may be suitable for a range of traditional and novel uses, such as geotextiles for erosion control, shading and mulching which could use natural fibres based on long plant fibres. However, this market is not large. The predicted

world market for the year 2000 is 1,400 million m^3. This would be the equivalent of about 70,000 tonnes per year for all applications, world-wide.

Another potential market for hemp is composites a material consisting of 30-70% fibres and 70-30% matrix. Fibres are introduced into plastic to improve physical properties. These fibres are usually man-made, but the use of plant fibres could result in cost savings. Composite production in Europe is 348,000 tonnes with UK producing 41,000 tonnes However, there is a danger that both geotextiles and composites might be undercut by lower cost imported fibres from developing countries, such as Bangladesh.

The capital costs associated with establishing of fibre crop processing plants are high, partly due to technical constraints. To date, most plant fibre processing technology have been developed for soft wood timber and as plant fibres are monocotyledons, with different fibre characteristics the technology needs adapting.

The cost of raw materials for processing plant fibres is currently similar to wood processing, although these costs may reduce as the technology improves.

3.6 Countryside Sports

Participation in countryside sports continues to rise (Cobham Resource Consultants, 1992)..

3.6.1 Game Shooting

Field shooting is a major field activity with membership and the numbers of affiliated clubs increasing by 254 % between 1980 and 1990.

Wet fens are a popular habitat for pheasants providing there is some un-flooded land among the reeds. The reeds act as a refuge from which the pheasants can forage out on surrounding arable land. In fact, reedbeds with some associated dry land are similar to woodland in their ability to hold pheasants. (Game Conservancy, pers comm.).

Much of the shooting in the Fens is in private hands, often with no paying Guns. However, the value of the shoot often lies in the ability to return invitations to shooting days with neighbours and is therefore just as valuable to some individuals as a commercial enterprise. The cash value of habitat improvement for shooting is often difficult to estimate, as rents vary considerably depending upon the reputation and location of the shoot, the quality of sport that can be provided and charges for similar shoots in the area. The rental value might range from

£0.80 per hectare for the right to shoot over "unimproved" farm land up to perhaps £4 per hectare, for areas of known reputation where the habitat is ideal for shoots.

The figures presented in Table 3.9 demonstrate that any profits from game shooting are likely to be small.

Table 3.9: Game Conservancy Shoot Revenue and Cost Analysis 1995/1996

Inputs	Owner's Shoots		Rented Shoots	
	Average Costs	Premium Costs	Average Costs	Premium Costs
	£/bird shot	£/bird shot	£/bird shot	£/bird shot
Output				
Game sales	1.69	1	0.82	0.24
Let of shoot	17	17	17	17
Total Output	18.69	18	17.82	17.24
Rent	0.39	0.23	1.39	1.45
Rates	0.11	0.12	0.2	0
Keepering	8.57	3.03	4.41	1.06
Equipment	1.11	0.77	0.56	0.74
Restocking	3.23	2.16	3.64	2.92
Post Rel. Feed	2.48	2.18	2.71	2.78
Game Crops	0.53	0.35	0.42	0.68
Beaters	1.38	1.47	0.98	0.16
Total Costs	17.8	10.31	14.31	9.79
Net Cost per Bird	0.89	7.69	3.51	7.45
Net Income/ha (assuming 5 birds/ha)	4.45	38.45	17.55	37.25

* Premium costs are taken from top 25% of sample.

(Source: Game Conservancy, 1995)

Some of the Fenland farms have planted woodland to enable more pheasants to be retained on the farm and to provide shooting drives. It is possible that some farmers might be prepared to use reedbeds as part of their habitat creation, providing the grants available are as favourable as those for woodland planting. (Game Conservancy, pers. comm.)

3.6.2 Wildfowl Shooting

The shooting of duck and geese, is a popular sport in the Fens with most of the shoots run by organised wildfowling clubs. The largest club is the Fenland Wildfowlers with over 300 members. Usually agricultural land is sold to clubs and individuals to shoot over. Recently a

club bought land in the Fens for £7,100 per hectare. If the land is rented for shoots then the annual rent would be 20 to 40 times less than the purchase price, approximately £5,000 per hectare per year. Farmers usually prefer to sell, rather than let their land for shooting, (BASC, pers. comm.).

Establishment costs for a wildfowl shoot are minimal, with only a requirement for cover. Running costs are also low; the main cost is associated with habitat maintenance, such as thistle removal and pollarding of trees. Where land is owned by clubs, members often carry out maintenance tasks in organised work parties. The clubs charge between £70 - £80 per year for membership and these fees also go towards maintenance costs.

3.6.3. Fishing

In the past fisheries formed one of the most characteristic elements in Fenland economy. Some were open-water fisheries, others were weirs consisting of fences made of stakes on which nets could be hung, and others involved eel traps built into the system of sluices of water-mills. The main fish were perch, eels, tench and pike.

There is still a diverse range of fisheries with the Fenlands with varying fish communities and series. The Fen area and in particular the Ely Ouse River, supports a nationally famous coarse fishery. It has been used extensively by both match and pleasure anglers and has hosted national angling championships. In the upper sections of the River Wissey and the River Lark, there are a number of trout fisheries. A small run of sea trout is known to occur in the River Wissey and occasionally other rivers in the area. Angling also takes place in a number of enclosed stillwaters. The popular coarse fisheries at West Stow County Park, close to the River Lark and the Nummery Lake complex near Thetford are of particular note. Commercial eel fishing, a seasonal activity between April and October, is found in the lowland fen section of the River Ely.

Cobham Resource Consultants (1992) found that the total number of anglers in the UK has grown by 175,000 from over 3.7 million in 1983 to 3.9 million in 1990. This is reflected in the Fens where fishing is a popular recreational activity. 60% of coarse anglers in Britain come from East Anglia and West Midlands region. The potential for growth in angling has been identified by the Water Utility Companies who have been active in promoting angling facilities in lakes and reservoirs. The key to expansion of the angling industry would lie in successful marketing.

For freshwater coarse fishing, which includes fishing for roach, bream, carp, rudd and tench, there is a high density of rods, approximately 1 per 25 metres of bank. Access and parking facilities would be required to meet this demand.

Depending on the quality of fishing typical rates are:

£0.03 - £0.65 per metre of bank per annum
£12 - £55 per peg per annum
£2.50 - £5.50 per rod per day
£750 - £2,500 per hectare for lakes

Charges for fishing rights let to a Club are £2,900 to £7,400 per hectare for an average stretch of water.

Game fish occur in lakes and reservoirs. Many are run as put-and-take fisheries which require a minimum area of 0.8 ha at an average depth of at least 2.5 metres and a pH level of 6.5 to 8.0, fed by a spring or other clean water source. Establishment may involve excavation of any existing or new ponds. Investment in an access road and car park may also be required. Put-and-take fisheries have the advantage of being run on a year-round basis because they are not affected by the fishing season. It may be necessary to employ a full-time manager.

The quality of fishing and local competition determine charges. However, typical rates for trout fishing, with no more than 1 rod per 50 metres of bank are:

£12 - £20 per day (2-6 fish)
£7 - £14 per half day (2 fish)
£5 - £10 per evening (1-2 fish)

Season tickets, allowing for 31 days of fishing, cost between £100 and £200 for lakes and £400 and £750 for rivers. Seasonal letting rates to an angling club which manages their own stocking and maintenance are between £500 and £1,500 per hectare of water, depending on quality of fishing and surroundings

If stock are brought in rather than home reared, replacement costs are about £1.25 per brown trout and £1.60 per rainbow trout. In general, after allowing for mortality, re-stocking costs are about 35-50% of sales. For example, if annual sales are 220 full day equivalents at £14 a day amounting to £3,080 per hectare, the restocking costs will be £1,000 and £1,300 per hectare (Agro Business Consultants, 1996).

A high level of management is required to keep anglers satisfied and to minimise poaching. Additional costs include advertising, labour and transport. Table 3.10 calculates an estimated net income for a small trout fishing enterprise.

Table 3.10 Estimated net income for trout fishing enterprise

	£/ha
Price per ticket	20
Tickets per year	860
Gross output	**17,200**
Variable costs	
Stocking @ one-third output	5,830
Gross Margin	11,370
Fixed Costs	
Labour	8,000
Advertising	600
Total Fixed costs	**8,600**
Net Income	**2,770**

(Source Adapted from Williams, 1988)

3.7. Nature Conservation

In terms of conservation, re-creating wet fen is extremely beneficial. Even a small area of wetland provides a habitat for many rare species. With increasing leisure time and greater value placed on environmental quality and sustainable development, the benefits to society in terms of improved access to the countryside and preservation of unique areas are considerable, although hard to quantify in monetary terms. Wet fenlands for nature conservation could be created on either privately-owned farms or through conservation bodies purchasing suitable land.

Expenditures by visitors to nature conservation sites account for a large proportion of the impact of nature conservation on the local economy. Wildlife is often responsible for generating a significant proportion of tourist revenues. Visits to nature reserves are less concentrated in the summer months than are other types of tourism, and can therefore play a valuable role in extending the tourist season in many areas.

The future market for wetland reserve can only be deduced by looking at the current numbers of visitors to existing wetland reserves in the Fens each year.

Wicken Fen, Cambridgeshire	30,000
Welney Wetland and Wildfowl Centre, Cambridgeshire	30,000
Strumpshaw Fen, Norfolk	17,400
Fowlmere, Cambridgeshire	14,600

The average charge for reserves range from between £1.50 to £3.00 for adult reserve permits and £0.50 for children. Assuming a two adults/one child visitor ratio, with 12,000 visitors and a £1.50 charge for adults, the income would be £ 14,000 and with 30,000 visitors and a £3.00 charge for adults it would be £65,000.

Establishing a nature reserve involves high capital costs, especially if facilities are to be provided for visitors. Capital items may include a visitors centre, boardwalk for access to damp areas, hides for viewing birds. Approximate costs for capital items and annual running costs are presented in Tables 3.11 and 3.12.

Table 3.11: Capital items for wetland nature reserve

	£
Machinery store, workshop and warden's office	50,000
Toilet block	40,000
Sewage disposal digester	25,000
Picnic tables	1,500
3 12' hides with disabled access	5,500
2 12' tower hides	4,500
Car park, paths and boardwalk	50,000
Mini-tractor with flotation tyres and reed-harvesting capability	10,000
Tools and safety equipment	1,500
Displays and other interpretative material	15,000
Warden's office equipment	2,000
Pump and power unit	6,000
Approximate total costs	**211,000**

(Source: Andrews Ward Associates, 1990)

The cost of establishing a Visitor Centre will depend on the style and the scale. The figures presented above are for an average estimate. As Table 3.12 shows capital costs are an important element of nature resources and can effect the profitability an enterprise.

Table 3.12: Annual net income for wetland nature reserves

GROSS OUTPUT	£/ha	£/ha
12,000 visitors charged £1.17 (70 ha)	14,040	
30,000 visitors charged £2.17 (200 ha)		65100
Gross output	14,040	65100
Establishment costs annualised over 30 years at 6% interest rate	15,403	15,403
Gross output (after establishment costs)	-1,363	49,697
VARIABLE COSTS		
Consumables	400	1,000
Total variable costs		
Total gross margin	-1,763	48,697
FIXED COSTS		
Warden's salary, NI and pension	6,500	15,000
Supervision and specialist support	1,000	2,000
Sinking fund for maintenance of buildings, hides etc @ 2%	2,000	4,000
Pumping costs and maintenance	500	1,000
Engineer's inspection of water storage and retention structures	500	1,000
Total fixed costs	10,500	23,000
Total Net Income	-12,263	25,697
Total Net Income per hectare	-175	128

(Source: Andrew Ward Associates, 1990)

There will be a limit as to the number of nature conservation sites opened to the public that the Fenlands can absorb. However, the creation of more sites will encourage a greater number of tourists to the area which will have a positive knock on effect on the local economy.

3.8 Tourism

Tourism development in UK is continually expanding. Much of this expansion is due to a decrease in the working week, longer holidays and an ageing population who have more leisure time. As there is this potential to generate an income from the provision of tourist activities, tourism should be an important component of any future strategy for the Wet Fens for the Future initiative.

In mid 1991, a partnership of several local authorities covering the wider Fens area, together with Regional Tourist boards and the Rural Development Commission established the "Fens Tourism Initiative" to raise the area's profile and promote it for short day trips, short breaks and activity based tourism. So, far the project is proving successful in meeting these objectives in terms of generating interest in visiting the area.

A survey conducted by the Fen Tourism Group of 639 households highlighted the most popular tourist activities in the Fens. The results are presented in Table 3.13.

Table 3.13: Interest expressed in particular tourist activities

Activity	% interest expressed in 1994	1993 result
Historic towns	65%	72%
Wildfowl and wildlife	46%	51%
Blossoms and blooms	36%	38%
Walking	31%	27%
The drainage story	26%	25%
Towers in the landscape	18%	22%
Boating	12%	10%
Angling	11%	4%
Special events	10%	13%
Cycling	9%	5%

Source: Fen Tourism Group, 1996

These figures suggest that the creation of wetland areas could provide an attraction for tourists, particularly if the site is associated with wildfowl and wildlife. This is demonstrated both at Wicken Fen and Welney Wetland and Wildfowl Centre which receive approximately 30,000 visitors each a year. Wicken Fen offers a visitor centre, and provides an insight into traditional industries and way of life in the region. Welney is managed as a wet grassland habitat, providing an ideal habitat for wildfowl and waders with provision of hides.

Other wetland tourist attractions may include the interpretation of the drainage story, birdwatching, fishing and boating. For example, the Fens already offers over 200 miles of waterways for cruising. Although fishing is a popular recreational activity experience from tourist boards have found it difficult to promote fishing as a tourism initiative.

3.9. Summary and Conclusions

This section has reviewed selected non-agricultural activities suited to wet fen conditions. Reedbeds and willow coppicing offer the most potential for generating an income from non-agricultural wetlands as they have a variety of uses which have a relatively high level of demand. The financial viability of these enterprises is however dependent on grants and allowances, especially during the early years before plantations reach full harvest potential. The is scope for improving the performance of wet fen plantations through adaptive research and technology development.

The demand for some products of wetlands, such as thatching reed and osier baskets is presently met by imports from other countries. The creation of wetlands may be able to recapture this market for home products.

Smaller-scale activities such as trout fisheries or cricket-bat willow may be viable if run in conjunction with an existing arable enterprises, but are unlikely to provide the basis for a whole-farm enterprise on their own

The net incomes from all non-agricultural activities considered are substantially less than the net farm income produced from arable fenland farms. Alternative systems are unlikely in themselves, without substantial and targeted incentives, to be sufficiently attractive to encourage a switch out of arable farming on any significant scale. Furthermore, local and regional market constraints may limit the scale to which any one activity can offer a realistic option to agriculture. Nevertheless they represent options which can be promoted and encouraged as part of a strategy which seeks the establishment of sustainable land and water use in the Fens

4. SOCIO-ECONOMIC IMPACTS OF WET FENS

The purpose of this section is to review the socio-economic characteristics of the study area and, in the context of sustainable development, examine the social and economic impacts of the Wet Fen for the Future initiative.

In this respect the analysis recognises the multi-function properties of wet fens which can serve the interests of a wide range of social groups. An important element in the success of the proposed Programme will be to identify and harness these diverse yet converging interests to good effect.

4.1 Socio-economic Characteristics

4.1.1. Policy Framework

The proposed Wet Fen initiative fits within a number of recent policy commitments by Government. In 1995 , the Government set out its policies for the Countryside in the White Paper Rural England: A Nation Committed to a Living Countryside. This drew on the earlier (1994) endorsement of Sustainable Development: The UK Strategy. These policy documents provide the framework for pursuing socio-economic development objectives whilst simultaneously protecting and enhancing the natural environment. The policy statements recognise the important links between development and environment, and that environmental quality is an important, but often neglected, indicator of socio-economic welfare.

The Rural White Paper gives six guiding principles:

- the criteria of sustainable development should apply;
- shared responsibility for the countryside as a national asset serving people who live and work there as well as those who visit it or derive benefits in other ways;
- dialogue amongst various groups to help reconcile competing interests and priorities;
- distinctiveness in rural policies which respond to particular local characteristics;
- economic and social diversity; and
- information and understanding as a basis for policies and action.

Sustainable Development has emerged as the guiding principle for rural policy. This requires that the countryside is managed so that rural dwellers and users enjoy sustained improvements in the quality of human life without degrading the natural environment. The principle requires that the stock of 'natural capital' and its capacity to support living systems (including human activity) remains intact. Sustainability requires that current users do not derive benefits at the cost of future generations who otherwise might face a deteriorated natural and resource environment. Sustainability requires the integration and reconciliation of a number of objectives, such as:

- conserving and enhancing the countryside for the benefit of current and future generations with respect to landscape, wildlife, agricultural, recreational and natural resource values;

- meeting the social and economic needs of people who live and work in rural areas, especially promoting the efficiency and competitiveness of rural businesses;

- encouraging local participation in development initiatives;

- reducing pressure on the countryside associated with inappropriate development and resource use;

- recognising the interdependency and complementarities of rural and urban policies.

The Government's White Paper recognises that social and economic development in rural areas has not been uniform. Employment in agriculture and primary industries has generally declined. Areas close to urban centres have done better economically than remote areas, but this relative prosperity has brought its own pressures.

The Government's rural economic objectives seek to encourage economic diversity by stimulating new and varied forms of wealth creation and employment, especially in areas of greatest need. This may involve exploitation of new technologies which can facilitate economic activity in relatively remote locations. The Government also recognises that wealth creation and environmental quality are closely tied. This is readily apparent for tourism and recreation which trade in environmental quality. But environmental quality is also an important draw for many other business which can bring jobs and prosperity to rural areas. In this respect environmental quality offers economic opportunity both directly and indirectly.

The Rural England White Paper contains the objectives for the quality of the rural environment, and implicitly the social and economic value derived from beneficial environmental management in the countryside. Reference is made to:

- conserving and managing the natural assets of the countryside;
- reversing the decline in the diversity of flora, fauna, landscapes and related bio-physical systems, and redressing the damage of the past;
- safeguarding the character and vitality of rural towns and villages which provide jobs, housing and services to support living communities;
- increasing the opportunity for people to enjoy the countryside;
- facilitating local processes to reconcile competing demands on the countryside;
- acknowledging and exploiting the synergies between environmental quality and economic development;

The White Paper acknowledges the central role played by agriculture as the dominant land user. It confirms the integration of environmental objectives into agricultural policies, and the pressures on farmers to diversify beyond conventional farming in order to supplement incomes. Reference is made to the range of economic options for the economic use of land, including non food crops, woodland planting, recreation and leisure enterprises, the management of land to provide environmental benefits and the restoration of damaged landscapes and habitats.

Particular reference is made to the challenge of the urban fringe which accommodates 'essential but unneighbourly' functions such as waste disposal and waste water treatment, as well as derelict or under-utilised land and agricultural land suffering urban blight. There are opportunities here for delivering environmental enhancement and socially beneficial land use, improving public access to the countryside, and reducing potential conflicts between adjacent land uses.

4.1.2. Policy and Wet Fens

The preceding policy statements provide the context for the Wet Fen for the Future initiative. In particular the policy statements emphasise the multi-functionality of the countryside as a key element of national sustainable development. They indicate the socio-economic as well as

environmental criteria against which the Wet Fen Programme will be judged. The policy statements, and the related guidance notes to development agencies, emphasise the link between economic development and environment quality. They also recognise the importance of resolving the potentially conflicting interests for resource use in the countryside through local processes.

The key to the successful implementation of a Wet Fen Programme is to identify the multiple purposes to be served for a broad church of potential beneficiaries. The following socio-economic analysis attempts to do this by identifying in general terms the type and distribution of impacts, both positive and negative associated with Wet Fen creation.

4.2. Current Socio-Economic Situation in Fenlands

This section considers the present socio-economic challenges affecting rural communities in the Fens, characterised by declining incomes and employment opportunities in an economy mainly dependent on intensive, commercial agriculture.

Relative to the national and East Anglia region as a whole, The Fens area demonstrates a low level of socio-economic development. Key problems, as identified in "Objective 5b Status: The Case for the Fens" (1993), are:

- relatively low GDP per capita (equivalent to 86% of the EU average);
- an under-diversified and "small firm" economy with low value-added products;
- high unemployment; and
- relatively low skill levels;

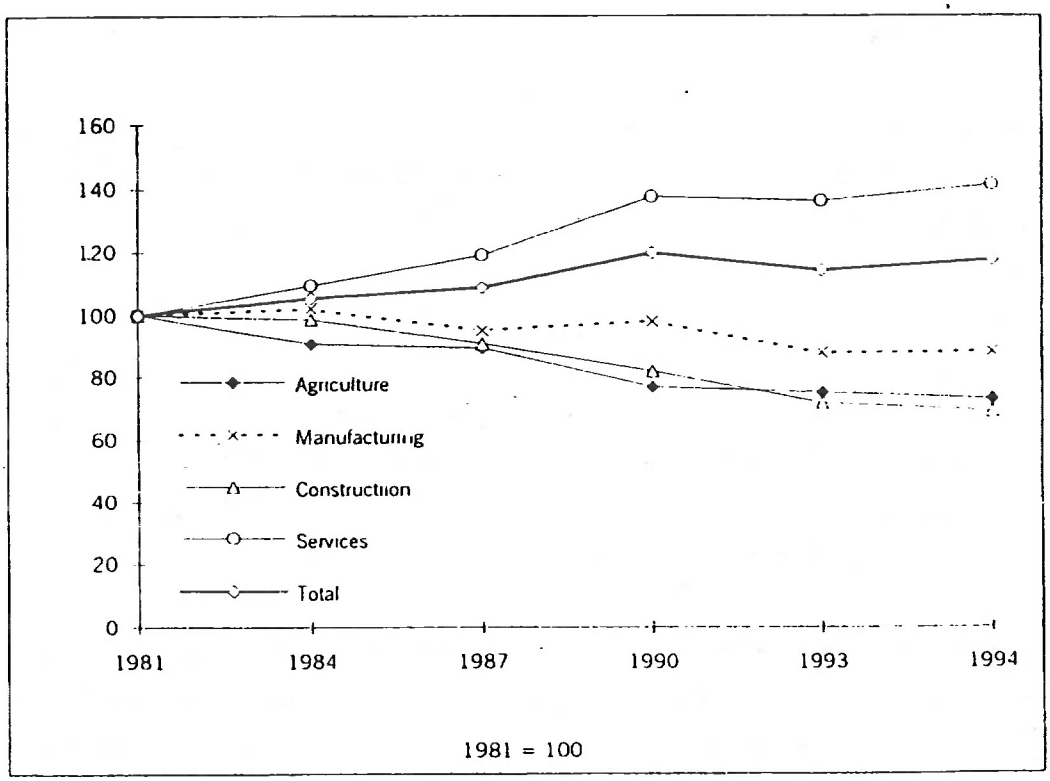
Agriculture and related industries remain very important to the local economy, despite declining farm employment resulting from mechanisation and consolidation of holdings. The 1989 Census of Employment figures, updated by information available from the Cambridgeshire County Council Research Group indicates that 17% of Fens employment is in primary farming activities, compared with 2.2% for Britain as a whole, and over 36% is in agricultural related industries.

In response to declining real output prices and rising real input prices, together with the incentives of the Common Agricultural Policy in favour of arable farming, the average size of holding and the degree of specialisation has increased as farmers seek survival by means of

economies of large scale production. Average farm size is now 130 ha, and in many parts of the fens, livestock are virtually absent.

The specialisation and related further mechanisation of agriculture has contributed to a reciprocal decline in total agricultural employment, particularly permanent labour, as identified in Figure 4.1. This is predominantly as a result of the diverging relative prices of labour and capital and the economics of operating large scale mechanised arable systems. In spite of these structural changes and significant improvements in productivity (especially yields), the 'cost-price squeeze' of declining real output prices and rising costs has lead to a fall in real incomes of 40% over the last decade. According to Cambridgeshire County Council's Structure Plan (1993), CAP reforms are likely to result in lower farm incomes and further shedding of labour, as farmers try to cope by reducing fixed costs.

Figure 4.1: Changes in employment in East Anglia 1981-1994



Source: SCEALA, 1995

The composition of the labour force has also changed. In fact, over half of those who work on farms in the region are now on a part-time or seasonal basis. (Murphy, 1996). There is evidence of increased off-farm income as members of farming families attempt to cushion against decling farm revenues.

A relative decline in the prosperity of the farming sector can significantly affect the prospects for ancillary industries engaged in the supply of agro-chemicals, fertilisers, seed and machinery and the distribution, storage, processing and packing of farm produce. For example, approximately 19% of Fens employment is reliant on agricultural related industries. Whilst the Fens produce many high value agricultural products, value added is low relative to industrial products. Because much of the industrial base is tied to agriculture and related services, the Fen area's gross value added, and net capital expenditure for manufacturing are amongst the lowest for the whole of East Anglia. For example, figures for the East Cambridgeshire part of the Fens show Gross Value Added in 1989 at £800 per head of population and net capital expenditure at £66, compared with the East Anglian averages of £1,915 and £240 respectively.

The UK Government and European Union recognise that the region faces the risk of serious socio-economic deterioration, especially in the face of reduced support to farming. Consequently the area has been designated to receive a variety of aid packages (See Table 4.1). Grant aid under each scheme covers half the cost of ventures with the balance met by public or private organisations.

Areas which have been seriously affected by the decline in the agriculture and fishing industries in the Fens have gained European Priority Area Status under Objective 5(b) of the European Structural Funds. Such areas are designated where the level of social and economic development is below average.

The overall aim of Objective 5 (b) Programme is:

- To strengthen the local economy within and adjacent to 5 (b) area in order to generate job opportunities and increase incomes for local residents in the 5(b) area whilst sustaining the environmental quality of the area.

It is recognised that existing industries within the Objective 5(b) area, mainly agriculture, fishing and related industries, need to adapt to changing circumstances, especially with on-going market and regulatory changes. The strategy objectives are to encourage new ventures and technologies on farms to help develop new products and markets. Any activity in pursuit of these objectives must meet the requirements of sustainable development. The designation of these areas is for six years and provides access to funding for infrastructure, training and tourism schemes.

Table 4.1: Assistance approved by the United Kingdom government and the European Union by January 1995

Intermediate Assisted Areas:	
Grants for firms in Great Yarmouth travel to work area	£753,000
Grants for firms in Wisbech travel to work area	£1.68m
Single Regeneration Budget 1995/96 - 1997/98	
Norwich Regeneration - Greater Mile Cross Area	£2,245,000
Ipswich Wet Dock - Business Link etc.	£2,150,000
Greater Peterborough TEC	£1,010,000
Wisbech Regeneration	£413,000
Norfolk and Waveney TEC	£405,000

Objective 5b 1994-99
The European Agriculture Guidance and Guarantee Fund (EAGGF), the European Regional Development Fund (ERDF) and the European Social Fund (ESF) are available to support a wide range of infrastructure, training and tourism schemes. The total amount available for the period 1994-99 is 60m ecu (approximately £47m) which is about 7% of the United Kingdom's allocation. Part of the funding (About £2m to 1996) will be subject to competitive bidding under the Government's Regional Challenge scheme.

KNOVER I and II 1994 and 1995 (parts of Norfolk and Suffolk)
KNOVER provides funding to help address the problems caused by the run down of the defence industries. The region received £400,000 under KNOVER 1. Parts of the region have also been proposed for KNOVER II and a decision is expected by August 1995.

LEADER II 1994-99 (available in Objective 5b areas except Lowestoft)
25.5m ecu has been approved for England. East Anglia's allocation is likely to be 3.1m ecu (about £2,4m) up to 1999. A decision is expected in spring 1995.

European Soical Fund (Objective 3 - available throughout East Anglia)
A total of £492,000 was approved in 1994 for vocational training projects for unemployed people. A similar amount will be available in 1995

Rural Development Areas 1995-98 (RDAs)
The following funds area available from the Rural Development Commission to support economic, social, community and environmental projects in:

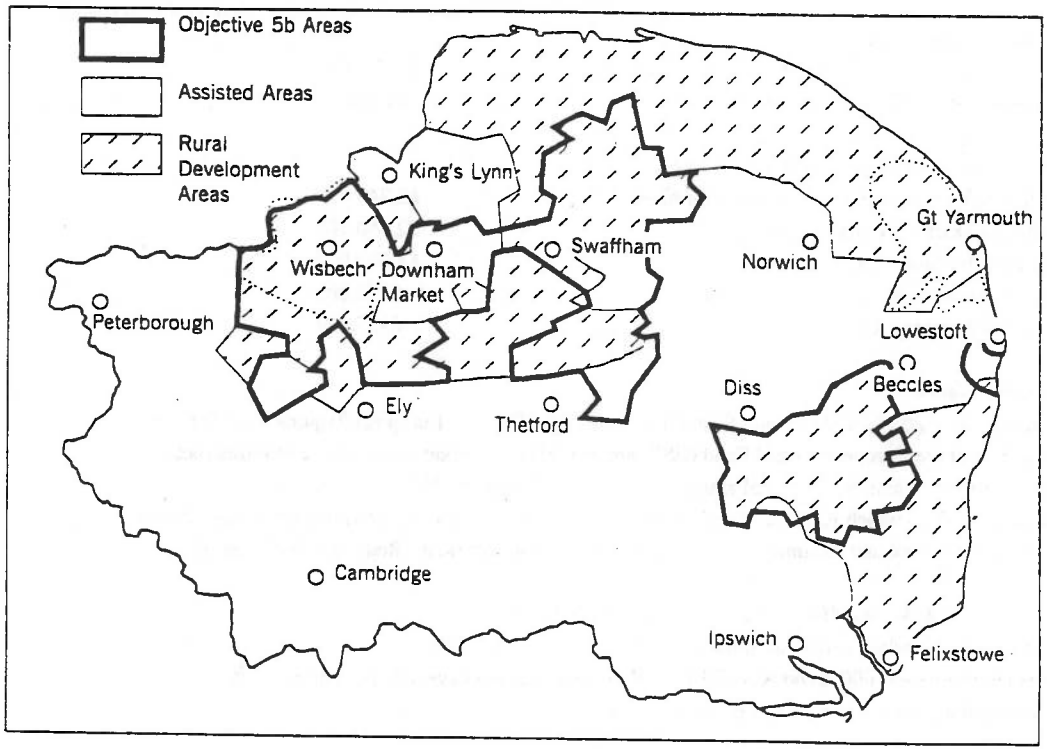
Fenland RDA	£200,000 in 1995/96
Norfolk RDA	£914,000 in 1995/96
Suffolk RDA	£383,000 in 1995/96

Rural Challenge 1994-96 (available in RDAs)
Phase I bids for projects starting in spring 1995 were unsuccessful in Norfolk and Suffolk. Phase II bids for projects starting in spring 1996 are being prepared by Cambridgeshire and Norfolk.

Source: SCEALA, 1995

Predominantly urban areas lying within designated areas can qualify for Intermediate Status, such as the Wisbech travel to work area. Here industries may receive selective assistance, including project grants and loans. The Scheme's Rural Development Areas may qualify for grants for community-based projects and business enterprise initiatives. Areas receiving the grants outlined are identified in Figure 4.2.

Figure 4.2: National and European designated areas



Source: SCEALA, 1995

Businesses related to alternative sustainable Fenland products, such as those considered in Section 3 of the report, may receive assistance under the above schemes for the purpose of regenerating the rural economy.

The preceding description of socio-economic conditions indicates an economy made vulnerable by its overwhelming dependency on the farming and municipal sectors and related industries. These sectors are experiencing considerable pressure and change. Whilst there is a call for greater and more diverse economic development, there is a simultaneous commitment to secure the intrinsic characteristics of the Fens and their communities: reconciling economic development and environmental quality. The Wet Fens for the Future Programme needs to be set in this context: the achievement of balanced and sustainable development.

4.3 Environmental Uses and Functions of Wet Fen

From a socio-economic viewpoint, the environment provides a number of functions. As a supplier of resources, it supports all income generating and wealth creating activities. It acts as a sink for wastes of various kinds which arise from economic activities. It also describes the

medium for living organisms and is therefore an essential part of the natural system which supports human existence.

The environmental goods and services provided by wetlands and other protected areas can be either according to user/beneficiary or type of function. Two main beneficiaries types can be identified (Barbier, 1991; Turner & Jones, 1991; Pearce & Markandya, 1987): users and non-users. Users of wetlands can either derive direct benefit from consumptive use such as fishing or game harvesting, or indirect benefits such as the hydrological functions provided by wetland areas which can store water, thus avoiding flooding and conserving water resources. Wetlands can also provide benefits to non-users who draw satisfaction in the fact that they and their ecological functions exist and remain intact for future generations. Both users and non-users also derive benefit from the protection of wetlands in that options remain open for future uses.

Similarly attention can be drawn to the functionality of protected areas and the values implied to human society (de Groot, 1994), namely:

regulation functions: the contribution to the maintenance of a healthy living environment with particular reference to the media of air, water, land and bio-systems;

carrier functions: the contribution of the environment to support human activities such as habitation, cultivation, recreation;

production functions; the contribution of the environment as a supplier of natural resources for the production of other goods and services;

information functions: the contribution of the environment to human welfare with respect to natural, spiritual, historical, locational, aesthetic, cultural and scientific elements.

These perspectives are relevant to the socio-economic analysis of wet fens. Table 4.2 shows the range of potential functions provided by wet fens and associated social and economic benefits. The contribution of wet fens to the maintenance of natural capital delivers across a broad range of functions. Wet fens offer regime benefits particularly with repeat to the integrity of environmental media and natural processes. Existence and bequest benefits relate to the maintenance of non renewable resources, and irreplaceable ecological systems and human artefacts. Social welfare, with respect to health, education, and the quality of human life, benefits through countryside access and related activities, especially interpretative functions which add meaning to human existence such as those found in heritage sites.

Table 4.2: Functions and socio-economic benefits of wet fens

Functions	Consumption use	Productive use	Income & Employment	Regime Services:	Social Welfare: health, education	Nature Conservation	Management of Natural Resource	Existence and Bequest	Social and Environmental Risk
Regulation									
Maintenance of environmental media		✓						✓	✓
soil quality (erosion risk)		✓		✓					✓
water quality		✓		✓	✓	✓			✓
water quantity		✓		✓	✓	✓			✓
air quality		✓		✓	✓	✓			✓
catchment management		✓		✓				✓	✓
erosion/sedimentation				✓					✓
flood risk				✓					✓
land drainage				✓					✓
habitat provision for flora and fauna						✓		✓	✓
storage and recycling of organic matter				✓	✓	✓			✓
waste assimilation		✓		✓	✓				✓
biological systems and diversity						✓		✓	✓
Carrier and Production Functions									
human settle settlements			✓						✓
habitats for natural species						✓		✓	✓
natural food supply						✓		✓	
commercial crop and livestock production	✓	✓	✓						
non-farm land & water based production & processing activities	✓	✓	✓						
rural business & enterprise development		✓	✓	✓			✓		✓
renewable resources		✓	✓				✓		
non renewable resources		✓	✓				✓		✓
waste disposal and assimilation		✓					✓		✓
fuel and energy supply	✓	✓	✓				✓		
water supply	✓	✓					✓		✓
rural infrastructure		✓					✓		
leisure and recreation	✓	✓	✓		✓				
tourism	✓	✓	✓		✓				
nature based activities			✓		✓		✓		
genetic and biological resources					✓		✓	✓	✓
Information and Contextural functions									
Aesthetics (landscape and amenity)	✓				✓				
Historical and heritage association	✓				✓				
Community of place and interest					✓				
Cultural and artistic inspiration					✓				
Education and scientific purpose			✓		✓				
Spiritual and religious meaning					✓				

Wet fens provide socio-economic benefits to users through direct consumption of environmental goods and indirectly through resource supply to production and process activities, and due to incomes and employment generated in production of environmental goods and services. In general, wet fens can, through their contribution to sustainable development, help to manage social and environmental risks associated with development. They can also assist in protecting and delivering environmental and economic diversity, thus exploiting the potential synergy between environment and economic development in rural and urban fringe areas.

4.4 Environmental Values of Wet Fen Functions

Whilst the identities of potential impacts of protected areas are not difficult to determine, placing economic values on these in order to assess the benefits and costs to society associated with a loss or a gain of and environmental use or function is much more difficult. Two approaches are possible. One is to specify minimum acceptable environmental standards, such as objective water quality standards to be met or endangered habitats to be protected. Economic analysis is confined to determining the best, most cost effective means of delivering the standards, i.e. the best practical environmental option. This concept implies a measure of acceptable environmental risk.

Alternatively, environmental functions, such as those listed above for wet fens, can be viewed as potentially tradeable commodities to which the equivalent of a market price can be attached. These surrogate market prices, should if the theory works in practice, indicate the value in consumption or use, or the resource costs of making the particular items available for use. This requires that money values are placed on environmental goods and services. As a consequence, the associated benefits and costs of environmental change can be included in an analysis of development options, including those designed to enhance environmental quality.

Table 4.3 summarises the methods which can be used to place values on user and non user environmental benefits and costs. They comprise two main types. Non-demand estimation methods assess the economic consequences of environmental change in terms of loss of productivity, the additional costs of avoiding or compensating for environmental degradation, or the cost of replacing lost natural assets.

By comparison, demand estimation methods can provide a more comprehensive estimate of environmental benefits because they attempt to determine how much society is willing to pay to secure environmental goods and services. Revealed preference methods observe how people actually purchase environmental goods. Market prices for traded natural resources

Table 4.3 : Valuation methods for environmental benefits and costs

	Consumption use	Productive use	Income & Employment	Regime Services:	Social Welfare: health, education	Nature Conservation	Management of Natural Resource	Existence and Bequest	Social and Environmental Risk
Non demand based methods									
substitute goods	✓			✓	✓	✓	✓		✓
loss of earnings/productivity			✓	✓					✓
dose response (pollution impacts)				✓	✓				✓
replacement cost	✓	✓		✓		✓	✓		✓
defensive/mitigation expenditure					✓	✓	✓		
capital and maintenance costs					✓	✓	✓	✓	✓
shadow project						✓	✓		
Demand based methods									
revealed preference									
market prices	✓	✓							
environmental (hedonic) price premia	✓	✓	✓	✓	✓			✓	
travel cost	✓	✓			✓				
expressed preference									
contingent valuation									
willing to pay/be compensated					✓	✓	✓	✓	✓

such as land reflect financial benefits to users. These may, of course, be affected by government intervention (as in the case of commodity or set-aside payments to support farm incomes) such that resource prices may not reflect their real productive values. Other methods can be used to value non-traded items. For example the cost incurred travelling to a nature conservation site can provide an estimate of benefit derived. Similarly, business and residential property prices may reflect environmental premia.

Expressed preference methods such as contingent valuation obtain estimates of willingness to pay for the maintenance or gain of an environmental function, or willingness to be compensated in the event of its loss. This technique, because it deals in responses to hypothetical circumstances, is subject to much bias in application and interpretation.

Table 4.3 considers the suitability of the aforementioned techniques to the valuation of wet fen benefits. Direct and indirect user benefits associated with consumption, production and regime functions are suited to non-demand based assessment methods. Conservation and social welfare can be measured by a variety of methods. Existence, bequest (and option) values are mainly derived through hedonic pricing and contingent valuation methods. The economic value of different levels of social and environmental risk can be assessed by a range of methods.

The choice of method depends to a large extent on the purpose of the analysis. Non-demand methods are suited to cost-effectiveness analysis: assessing the cost of a given environmental change and the benefits of avoidance. Demand methods are best suited to deciding the best level of environmental quality: comparing the relative benefits and costs associated with different environmental qualities.

4.5 Socio-economic Performance of Wet fens

The following section examines the potential contribution of wet fens in the context of the preceding analytical framework. The 'without' Fen project situation is assumed to be that which currently prevails, that is conventional, relatively intensive agriculture. As mentioned earlier, however, changing economic, political and indeed environmental conditions could reduce the relative attractiveness and performance of conventional farming in the area. The 'with' Fen project situation could take a number of forms reflecting the range of objectives to be served and local circumstances. Table 4.4 examines the major type of wet fen development options against selected socio-economic indicators. The latter reflect the various functions delivered by wet fens which have welfare and therefore socio-economic implications.

Table 4.4: Comparison of socio-economic indicators for wetland activities relative to arable production.

	Wet grassland production	Reedbeds	Energy Coppice	Nature reserve	Countryside sport	Tourism
Socio-economic values						
Income generation	*	**	**	**	**	*
Employment creation		*	*	*		*
Social Welfare: health	*	***	***	**	**	**
Nature Conservation	*	***	*	***	*	*
Regulation functions						
Soil quality	*	**	**	**	*	
Water quantity	*	*				
Water quality	*	***	**	**		
Flood defence	**	***		***		
Carrier & Production functions						
Food supply	**	***	***	***	***	***
Fuel and energy supply		*	***	*		
Countryside recreation		*	*	***	***	***
Interpretative & contextural functions						
Aesthetics (landscape & amenity	**	***	*	***		
Cultural & artistic inspiration	*	**	**	***	*	*
Education and scientific purpose		**	*	***	**	**

blank = no change, * = small change, ** = moderate change, *** = large change

4.5.1. Income Generation

Farmers in the Fens achieve amongst the highest gross margins and net incomes per ha and per farm in Britain. Comparative analysis of conventional farming and alternative wet fen land uses (Table 4.5) shows that the latter are unlikely to produce equivalent net incomes unless either substantial grants are available to encourage a change, or the performance of conventional farming is in some way compromised. Some very specialised, niche activities such as put-and-take trout fisheries or cricket bat willow may produce equivalent returns, but the market for such and the areas involved will be very small.

Table 4.5: Summary of financial performance of main options for Fenland

	Arable	Grassland Scenario 3	Grassland Scenario 4	Grassland Scenario 5	Reedbeds for thatch	Energy coppice
Gross margin	892	659	265	82	776	426
Fixed costs *	717	595	420	300	701	375
Net income after adjustment for delay to harvest	**175**	**64**	**-155**	**-218**	**75**	**51**

* Fixed costs include machinery and labour including unpaid family labour, land rent and general expenses (latter at £65/ha and £40/ha respectively for grassland scenario 5, reedbeds and coppicing)

4.5.2 Employment creation

Agriculture and related industries are the main employers in the Fen area. Even though, increased mechanisation and amalgamation of farms has resulted in a decline in total agricultural employment, fen farms remain relatively labour intensive due to the large area of root, vegetable and horticultural crops, much of which is irrigated. Table 4.6 compares total labour and hired labour employment on farms in the Eastern Region, confirming the relatively high employment levels on fen farms, especially against predominantly cereal farms.

Table 4.6 Labour Employment on Farms in the Eastern Counties (1994/5)

	Farm Size (ha)				
Farm type	100<200	200<300	300<400	400+	General Mean
Labour units per 100 ha					
Mainly cereals	1.26	1.10	0.94	1.05	1.18
Mixed cropping	1.81	1.79	1.13	1.27	1.83
Fen farms	2.16	2.54	1.71	2.54	2.48
All farms	1.72	1.46	1.35	1.45	2.06
Hired labour per 100 ha					
Mainly cereals	0.70	0.82	0.79	0.98	0.71
Mixed cropping	1.32	1.57	1.03	1.22	1.44
Fen farms	1.53	2.23	1.55	2.49	1.57
All farms	1.17	1.18	1.22	1.39	1.31

(Source : Murphy, 1996)

Table 4.7 shows the estimated labour costs and hours of employment per ha associated with the alternative fenland activities previously examined.

Table 4.7: Labour costs labour hours per ha for alternative fenland activities

	Arable	Grassland 3	Grassland 4	Grassland 5	Reedbeds	Coppicing
Labour costs £/ha	170-334	230	170	116	380	87
Labour hours/ha	30-56	38	28	23	76	18

In the arable sector employment levels and costs reflect the degree of labour intensive field vegetable and horticultural crops. A switch from mechanised cereals, oil seeds and root crops to relatively intensive livestock production would marginally increase labour employment. But the skill requirements and the working conditions of arable and livestock systems are very different such that automatic transfer of labour from one to another cannot be assumed.

Extensive grass land systems and energy coppicing involve relative reductions in labour employment. By comparison reedbeds for thatching material is labour intensive, but the total contribution to labour employment is likely to be small.

A change in land use of any significant scale would have implications for ancillary industries engaged in the supply of agro-chemicals, vegetable processing and packaging, agricultural machinery manufacturing, and the distribution and haulage of agricultural goods. Approximately 19% of employment in the Fens is reliant on these agricultural related industries compared to 17% directly employed in agriculture.

Alternative enterprises tend to be relatively labour intensive. Bateman *et al* (1990) estimated that total employment in commercial reed growing and thatching in England is about 1,000 people, including thatchers, growers, labourers, cutters and trainees. Although labour inputs and costs for reed growing are high, the majority of workers were engaged for only part of the year, and often on a casual basis. An expansion in the reed growing industry would offer employment but probably not on a significant scale, and probably no greater than that associated with intensive field vegetable production if this were the displaced crop.

Although the total labour requirements of energy coppicing are relatively low, biofuels could provide new employment opportunities in the rural economy. Foster, (1993) suggests that a 6 megawatt station, fuelled by approximately 1,250 ha of energy coppice, would need more than 20 full-time staff. Employment opportunities would also be created in service industries, such as fuel delivery, forestry contracting and supply of equipment and inputs.

Countryside sports can make an important contribution to employment. Significant numbers of full and part-time staff are directly employed both by organisers and providers of countryside sports. The British Association for Shooting and Conservation estimates that there are 5,000 full-time game-keepers in Britain. The Cobham report (1992) estimated direct employment in Britain shooting and stalking at 13,000 and from angling at 14,500.

Although the direct employment of nature conservation sites is small, sites can support four to six times more jobs than those involved in site management in the sectors which provide local services to visitors. Nature and landscape conservation provided direct employment amounting to 8,700 full time equivalent jobs in England and Wales in 1991/2 (Rayment, 1995). Estimates from Scotland (Rayment, 1995), gave labour employment of about 2 jobs per 100 ha for lowland cropping systems, compared to about 0.2 jobs per 100 ha for both extensive grazing systems and wildlife reserves. Scottish data suggested that the average combined

direct and indirect employment per ha in agricultural production tended to be about twice that associated with wildlife sites.

The employment opportunities for managed fens can be significant and comparable with agriculture. Wicken Fen, a reserve of 250 ha, employs 5 full-time staff on site. This is virtually the same labour employment rate per ha as the typical fen farm. In addition, conservation site offer an opportunity for voluntary workers who, whilst unpaid, derive much enjoyment and satisfaction from their activities.

4.5.3 Social Welfare: Human Health

Many environmental functions provided by wetlands may contribute directly or indirectly to the maintenance of human welfare through the provision of a healthy, convenient, risk free and stable environment. These benefits accrue to both users and non-users.

The maintenance and improvement of land, water and air quality in rural and peri-urban areas are examples of the potential contributions to human health and quality of life. Similarly, wet fens, in areas otherwise dominated by intensive agriculture can provide access to the countryside for outdoor leisure, recreation, formal education and research, and interpretative pastimes. These contributions are made more valuable by the pressures of agro-industrial lifestyles on the natural and human environment.

Alternative land uses, such as extensive grazing and fuel wood coppicing, can deliver against particular health related indicators such as water and air quality respectively. Energy coppice produces renewable fuels with relatively small emission of contaminant gases. When burning it produces no more carbon dioxide than it captures. In Britain, a million hectares of coppiced willow could counter a 3% increase in national carbon dioxide emissions (Pearce, 1994). Energy coppice of willow has the potential for reducing nitrate and phosphates in rivers and groundwater. Reedbeds can be used as low cost water and sewage treatment systems.

4.5.4 Nature Conservation

Conservation of biodiversity is a priority in the UK's strategy for sustainable development. Intensive arable activities in Britain have led to a decline in habitats and associated wildlife throughout the country. Many farmland species have declined in population size over the last twenty years, especially in arable areas. Fuller *et al* (1996) found that 86% of farmland species were in decline compared with 51% of non-farmland species. In the Fenland area where there

has been a significant loss of natural habitats, such as fen, reedbeds and flood plain grazing marsh to agricultural land.

Creating wetland sites for nature conservation complies with the objectives of the UK Biodiversity Action Plan for maintaining and enhancing species, habitats and ecosystems that are characteristic of the local areas. The fen habitat in particular is considered internationally important. The East Anglian Action Plan (1996) gives priority to conserve and enhance those species and habitats for which the region has a significant proportion of the UK total.

There are opportunities for combining the objectives of nature conservation, landscape improvement and economic land uses in the fens. Wet grassland used for livestock production can be ecologically sustainable provided stocking rates remain within the carrying capacity of the ecosystem. Flood pasture or water meadow is species rich in flora and of high conservation value. Species-poor inundation grassland is of little botanical value, but can provide good conditions for breeding waders and wintering wildfowl. Wet grassland containing grazing stock can break the monotony of the Fenland arable countryside and add variety to the Fenland landscape. The extensification payments offered to livestock farmers reflect the contribution of grassland to environmental quality.

Large reedbeds, over 20 ha in extent, area are a nationally scarce habitat which may support up to five 'Red Data' bird species - bittern, marsh harrier, bearded tits, Cetti's warbler and Savi's warbler. Bitterns and Marsh Harriers are already breeding in some Fenland reserves, Bearded tits have autumn dispersal strategies which aid the discovery and colonisation of new sites. Savi's and Cetti warblers have also colonised a number of sites in the Fenlands. In addition, reedbeds may also have botanical and invertebrate interest, for example otters regularly use and breed in reedbeds and some 40 species of insect feed solely on reed.

There is a national action plan for the creation and management of large reedbeds which is regarded as a high priority for nature conservation in Britain. As an indication of the value of such sites RSPB spent over £20,000 on water control measures to reduce the environmental impact of groundwater abstraction on its Fowlmere reedbed fen reserve in Cambridgeshire in order to protect the habitat of several Red Data birds,(Fowler & Buisson, 1995).

Energy coppice can provide fertile habitats for wildlife. Sage (1993) suggested that growing willows coppice on pasture, ley or arable land will lead to an immediate increase in the overall biodiversity of a typical farmland ecosystem. Access rides between blocks of coppice provide large areas for wild flora and fauna. Once the crop has been established it shades out invasive weeds and allows the development of non-competitive flora. Also native willows are known to

support a large number of insect and mite species and a substantial bird population. However, the creation of large blocks of trees would will have a strong visual impact on the countryside which may not be considered in-keeping with the traditional landscape characteristics of the Fens.

Countryside sports, such as game shooting and wildfowling are often a main motivating force behind the actions of many landowners to conserve habitats, such as wetlands and woodland. Countryside sports contribute to both the conservation and creation of countryside features. However, active sports, such as water sports, may conflict with the interests of nature conservation. For example, the propellers of power boats can damage aquatic vegetation and anglers break down wetland vegetation for access purposes.

Nature conservation and biodiversity provide important social benefits in the form of a sense of place, scale, history, and belonging both to the natural and human world. These feelings are particularly evident in social attitudes to landscape and countryside characteristics, including habitats. Green and Tunstall (1991), suggest that moral and altruistic attitudes can motivate peoples preferences for nature conservation. As previously mentioned, the loss of these natural characteristics and related feelings results in a loss of social welfare and, implicitly an economic loss. Measuring these values is difficult. The commitment to nature conservation and enhancement of tax payers' funds by Central and Local Government and of donations and membership subscriptions by Non-Government Organisations such as RSPB are indicative of the value placed by society both nationally and within the region on the type of benefits associated with the wet fen environment. The payments to farmers for wetland related management agreements which range from £70 to over £300 per ha are indicative of social value and willingness to pay, although they are complicated by the other types of support given to farmers. The acquisition of land at agricultural prices to create nature reserves provide a minimum estimate of the benefits obtained.

4.5.5 Soil quality

Soil quality is one of the UK Government's indicators of sustainable development (DOE, 1996). The physical, organic and chemical properties of the soil as they determine its ability to support natural and economic activity are under threat. Intensive cultivations, drainage, heavy in-field traffic, the application of many potentially toxic chemical additives and controls, and reduced input of organic residues have led to a deterioration of soil quality. Oxidisation of peats and the creation of acid sulphate soils are cases in point. Under these conditions, crop yields can be maintained only at the cost of additional inputs and soil amelioration measures.

Peat shrinkage and lower ground levels has meant additional capital and operating costs for land drainage as witnessed in the Middle Levels.

There is scope for reducing the risk of soil damage on fen farms through selective use of new technologies such as improved groundwater management, minimum tillage, precision farming and gantry based mechanisation systems. The mechanised production of vegetables and root crops is, however, particularly damaging. A return to integrated crop management based on crop rotations rather than chemical control could also help, together with the inclusion of temporary leys. The reversion of land from arable to wet grassland or other wetland habitats, such as energy coppice, will reduce the risk of peat wastage be halted. However, a potential problem with peat soils which have undergone prolonged oxidation due to drainage is that pH may fall on rewetting.

The recent Royal Commission on Environmental Report on Sustainable Use of Soil, (1996), appears ambivalent on the best way forward. In one instance it concluded "only by re-creating wet fenland can the remaining peat be conserved in the long term" while in another instance it recommended that "drained peat soils should be regarded as a resource for agriculture and managed in a way that will maintain productivity for as long as possible." Switching fen peats out of agriculture may be sustainable, but not consistent with perceptions of the comparative economic advantage of the area.

4.5.6 Water Quantity

The East Anglia is one of the driest regions in the UK and one which has experienced increasing water deficits as growing water demand outstrips available supply from surface and groundwater sources. This condition is common to the Fenland, where water abstracted for spray irrigation accounts for the second largest use by volume and the majority of abstraction licences. A considerable and unmeasured volume of water is consumed in sub-irrigation through the retention of high field groundwater levels in summer. Irrigation water use is especially significant in that little water is directly returned to the hydrological system due to crop retention and/or evapotranspiration.

Fifty percent of UK irrigation occurs in East Anglia. In the Middle Levels of Cambridgeshire irrigation accounts for about 7% of the cropped area, mainly for potatoes, other roots and vegetables. Typical water requirement use for irrigation ranges from about 900 m^3 per ha for sugar beet to about 1500 m^3 per ha. In many areas, theoretical needs for the fifth driest year in 20 (the usual design standard) outstrip licensed quantities such that restrictions are placed on the timing and size of abstractions.

The irrigated area and the demand for irrigation water is predicted to increase by about 1% per year over the next ten years,, although this could be constrained by limited water supply and competing demands (Weatherhead *et al*, 1993).

Growing water deficits have encouraged the view that water is an economic commodity, with prices which reflect value in use and existence, including the value of the water environment. The value added (before water charges and costs) of water for irrigation ranges between about £0.4/m^3 on sugar beet to about £0.75/m^3 on quality potatoes (1996 prices). Existing summer licensed abstraction charges are currently £0.02/m^3 which some argue does little to encourage economic use. But supply deficits and abstraction restrictions are persuading farmers to invest in reservoirs at costs approaching £0.5/m^3. These estimates (Morris *et al* 1996) are indicative of the value and growing scarcity of water in the region where water storage on farm and possible within prescribed hydrological catchments will become more important. In this respect wet fen development could complement ground and surface water storage initiatives to protect supplies to agricultural and non-agricultural users.

Of course the fenland environment is itself a large user of water. A wet fen is likely to use 20% more water than a short grass crop. According to Atkins (1995) wet fens will require up to about 300 mm of additional water to maintain wet conditions during dry summers. This is the case with the 28 ha Woodwalton fen into which over 1000m^3 is pumped each day during three months of the summer. A study on the Nene Washes (Morris *et al*, 1996) estimated that the per ha additional water inflows for wet fen are likely to be two to three times the average irrigation water requirements for arable crops. Reedbeds in particular have a high water demand.

The water requirements of energy coppice and conventional crops are broadly similar. They require about 500 mm of precipitation; about the same needed by winter wheat and sugar beet. However, energy coppice would have a higher water demand than grass and other woodland. This is due to a large leaf index area, low aerodynamic resistance and the edge effect of small sized plantations causing higher transpiration. Whilst reedbeds require ample water, they offer opportunity for waste water recovery, groundwater and surface recharge, and re-use into irrigation, or industrial processes such as cooling systems.

Wet fens are consumers of water and water availability is a precondition for their creation. The water directed to them has alternative uses and values which could be prejudiced. However, the growing pressure on water quality and quantity should emphasise the potential

contribution of wet fens as one of a number of initiatives to protect and enhance the integrity of water resources.

4.5.7 Water Quality

Water quality in the Fens has declined in recent years, due to a combination of drought conditions exacerbated by higher abstraction levels and increasing levels of waste emission to water. Water is polluted by high levels of nitrate and phosphate, usually as a result of fertiliser run-off from agriculture and from treated sewage effluent, which includes pollutants such as phosphates.

Converting arable land to wetlands could reduce pollutants in water, thus reducing the costs of water treatment expended by Anglia Water. It is estimated that Anglian Water will spend about £70m over the next 10 years to achieve the 50 mg per litre standard for nitrate pollution. This is over half the total capital budget for the authority. The nitrate removal costs at 10p per m^3 are a large proportion of the overall operating cost of metered water of about 30p per m^3 (Croll & Hayes, 1988). Non-users may also derive benefits from cleaner rivers. A study conducted by Green and Tunstall (1991) used the Contingent Valuation Method to conclude that households were willing to pay over £16 per year in 1996 prices for improved river water quality.

Constructed wetlands are effectively used for purification of wastewater discharges to surface freshwater and groundwater. However, little is known about the long-term capacity to remove toxic material and the impact on the health of wetland itself. Data from Norfolk Broads which have received long-term applications of waste-water, show decreased plant and animal diversity. (Moss, 1983). Wet fens could provide the services of buffer zones, cleaning water from intensively farmed parts of the catchment before release to rivers and aquifer

Nitrate run-off and leaching into surface and groundwater will be less from energy coppice than conventional farming as few chemical inputs are required. Coppiced willows also has the potential to be used on buffer zones adjacent to river to help prevent run-off of nitrates and phosphates from farmland to surface water

Contingent Valuation has been used to estimate the value of water quality standards and improvements amongst users and non-users. The estimates tend to be very situation specific. Generally, users such as boaters and anglers are willing to pay more for quality than non-users. But the large numbers of non-users who express an interest in the protection of the water environment and wish work carried out on their behalf, means that the non-users benefits are

often greater in sum than immediate users. This suggests that the design of wet fen projects must pay due regard to the existence, bequest and option values implicit in non-use values.

4.5.8 Flood Defence

Much of the Fens are at or below sea level. Flood defence works provide protection against riverine and coastal flooding. The 1953 floods, in which many lives were lost, are a reminder of the vulnerability of the area and its dependency on standards of flood defence. The land drainage capital and maintenance works undertaken by organisations such as the Environment Agency, Internal Drainage Boards and Commissioners, and Local Authorities are justified in terms of the value added to agricultural and urban land use.

Flood defence is a major area of public expenditure. Annual expenditure on flood defence in England and Wales exceeds £300 million per year. A review of selected flood defence schemes showed capital costs of between £460 and £750 per ha in 1996 prices for large scale fen land drainage projects undertaken in the 1960s. Subsequently farmers spent an additional £500 per ha on field drains. As an example of maintenance costs, the annual operation of regional pumps and highland carrier systems in the Spalding/Boston area costs around £30 per ha served (excluding on-farm costs). These costs are low relative to land drainage schemes in other parts of the country because of the economies of large scale operation. The value added from agriculture is also relatively high, as shown by the analysis in section 2 above. Without flood defence land would revert to wet grassland.

The reversion of selected areas to wet fens could contribute to the flood defence function whilst simultaneously delivering environmental benefits. Unprotected but managed wet fens could provide flood storage, even out the peaks in river hydrographs, and help to deliver higher defence standards at lower cost to strategically important areas. These functions are apparent in the Ouse and Neane washes and in Woodwalton were the fen acts as an interceptor reservoir for highland water, thus reducing the capacity requirements and costs of the lowland drainage system. The contribution of wet fens can be assessed in terms of savings in capital and recurrent costs of flood defence schemes. Site conditions or designs must be such however that these fens can operate in areas which are generally drained (CIRIA 198)

4.5.9 Countryside Recreation

Countryside recreation can be informal and unstructured, such as walking, cycling and picnicking by individuals not part of any organised group action, or formal and structured, such as organised field sports. In the main, the first are low cost activities which require public

rights of way access to the countryside without payment. Young families and retired persons are often major participants of informal outdoor recreation. Wet fens have potential to increase countryside access and participation for these groups. Wet fens in the peri-urban fringe could significantly improve access and countryside awareness for urban dwellers, without requiring motorised transport.

There has been a considerable increase in participation and expenditure on formal countryside recreation, such as game shooting, horse riding, cross country athletics, angling, organised walking and orienteering. Most of these involve membership subscriptions, licences or activity fees. These activities draw from a cross section of society. Game shooting and angling are an important rural activity for urban male industrial workers. For example, 58% of those shooting for sport and 68% of anglers are either skilled manual or semi-skilled workers.

Arable production on the Fens presently supports some game shooting. A switch to grassland with winter flooding could provide more cover and food for wildfowl, whether this be for shooting or for birdwatching. Recreational use of energy coppice is limited although they may provide scope for enhancement of game cover for shoots. According to Sage (1993) well coppiced willows could provide winter cover to pheasants comparable with other good woodland cover within two years of planting.

Reedbeds can offer passive recreation to ornithologists. Water treatment reedbeds may be particularly suitable for this purpose as their use avoids the need to frequently disturb other natural wetland ecosystems. They also have a potential as an educational resource and could be used as study centres for science and education.

Estimates of water related recreational benefits derived from various studies using travel cost and willingness to pay methods are reported in Postle (1993). These include informal recreation alongside water courses of about (in 1996 prices) £1 per person per visit, £0.6 per person per visit for out of stream water quality improvement, about £20 per visiting household per year for river corridor improvements, and boating on reservoirs of over £20 per individual per day. These estimates reflect particular circumstances such that general application is inappropriate. They do indicate that benefits are positive, and potentially large when spread over a large user group.

Licences. membership fees and entry charges are often made for made for the recreational activities related to wetlands, such as fishing, birdwatching, and boating. Such user charges indicate the value of the services rendered to the individual visitors. Where no fee is charged,

as for example in Country Parks or the open countryside, questionnaire surveys can provide estimates of the value that visitors derive over and above the cost of travelling to the site.

4.5.10 Tourism

Re-creating areas of wet fen would enhance the tourist attraction of the Fens complementing the other features of fenland history and landscape. An increase in tourism could create many employment opportunities for the region, providing a major impetus for local businesses by regenerating and diversifying the rural economy.

This is not to say that the large, flat fields of well tended crops are not attractive to visitors, but traditional fen areas would provide variation in the landscape, with an opportunity for direct access to the countryside. Visitor attraction and access will depend on site objectives and attributes. Reedbeds evoke a sense of wilderness, mystery and natural history particular to the wet fen setting. The quality of bird-watching in reedbeds is especially high in spring and summer and poplar sites attract large number of visitors from considerable distances.

Some sites, especially those of scientific and conservation interest, may limit visitor access. Others, however, emphasise access and visitor participation, with visitor centres, guided pathways and interpretative data. Special provision could be made for particular interest groups, notably children and the disabled. Visitor sites may require considerable investment in infrastructure, especially for car and coach parking. Fen sites on the urban fringe could emphasise access by non-car transport.

Cost recovery may be by entrance fee or cost recovery through purchases on site. Some sites may offer visitor experience of traditional farming methods, rural crafts and industries, including livestock rearing, thatch making, fisheries and woodland trades.

Considerable socio-economic benefits can be received through the management of wetland for wildlife and the visitors which this attracts. The socio-economic impact of eco-tourism will depend on the number of visitors, the size and pattern of their expenditure and the extent to which the local economy is able to provide the goods and services which they require. Rayment (1995) found that in Scotland typically £1 of expenditure by visitors generates total expenditure of £1.20-£1.35 and wages, salaries and profits of £0.25-£0.40 in the local economy. On average approximately one local job was created per £20,000 of expenditure by visitors. Visitors on short breaks staying in local accommodation spent more per visitor day and generated a greater local income than day trippers. Furthermore expenditure on small accommodation establishments such as guest houses and farm bed and breakfast had a greater

beneficial effect on the local economy than that involving large hotels. Seasonality of employment is a characteristic of the tourist sector such that many jobs are temporary and seasonal. In the case of wet fens, however, ecological interests vary between seasons and seasonal peaks in activity may be lessened as a result. Many workers in rural tourism use the latter to supplement income from farming and other rural trades.

It is important that tourism in the Fens develops in a way which draws on the character of the countryside and does not destroy the very asset on which its popularity depends. Although increased tourism offers potential economic benefit, it can result in negative social and economic impacts. Increased tourism usually means more traffic, greater demands on civil, police and emergency services, and social risks associated with influx of visitors from elsewhere. Locals may feel there needs are compromised as a consequence. There are often concerns about increased traffic, congestion, pollution and road safety, especially in location unsuited to heavy traffic. The award of planning consent for Visitor Centres requires careful attention to the inherent social and environmental risks.

Influx of second home owners to the area may reduce the social fabric of fenland community. Therefore, it is important to control the soil impacts of tourism, by gradually developing the tourism, and ensuring community involvement and the integration of tourism into the local economy.

4.6 Stakeholder Analysis

The diversity of functions and attributes of the fens is reflected in the range of stakeholders who have an interest in the exploitation and management of Fenland. Stakeholder analysis can help to understand the objectives and interests, and explain the behaviour of the main actors who might exert influence on future wet fen initiatives.

To date, the Wet Fen for the Future programme has emphasised environmental objectives, but the preceding identification of potential wet fen benefits suggests that a variety of purposes can be served. The purpose of stakeholder analysis is to identify those areas of common ground in which progress can be made, whilst simultaneously recognising that conflicts exist which require resolution.

4.6.1. Stakeholder Identities and Interests

Table 4.6 identifies the links between the main interest groups and the attributes and functions of wet fens. The table is intended to be indicative rather than exhaustive. The following discussion considers the perspectives of selected representative organisations and groups.

Central Government has a diverse interest in wet fens according to the brief of individual Ministries. *The Ministry of Agriculture Fisheries and Food (MAFF)* is concerned with the strategic food, agricultural and related resource policy, as well as the design, funding and delivery of support to farmers. They are responsible for promoting environmentally sensitive, economically viable farming, including initiatives for sustainable agriculture and alternative land use. MAFF has conflicting objectives with respect to the re-creation of wetlands where these may be seen to compromise the comparative advantage of the fens for intensive commercial agriculture achieved as a result of large public investment in land drainage and flood defence. Similarly, *The Department of Trade and Industry* also has potentially conflicting interests in pursuit of regional economic development.

The Department of the Environment and its constituent Environment Agency are charged with the implementation of the Government's Strategy for Sustainable Development. In this respect they are well disposed to the potential functions of wet fens, especially if wet fens can relieve environmental pressure elsewhere.

The multiple and often conflicting interests of Central Government are mirrored at the **Local Government** Level with various elements concerned with planning, economic development and environmental quality.

For example, the economic development service committees of *Cambridgeshire and Lincolnshire County Council* and the constituent *District Councils* are concerned with the business and enterprise development, economic diversification, rural industries and employment opportunities associated with wet eco-tourism and related visitor attractions and accommodation services.

The Rural and/or Environment Service Committees of the same pursue multiple objectives for land management in the fens, especially where regulated economic development can fund environmental enhancement. They identify the re-creation of wet fens as an opportunity for improving habitat diversity, for promoting countryside access, whilst supporting vibrant communities in the fens.

Table 4.6 Matrix showing extent of common interest, attributes and functions between stakeholders in the Fens

Organisational Groups	Income & Employment	Regulation functions				Carrier and Production functions					Interpretive & Contextural		
		Water quality	Water quantity	Flood defence	Maintenance of biodiversity	Food supply	Rural business	Water supply	Leisure & recreation	Toursim	Aesthetics	Historical & heritage	Education & scentific
Central Government e.g.													
Department of Environment													
Ministry of Agriculture Fisheries and Food													
Local Government e.g.													
Economic development and planning													
Rural Group													
Farmers and landowners													
Rural business and enterprise development													
Nature conservation													
Heritage organisations													
Environmental regulators													
Water resources													
Tourist Boards and Initiatives													
Research organisations													

Farmers and landowners, both individual and institutional, have an obvious stake in the wet fen proposals. Farmers are driven mostly by commercial imperatives, modified, according to personal circumstances, by traditional ties and a sense of custodianship towards the countryside. Commercial organisations are likely to require financial incentives to switch substantial areas from arable to wet fen, unless other opportunities or motives prevail. Farm workers, and those in ancillary industries could be negatively affected. In areas where irrigation water supply is a problem, investment in storage reservoirs may be compatible with wetland re-creation.

The interests of **Rural Business and Enterprise Development:** are represented by Local Government, Chambers of Trade, Business Link and organisations such as the Rural Development Commission (RDC) which provide a wide range of assistance to businesses, individuals and communities in the countryside. Rural Development Areas have been designated by RDC in the Fenlands for which a development strategy and work programme have been created. Objective 5b Area funding could be drawn on for new rural businesses associated with wet fen creation. The switch from intensive agriculture to extensive land use could affect some businesses negatively, but provide opportunities for others.

A wide range of **Environmental Organisations** representing Government (such as the Environment agency), Quasi Government (such as the Countryside Commission and English Nature) and Non Government interests (such as The Royal Society for the Protection of Birds) have interests in wet fens.

The *Countryside Commission* is concerned with conservation of natural beauty and access to the countryside. The re-creation of wetlands would compliment its objectives by enhancing the existing landscape and providing opportunities for the public's enjoyment of the countryside. The creation of wet fens is consistent with *English Nature's* overall mission to protect and enhance habitats and maintain bio-diversity, and add to the understanding of natural systems. *Farmers and Wildlife Advisory Groups* (FWAGs) are concerned with the identification and promotion of environmental enhancement in farmed areas. Creation of small-scale wetlands is consistent with their overall aim, provided sufficient financial support is available for farmers. *The Royal Society for the Protection of Birds* (RSPB) wish to protect and create suitable habitats for birds. The creation and maintenance of wetlands and wet fens are central to its mission.

There are **Heritage Organisations** which have interests in the historic and cultural aspects of the Fens. These include the *National Trust* which is concerned with the preservation of Britain's heritage for education and public appreciation, with particular reference to

architecture and historic buildings and managed landscapes. The Government's *English Heritage* is responsible for identifying, protecting and managing the best historic and archaeological sites in the previous wet fens, including ancient settlements. The re-creation of wet fens would provide additional opportunities for interpretation of traditional fenland characteristics.

Environmental Regulators and Resource Managers include the new *Environment Agency.* Re-creation of wetlands would be within the Agency's remit for biodiversity and sustainability. The Environment Agency would act as a regulator for applications for wetland re-creation. The re-creation of wetlands could improve water quality and offer an alternative option for flood defence, but there is concern that the water requirements of wet fens may put pressure on existing resources.

Water Resources Agencies are major actors in the operation and maintenance of fen areas. The Environment Agency inherited the responsibility of the previous National Rivers Authority for water resource management, and the protection of the water environment, together with responsibility for flood defence in the main river System. *Internal Drainage Boards (IDBs)* and *Commissioners* such as the Middle Level Commissioners have statutory power to manage and operate the land drainage system to the benefit of occupiers, both farming and urban interests. For them, wet fens have advantages and disadvantages. They could reduce pressure on the need to evacuate excess winter water. They could be associated with winter storage which could protect summer groundwater and surface supply. Wet fens could be difficult to manage in areas that are generally drained. They could also compete with agriculture during the summer period. The creation of flood storage and or summer water supply reservoirs could, however complement the wet fen re-creation initiative.

Water Companies such as *Anglian Water* and *The Cambridge Water Supply Company* have potential interests in wet fen development as it influences water quality and the quality of surface and groundwater sources. These supply companies could view participation in the wet fen initiative as a means of securing future supply, especially relating to storage and quality improvement functions. whilst simultaneously demonstrating a commitment to stated organisational environmental policies.

Tourist Organisations such as the *Anglian Tourism Board* have interests in the proposed wet fen programme. In particular, *The Fen Tourism Group* promotes the area's attractive scenic quality with opportunities recreation, interpretative activities and a broader understanding of the Fens. The overall purpose is to achieve sustainable tourism which simultaneously supports local communities.

Research/Education Organisations undertake interpretative functions whose interests would be served by an increase in wet fen. These include local schools and community colleges, institutes of higher education such as colleges and universities, and specialist research centres such as the *Institute of Terrestrial Ecology.*

The **Local Population** living and working in the Fenland is a large and diverse group whose needs and interests are central to the success of the wet fen programme. Programme success will hinge on the commitment and participation of the local communities and their representatives. Members of the community stand to gain from the initiative, but there are also localised social risks, such as those associated with increased visitors and traffic to the area, as well as possible change in employment opportunities. The wet fen programme must gain the support of local communities.

4.6.2. Partnership

Wet fen development meets many of the principles of sustainable development, delivering a wide range of potential benefits to an equally wide range of social groups. Simultaneously the proposed switch to wet fens will result in direct or indirect costs borne by some groups more than others. Provision may be required to mitigate or compensate for such negative impacts.

The common interests amongst groups are apparent in Table 4.6. They relate to economic development, environmental regulation, and interpretative activities. There are potential conflicts, especially between pressure for development and environmental quality, and between local residents and users from outside the area. Given the diversity of interest in the wet fen proposal, it is important that the programme adopts a partnership approach which brings together the various stakeholders.

This stakeholder analysis can be used positively in the planning process to identify acceptable trade-offs and create a better understanding of compensatory measures that may be required. Income and employment appears to be an interest which is most common to the organisational groups. Any wetland re-creation activity which creates employment and generates incomes will have a positive effect on the rural economy.

4.7 Summary and Conclusions

This Section has examined the policy context for the Wet Fen for the Future Programme which calls for sustainable development which balances socio-economic progress and environmental

quality. The Fenland area shows signs of socio-economic underdevelopment as a consequence of its relative dependency on agriculture and its geographic isolation from major industrial centres and transport routes.

To date, the Wet Fen Initiative has emphasised environmental, mainly nature conservation objectives. The proceeding analysis, however, confirms that the wet fen programme has the potential to deliver a broad range of socio-economic and welfare benefits through the functions of a healthy and accessible environment. Simultaneously, there is a broad church of stakeholders with potential interests in the wet fen proposal who stand to gain or lose to varying degrees according to the way the initiative is designed and managed. The analysis concludes that the programme should be progressed by drawing on this partnership of interest.

5. PEAT WASTAGE

Agriculture in the Fens is characterised by the intensive, mechanised production of root and vegetables crops on organically rich peat soils sustained by a combination of drainage and irrigation. Peat soils are central to the prosperity of farming in the Fens. But their remaining extent and quality have reduced as a consequence of the intensive use. This section examines the factors associated with and responsible for the degradation of peat soils in the Fens, and the consequences for agricultural and other land use.

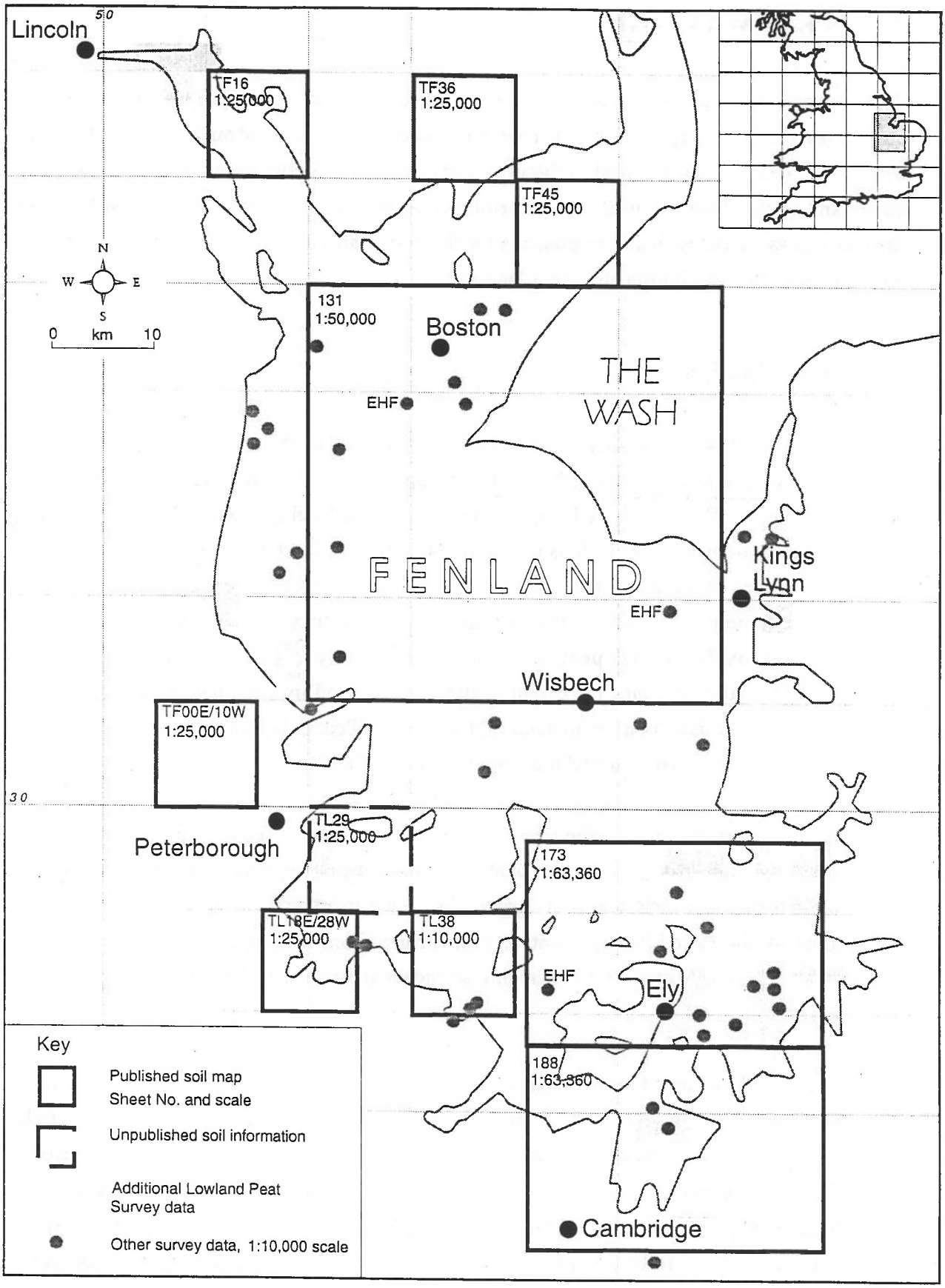
5.1 Introduction

The Fenland of Eastern England, as defined by Figure 5.1 of the Project's Feasibility Study, Phase I, occupies a broad clay vale between outcrops of Jurassic limestone to the west and the Chalk to the east. With drainage hampered by a rising sea level and coastal accretion in post-glacial times, floodplain mires or fens developed in nutrient-rich, freshwater environment along the lower reaches of the rivers that drain a large part of midland and eastern England. In the waterlogged, largely anaerobic conditions, plant material accumulation was far in excess of any losses through oxidation and peat was formed, largely by a process of *paludification* or swamping. Over the millennia, the extent of these fens spread over the old ground surface that had carried mature deciduous woodland and the peat filled in hollows in the topography to form a generally flat expanse stretching from Lincoln to Cambridge.

At its maximum extent, peat reached an elevation of 3.7 m above sea level around the margins where abutting high ground. As the peat layer thickened, the vegetation grew beyond the reach of groundwater and was fed largely by nutrient-poor rainwater in many parts, as exemplified by the raised bog remnant of peat formed from acid-loving plants at Holme Fen (Godwin and Vishnu-Mittre 1975). The bog surface had attained 1.62 m O.D. in 1848 prior to drainage (Fillenham 1963).

During several episodes the forerunner of The Wash extended inland bringing brackish estuarine conditions to all but the landward margins of the Fenland. In the earlier transgressions a grey-coloured alluvium of silty clay texture (termed **'Fen Clay'** or Barroway Drove Beds) was deposited throughout central Fenland over the underlying **'Lower Peat'**, with a maximum limit attained between 4,000 and 3,400 years ago. This marshland surface reached an elevation just below today's sea level and is noted for the dendritic pattern of silted former creeks (locally termed *roddons*) crossing it.

Figure 5.1 The Fenland of Eastern England



Soil Survey information available for the Fenland

FENSOIL1.CDR

A later, generally less-extensive marine transgression of 2,500 to 1,800 years ago caused a brown silty clay (Terrington Beds) to cover earlier deposits. These beds and the lighter textured silts of the seaward 'Townland' belt together form the 'Silt Fens', attaining an elevation of up to 5 m O.D. Intervening peat layers, including part of a major freshwater seaward extension from 2,900 to 2,650 years ago forming the **'Upper Peat'**, were buried and compressed and survive to form clear stratigraphic marker beds. The palaeogeography and environmental conditions are comprehensively described and mapped by Waller (1994) in a Cambridgeshire County Council publication.

The **'Meres'** or freshwater lakes began to form around 1,900 years ago with either the ponding of water behind tidal levée banks or from an increased input of floodwater from the uplands. With the last mere drained in 1848, the former lake beds now carry shelly, very calcareous silty soils.

The maximum extent of the Fenland peat in the early 17th century has been calculated from soil evidence to have been 1,480 km^2, (Burton and Hodgson 1987), in an area known as the **'Peat Fens'** or **'Black Fens'** between higher ground inland and the coastal alluvial deposits of The Wash (Phase I Report, Figure 12, after Godwin 1978). Between 1630 and 1850 large arterial drainage schemes described by Darby (1983) allowed land use to be upgraded from summer grazing, wildfowling and turf exploitation to arable cropping. With this change came the inevitable destruction of the fragile peat.

For the purposes of this report definitions are those currently used for soil classification by the Soil Survey and Land Research Centre, the national institute responsible for the mapping and description of soils within England and Wales. They are here somewhat simplified but are fully explained in Avery (1980) and Clayden and Hollis (1984).

- **peat** is soil material that contains more than 50 per cent organic matter (calculated from loss on ignition);
- **humose** refers to mineral soil material with between 6-10 per cent and 20-25 per cent organic matter, depending on the clay content of the material;
- **sandy peat** and **loamy peat**, and **peaty loam** and **peaty sand** are textures between peat and humose material with 50 per cent to 20-25 per cent organic matter content;
    - a **peat soil**, is derived from partially decomposed plant remains that accumulated under waterlogged conditions meeting both of the following criteria:

        more than 40 cm of peat material within the upper 80 cm of the soil profile, usually at the surface

        no non-humose mineral horizon extending below 30 cm depth;

- **skirt soil** is a general term referring to mineral soil with a dark, humose topsoil (plough layer), a remnant of the former peat cover; in soil classification terms these soils are equivalent to '*humic gley soils*'.

Note: The use of the term 'peat' here may differ from the (undefined) use of the word in the Phase I Report (e.g. p. 67).

The Soil Survey has been involved in mapping, describing and sampling soils in the Fenland since 1950. The early data form an important archive and are the basis of monitoring the state of the soils that are changing more than any other in the country, through peat wastage and acidification. Apart from mapping, two projects funded by the Ministry of Agriculture, Fisheries and Food (MAFF) are prominent in preparing this study – the inventory of Lowland Peat (Burton and Hodgson 1987) for which the peat resource remaining in the mid-1980s was systematically sampled at the intersects of a 500 m grid, and an evaluation of organic matter dynamics for skirt topsoils by resampling sites with historical data (Burton 1995).

5.2. The current extent of peat wastage

Drainage is a necessary part of reclamation for peatlands to be useful as improved pasture, or for agricultural or intensive horticultural use. The fate of peat once it is drained is dramatic and these days well known, resulting in the subsidence of the ground surface and eventually the complete destruction of the peat. There are several processes leading to **peat 'wastage'**, a general term used to account for the loss of peat:

- *shrinkage* — the removal of large amounts of water from the peat produces rapid initial shrinkage and ground surface subsidence;
- *compression* — drainage also reduces the buoyancy effect of water causing compression of peat under its own weight and increased bulk density, with the compaction increased by the passage of machinery;
- *decomposition* — under the ensuing aerobic conditions biochemical oxidation becomes the dominant process, mainly affecting the profile above the water-table and greatest where water-tables are lowest;
- *wind erosion* — the bare, loose surface of fields sown with spring crops is readily affected by strong winds and losses of soil, fertiliser and seed occur by deflation and saltation along with the damage to seedlings by abrasion;
- *removal* — over the centuries until about fifty years ago peat has been dug in a piecemeal fashion for burning, with rights of turbary providing

essential fuel for commoners; today, soil is removed on root crops and is used to build up subsiding gateways or fill hollows rather than being returned to the original field;

- *burning* once alight, peat can smoulder for months in a field and is difficult to extinguish.

Several studies have assessed (i) the *rate* of peat loss in terms of the thickness of the peat at two or more points in time, but less common have been estimates of (ii) its *areal extent.*

(i) The rate of peat loss is variable, with initial rapid subsidence of the land surface with the removal of large amounts of water, followed by a declining rate depending upon land use and water-table levels as the peat layer thins.

> Following the drainage of Holme Fen the surface subsided at a rate of 18 cm a year between 1850 and 1860 (Hutchinson 1980).

Other studies have shown generally lower subsidence rates during the later stages of wastage:

> At Peacock's Farm, Shippea Hill, there was an average subsidence of 1.8 cm a year over 26 years between 1934 and 1960 (Clarke and Godwin 1962).
>
> A mean rate of 1.37 cm a year (±0.78 cm) was calculated by Richardson and Smith (1977) by measuring the settlement of concrete slabs.
>
> Herbert (1971) measured mean annual wastage of 0.7 cm a year for thin peat (of less than 90 cm thickness) and 2.1 cm a year for thicker peat by resampling earlier Soil Survey sites. She formulated the (amended) equation.
>
> $$y = 0.570 - 0.0212x \quad (r = -0.49)$$
>
> for thin peat, where y is the rate of change of thickness of peat in cm/year and x is the original thickness of peat in cm.
>
> Bradley (1979), also resampling Soil Survey sites found a rate of lowering of 2.27 cm a year for peat over 2 m thick, compared with a rate of 1.79 cm a year for peat 1-2 m thick, and 0.76 cm a year for peat less than 1 m thick. Small, but statistically significant correlations were found between peat thickness and rate of lowering.

Burton (1989) estimated a mean decline of 1 cm a year 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.

Cook (1990), at a regularly monitored site in the Cam valley at Stretham, recorded subsidence over a 136-week period at approximately 2.8 cm a year. Pulverised fuel ash (PFA) added to the surface was observed to reduce this rate by approximately 1.4 mm for each 100 t/ha.

(ii) Published Soil Survey maps show the distribution of soil types at various scales, using a precise classification scheme that takes account of thickness and texture of layers or *horizons*, pH and wetness regime within a depth of at least 1.2 m. Each soil type or *soil series* has a limited range of characteristics and soil maps readily allow an understanding, assessment and comparison of land to be made. Unfortunately, not all of the Fenland study area has been covered by detailed (1:25,000 scale) or semi-detailed (1:63,360 or 1:50,000) soil maps, and because of the rapid changes in the soils of the Peat Fens, some of the earlier maps have already become outdated (e.g. Seale 1975 for the Ely district). Figure 5.1 shows the location and scales of such maps that are available.

A reconnaissance-level survey for the whole area (Soil Survey of England and Wales 1983) shows the up-to-date distribution of soil types grouped into *soil associations* at 1:250,000 scale. Each association consists of a dominant soil series with inclusions of other series either in a known pattern of occurrence or as discrete areas too small to be shown at the map scale. The area represented by soil associations dominated by peat is severely limited compared with the original distribution (Figure 12, Phase I Report).

The main residual areas are confined to:

- deep basins in the perimarine zone (beyond the landward limit of the Fen Clay) as at Holme Fen,
- deep river valleys such as the Witham and Cam,
- areas drained relatively recently as in Methwold Severals in Norfolk, and
- protected areas such as the nature reserves and flood-relief washes.

5.2.1. Peat soils

Four main soil series are developed in fen peat and one in raised bog peat:

Adventurers' and *Mendham series* are recognised in peat of neutral and acid reaction respectively. Where the peat is thin, *phases* of both series are distinguished according to the nature of the mineral substratum. With water-tables maintained at about a metre depth, subsoils consist largely of well decomposed, humified peat (less than 15% fibre content). Water draining into the Fenland comes from calcareous strata so that its alkaline nature has given rise to eutrophic peat-forming vegetation. Thus, Adventurers' soils are dominantly neutral or alkaline and frequently include lenses of shell marl, remnants of the temporary pools that were commonplace. Mendham soils are influenced by acid sulphate conditions. Both of these soils occur throughout all the remaining peaty areas of Fenland.

Altcar series is identified where the plough layer rests on eutrophic fibrous or semi-fibrous grass-sedge peat, commonly more than a metre thick. This soil type occurs as a rare remnant in the Norfolk fens around Methwold Severals, and is representative of much of the peat that has wasted away.

Prickwillow series is identified where a thin layer of clayey marine alluvium occurs within the peat soil profile. These physical conditions are indicative of an acid sulphate influence and subsoils are typically strongly acid (pH less than 4) where drained. The soil occurs throughout southern Fenland in a narrow zone around the landward edge of the Fen Clay deposit.

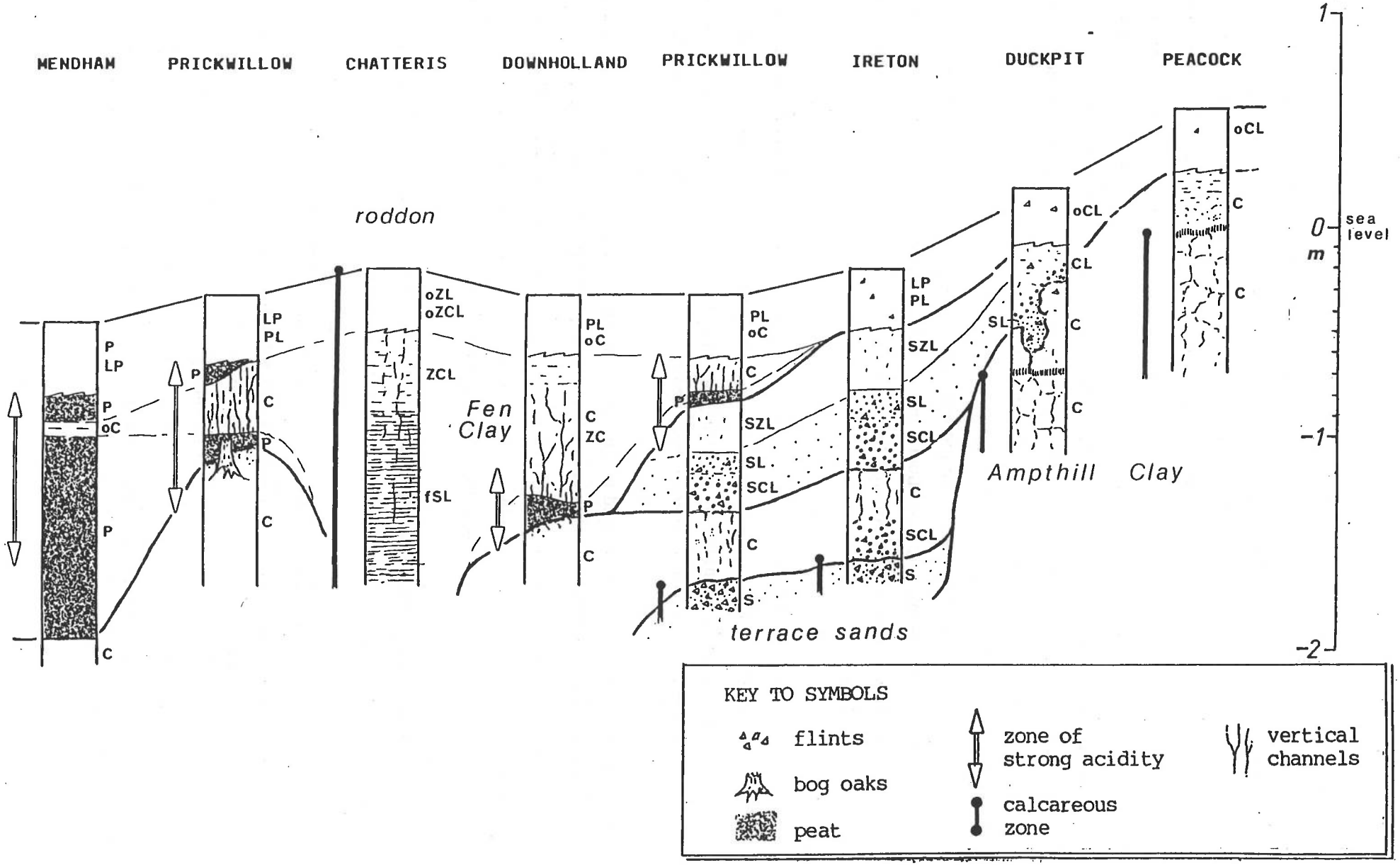
Turbary Moor series is developed in the remains of raised bog peat, being dark reddish brown in colour and semi-fibrous with identifiable remains of cotton-grass, sphagnum moss and heather. Although more acid than Adventurers' series, pH values are usually above 4, and the peat is commonly 1-3 metres thick. The soils are limited in extent to 12 km^2 in Holme and Yaxley Fens and parts of Conington and Farcet Fens.

Some typical soil profiles from the Arthur Rickwood EHF are represented diagramatically in Figure 5.2 as an aid to understanding some of these concepts.

The inventory of the main lowland peat deposits was designed to record the state of the Fenland peats by systematic sampling (Burton and Hodgson 1987). The survey records that only 240 km^2 of peat (thicker than 40 cm) was remaining in the Fenland in the mid-1980s. This was only 16% of the maximum extent of three and a half centuries earlier. A more detailed map was produced in that report (pp. 92-93) of the distribution of peat, upon which Figure 5.3 is based along with field sheets for all published and unpublished maps in the Soil Survey archive.

Diagrammatic representation of typical soil profiles at the Arthur Rickwood E H F, Mepal, Cambs.

Figure 5.2



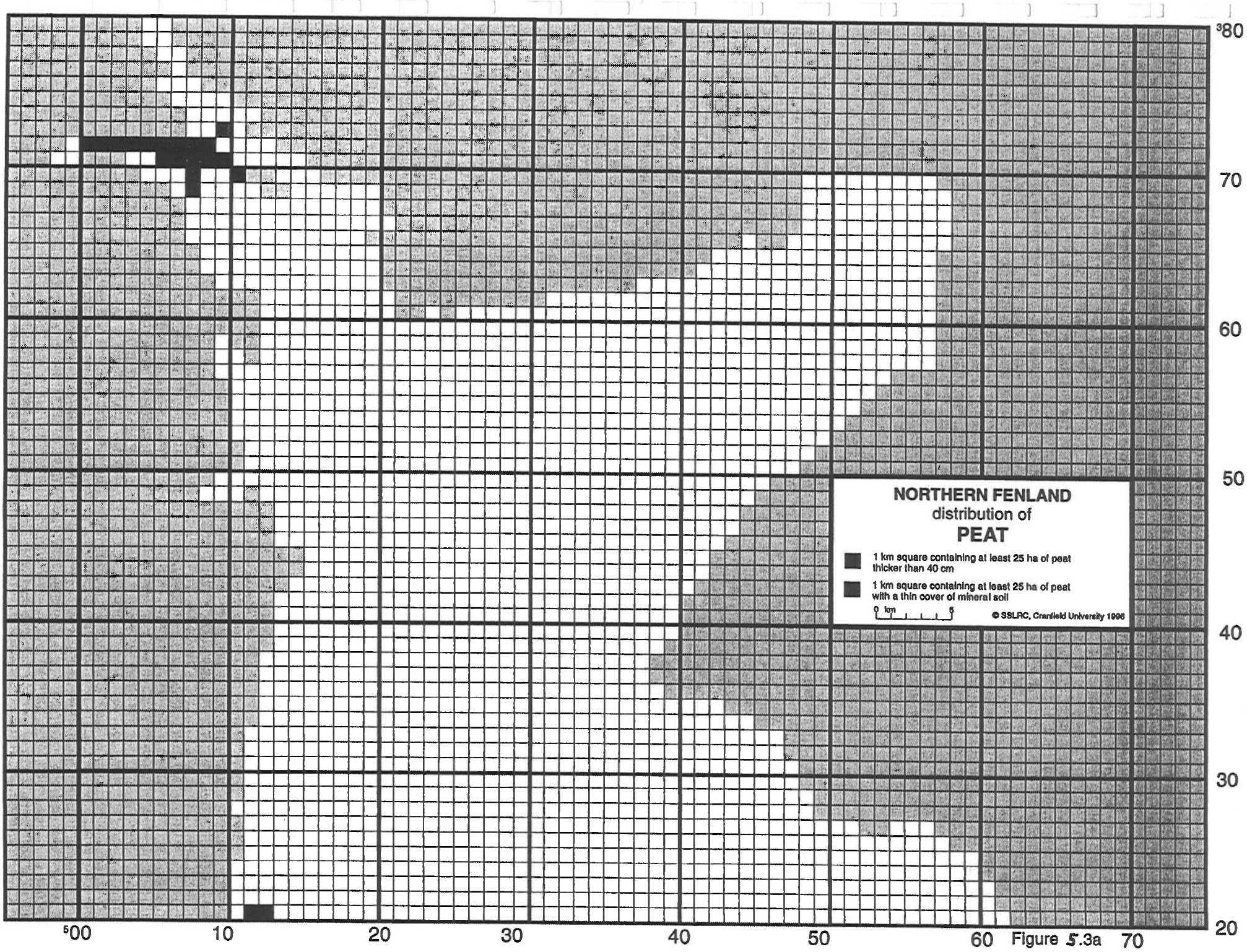

NORTHERN FENLAND
distribution of
PEAT
1 km square containing at least 25 ha of peat thicker than 40 cm
1 km square containing at least 25 ha of peat with a thin cover of mineral soil
0 km
5
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380
70
60
50
40
30
20
500
10
20
30
40
50
60
70

Figure 5.3a

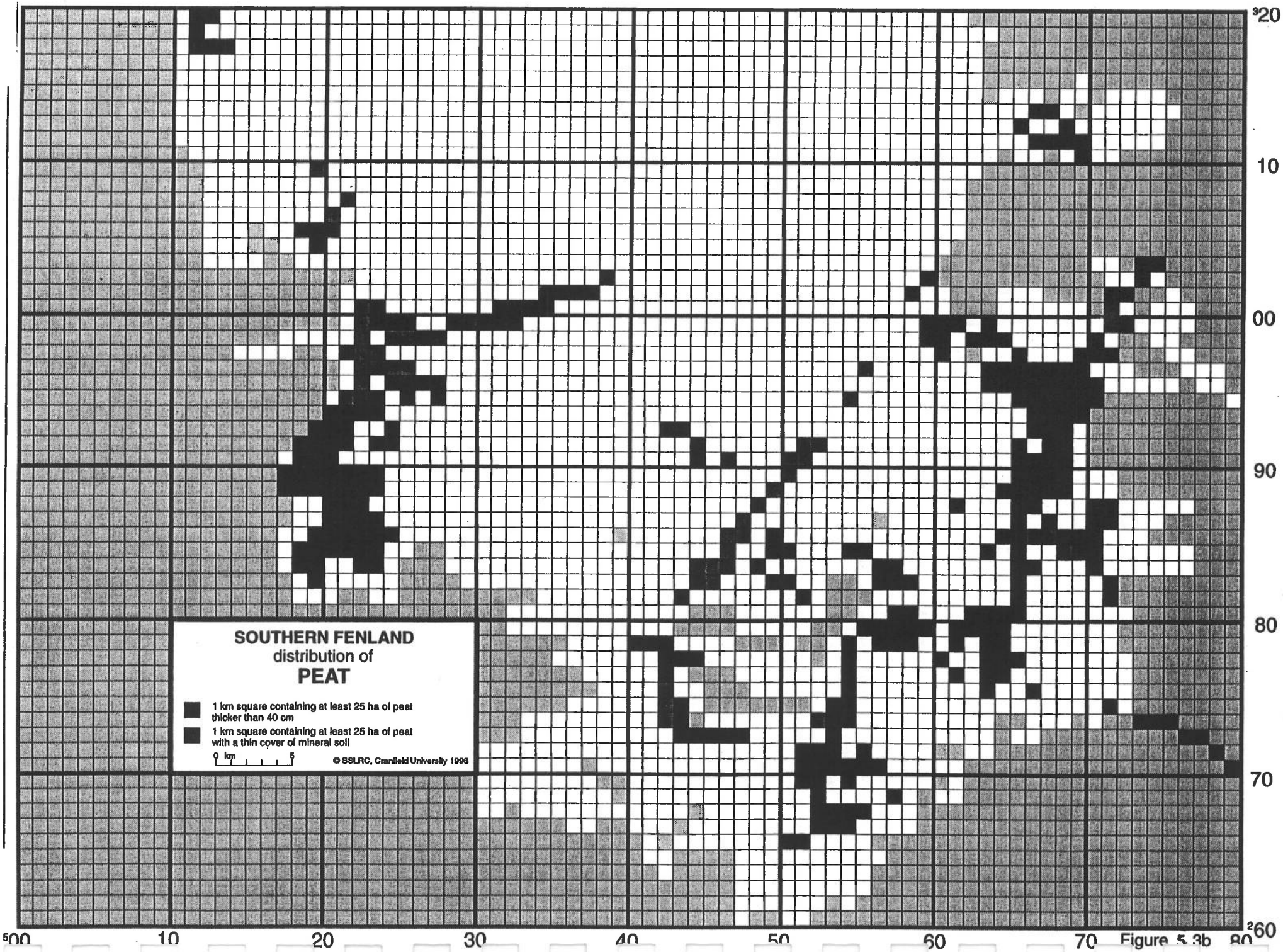

SOUTHERN FENLAND
distribution of
PEAT
1 km square containing at least 25 ha of peat thicker than 40 cm
1 km square containing at least 25 ha of peat with a thin cover of mineral soil
0 km
5
© SSLRC, Cranfield University 1996
320
10
00
90
80
70
260
500
10
20
30
40
50
60
70
80

Figure 5.3b

As in the Phase I Report, Figure 5.3 shows a general picture for the Fenland based on the estimated occurrence of peat soils over at least a quarter (25 ha) of each kilometre square. More precise information is held for most squares and could be accessed once appropriate squares are selected for the study.

The lowland peat inventory also allowed a summary to be made of the remaining peat thickness and divided this into two land-use categories, (i) arable land that is likely to continue to waste at a rate of 1 cm a year on average, and (ii) nature reserves and other protected land where wastage would be negligible. Figure 5.4, reproduced from Burton and Hodgson (1987, p. 94), shows the frequency of observations made for each 10-cm thickness class (left-hand vertical axis), which can be converted to an area of land (right-hand vertical axis). At that time, 56 per cent of the remaining 24,000 ha of peat soils were less than 1 m thick. Twelve per cent of the peat (representing 2,900 ha) was between 40 and 50 cm thick and such an area is likely to no longer be classed as peat in 1996, and the modal column of the 1985 histogram could now be erased. Predictions can be made of the future decline in peat thickness and area by using the lower horizontal axis and matching the date.

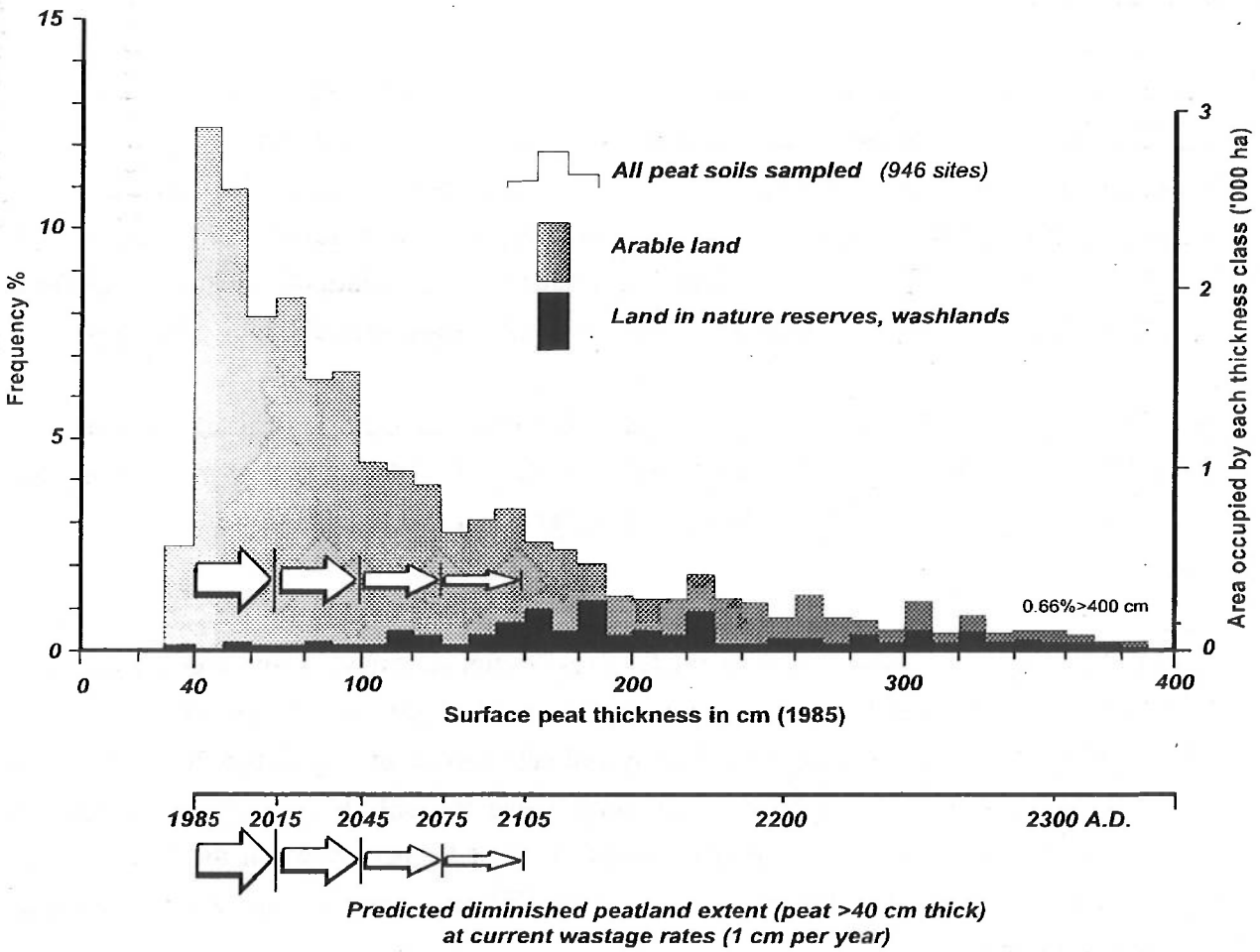


Figure 5.4: Frequency and area of peat soils in the Fenland (1985) by 10-cm thickness class, and a prediction of future peat soil losses.

5.2.2. Skirt soils

Peat wastage eventually reaches the stage where the surface organic layer alone becomes too thin to contain the cultivation, and mineral subsoil with a much lower organic matter level becomes incorporated into the plough layer. This process occurs first of all where the peat was initially thinnest, that is around the edge of the peatland. Such soils, therefore, usually fringe or 'skirt' the peatland and are locally known as **'skirt soils'**. The zone of skirt soils gradually extends towards the centre of the peatland and those profiles around the margins become less organic until they attain the status of a mineral soil. In the centre of the southern Fenland the surface of the Fen Clay deposit has also been exhumed to give extensive skirt soils at just below sea level. Once the large reserves of soil organic matter in peat and skirt soils are lost, there is no possibility of replacement through conventional agricultural management.

A range of skirt soils occurring at the Arthur Rickwood EHF are illustrated in Figure 5.2. These are *Chatteris series* on roddons, *Downholland series* over Fen Clay, *Ireton series* on terrace loams and gravels, *Duckpit series* in medium loams over Jurassic clay and *Peacock series* developed directly in Jurassic clay.

Figure 5.5 shows the distribution of skirt soils in the Fenland where each individual kilometre square is shown that contains at least 25 ha of humic gley soils. The dominant texture class is shown as either (i) clayey or sandy, or (ii) silty or loamy as this split distinguishes the soils which decline in agricultural quality with time (i) and those in which quality may be maintained (ii). Squares on this map and on the peat map (Figure 5.3) are mutually exclusive and those already ascribed to peat are not also shown to contain skirt soils, although they may do so.

The dominant skirt soils are clayey on Fen Clay (Downholland series) or Jurassic and Cretaceous clays (Peacock and Manea series). Sandy soils (Isleham series) occur along the eastern side of the Fenland from Mildenhall to Kings Lynn and bounding the Witham fens in Lincolnshire.

Loamy soils are more limited. Light loamy textures (Ireton series) occur on river terraces east of Peterborough and near Chatteris but these easily worked soils overlie gravel in the lower subsoil and tend to be more droughty. Loamy and silty soils over clay (Duckpit series) occur sporadically amongst more clayey Peacock soils, while the only high quality silty soils on alluvium (Chatteris series) occupy narrow strips of silted former creeks in the large area of Downholland soils. Chalky, loamy skirt soils like Wilbraham series occur along the south-eastern Fenland margin.

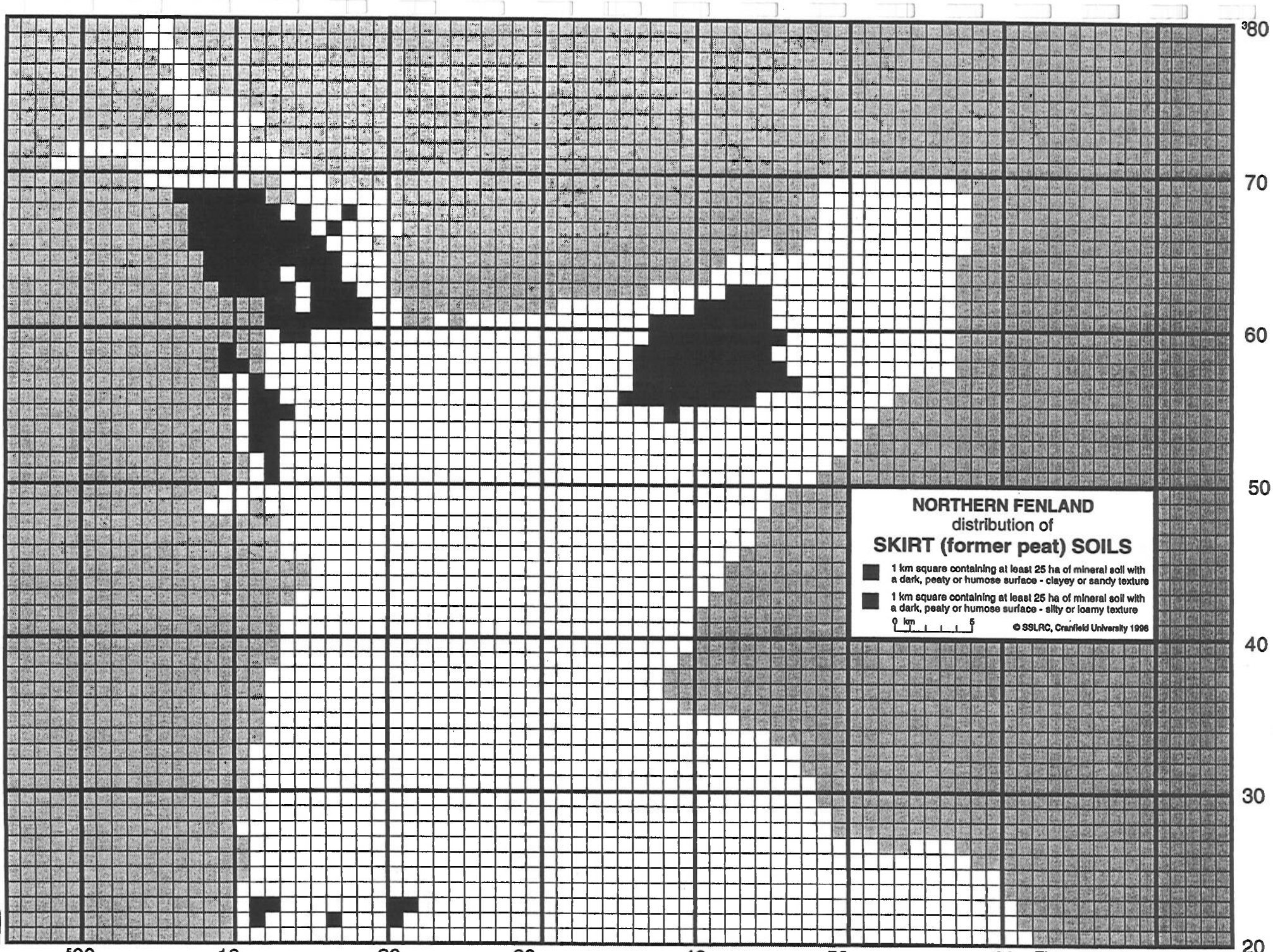

NORTHERN FENLAND
distribution of
SKIRT (former peat) SOILS
1 km square containing at least 25 ha of mineral soil with a dark, peaty or humose surface - clayey or sandy texture
1 km square containing at least 25 ha of mineral soil with a dark, peaty or humose surface - silty or loamy texture
0 km
5
© SSLRC, Cranfield University 1998
380
70
60
50
40
30
20
500
10
20
30
40
50
60
70

Figure 5.5a


SOUTHERN FENLAND
distribution of
SKIRT (former peat) SOILS
1 km square containing at least 25 ha of mineral soil with a dark, peaty or humose surface - clayey or sandy texture
1 km square containing at least 25 ha of mineral soil with a dark, peaty or humose surface - silty or loamy texture
0 km 5
© SSLRC, Cranfield University 1996
320
10
00
90
80
70
260
500
10
20
30
40
50
60
70
80

Figure 5.5b

Skirt topsoils become increasingly depleted of organic matter reserves with continued agricultural use, through mineralisation of soil organic matter and dilution with subsoil material being greater than inputs from crop residues. By resampling 31 sites with historical analytical data Burton (1995) was able to predict the likely rate of loss of organic matter from skirt topsoils (Figure 5.6). The general decline can be characterised by an exponential curve, a soil chronofunction:

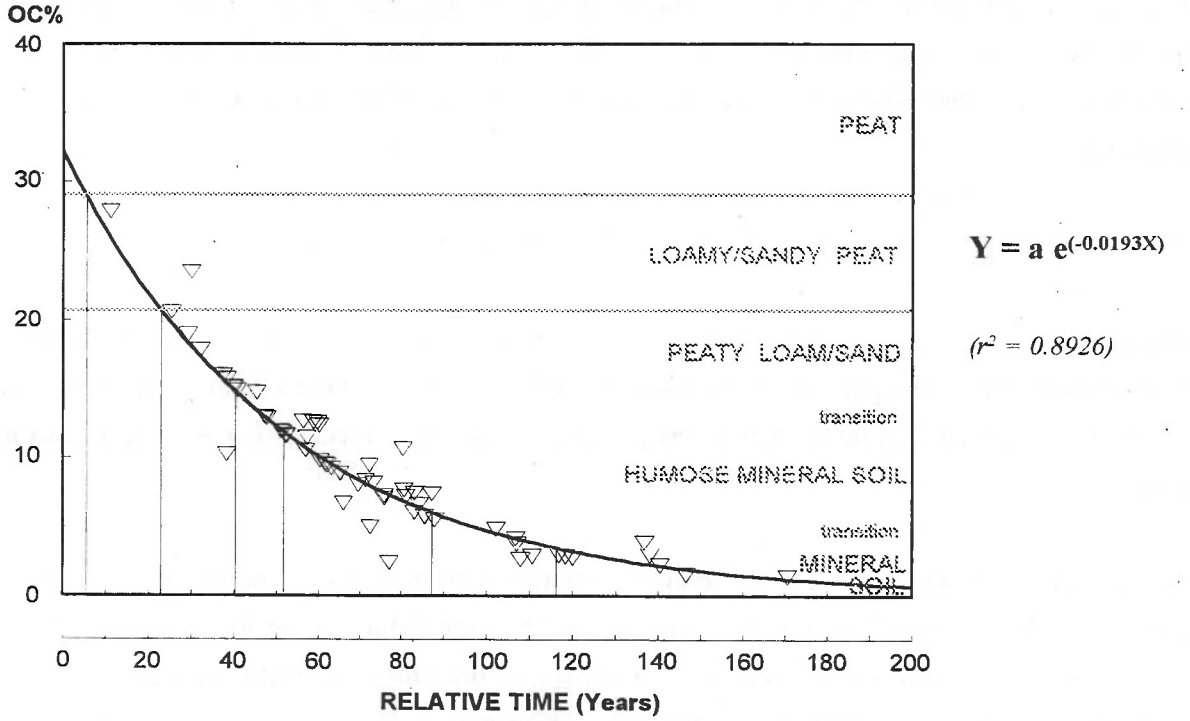
$$Y = a\, e^{-0.0193X} \qquad (r^2=0.8926)$$

where Y is the percentage organic matter, measured as organic carbon, X the time in years and a is a constant (Y intercept) dependent upon the original organic carbon level. The X axis has been drawn so that it can be used as a sliding scale to represent relative time from any starting point.

Superimposed on Figure 5.6 are the limits of organic matter status, based on organic carbon content. Although too few organic matter data exist for mapping the distribution of likely changes, this does allow for an estimate to be made of the time period taken for the topsoil of degraded peat soils typically to pass through each organic matter class. Class boundaries in Figure 5.6 are complicated by transition zones to account for the variable clay content. In addition, both the chronofunction and its graphical expression can be used to predict likely future changes to the soil organic matter status of 'skirt' topsoils.

The time period for a peat topsoil with 50% organic matter (about 30% organic carbon) directly overlying a mineral subsoil to pass through the 'skirt stage' to become a mineral topsoil is predicted to be about 100 years. It then requires a further loss of organic matter over about 75 years for this mineral topsoil to attain an organic carbon content of 1.5-3.0%, a typical equilibrium level for arable land elsewhere in Eastern England (Soil Survey National Soil Inventory data).

Figure 5.6: Organic matter decline with time in Skirt Soils in the Fenland



5.3. The likely future impact of peat wastage on agricultural land quality

The agricultural land quality of peat soils can decline through development of subsoil acidity brought about by drainage and wastage, and by the influence of an increasingly shallow mineral substrate, the level of quality loss depending on the nature of the substrate.

The maps of distribution of agricultural land grades in the Phase I Report (Figures 30-32) are taken from the Agricultural Land Classification (ALC) maps published at 1:63,360 scale in the early 1970s. These maps are described as 'provisional' and are mainly suitable for strategic rather than detailed decisions. The continuing wastage of the peat has caused significant changes in the soils so that a revision of the grading is needed from time to time. When the original assessment was made, the extent of acid sulphate soils (see section 5.1) had not been fully recognised, hence the statement '*Recent examination of peat soils in the Woodwalton Fen area indicates a particularly deep acidity, difficult to counter by mechanical methods because of the presence of large numbers of bog oaks in the subsurface layers. Investigations are to be carried out to decide whether such factors should lead to a downgrading of this area.*' (MAFF 1978) as a footnote to the description of Grade 1 land in the Huntingdon and Peterborough area, where '*limitations, e.g. acidity, can be readily corrected*'. A similar Land Capability grading assessment of that area (Needham, in Burton and Seale 1981) classed the land as grade 3.

Soils are now classified on the basis of their long-term capability and adaptability for agricultural crops, according to the revised guidelines and criteria for grading published by MAFF (1988), which are consistent with the original concepts. The classification is well established and understood in the planning system and provides an appropriate framework for objectively and consistently determining the **physical quality** of land in any locality. **Economic criteria** are not included in the assessment because of the difficulty in obtaining objective, up to date, accurate and consistent farm output data. Crop yield data are also excluded for being subject to variations in management skills, inputs and weather.

Using the standard procedures, the Grade for the full range of Fenland soils can be assessed on a scale of 1 (highest quality) to 5 with Grade 3 divided into an upper Subgrade 3a and a lower Subgrade 3b. These soil Grades can be compared with the mineral soil equivalents lacking a humose topsoil to which the skirt soils will eventually degrade. This will allow an area to be broadly defined where land quality has already fallen and where other land is likely to degrade in the future. Since soil varies appreciably field by field, resurvey at a larger scale with more investigations may show differences from the original grading and is recommended.

Table 5.1: Typical ALC Grades of Peat Fenland soils with Grades following continued degradation.

Current soil series	ALC Grade	Future soil series	Future ALC grade	Main reason to downgrade
Peat soils				
Altcar	1	various	1(-2)	–(impeded subsoil drainage)
Adventurers'	1	depending	1(-2)	–(impeded subsoil drainage)
Mendham	2-3a	on substrate		strong subsoil acidity
Prickwillow	3a-3b	–		strong subsoil acidity
Skirt soils				
Chatteris	1	Wisbech	1	–
Clayhythe	2	Ickford	2-3a	droughtiness
Downholland	1	Wallasea	3a	heavy texture
Duckpit	2	Papworth, Oxpasture	2-3a	impeded subsoil drainage
Fordham	2	Badsey	2	droughtiness
Ireton	1-2	Badsey	2	droughtiness
Isleham	3a	Blackwood	3b-4	droughtiness
Peacock	3a	Denchworth	3b	heavy texture, poor drainage
Wilbraham	2	Kelstern	2	slight workability limitation

The following are the main characteristics of the skirt soils within each Grade:

Grade 1

Chatteris series	well drained, very flexible light silty soils with large water holding capacity; will remain as Grade 1 with change to Wisbech series on organic matter loss.
Downholland series	friable, easily worked peaty loam topsoil; subsoils allowing deep rooting without drought stress; only slight seasonal waterlogging; will gradually become Grade 2 as the organic matter content of the topsoil and hence its workability declines; eventual downgrading to 3a with further organic matter loss.

Grade 1 - 2

Ireton series	friable, easily worked light loamy soils; well drained with some drought limitation due to sandy or gravelly subsoils at variable depth; weak structure and easily compacted in upper subsoil; likely to remain Grade 2 with droughtiness limitation on further organic matter depletion.

Grade 2

Fordham series	friable, easily worked light loamy soils; well drained with some drought limitation due to sandy subsoils at variable depth; weak structure and easily compacted in upper subsoil; likely to remain Grade 2 with droughtiness limitation on further organic matter depletion.
Duckpit series	medium textured soils (clay loam or silty clay loam) with slight workability difficulties; slowly permeable clayey lower subsoil impedes drainage but lateral water movement is aided by a sandy seam immediately above the clay; will remain Grade 2 as Papworth or Oxpasture series but may be downgraded to 3a in places.

Grade 3a

Peacock series	clay soils with heavy texture and increasing workability difficulties; difficulty in obtaining good tilth; with organic matter loss, eventually becoming Denchworth series and Grade 3b with reduced cropping flexibility; wetness limitations due to slow subsoil permeability.

Grade 3a - 3b

Isleham series	friable and free draining; droughty deep sandy subsoil; stone content variable and increases droughtiness; spring-sown crops liable to suffer from the abrasive effects of blowing sand; will become more droughty with organic matter loss and only Grade 3b to 4.
Prickwillow series	severe subsoil acidity and metal toxicity restricts rooting depth and induces drought stress; nutrient availability reduced; ochre accumulations in underdrains causing blockages and environmental pollution; possible moderate wetness limitation especially in low places between roddons where water from higher ground can accumulate.

Additionally in most parts of the Fens, the typically complex arrangement of contrasting soil types can cause problems with the correct application of lime, fertilisers and herbicides.

The Royal Commission on Environmental Pollution (1996), in recommendations for sustainable use of the soil, has recognised the importance of peat and peatlands and offer nine recommendations to help stem their loss, mainly addressed to the extraction industry and peatlands with significant conservation value. However, the Commission stated (Recommendation 28) that drained peat soils should be regarded as a resource for agriculture and managed in a way that will maintain productivity as long as possible.

5.4. The implications of peat wastage on future cropping

5.4.1. The benefits of topsoil organic matter

The soil organic matter content of topsoils affects workability, flexibility, water holding capacity, fertility and, ultimately, productivity of the soil. With its gradual but inevitable decline in both peat and skirt soils in the Peat Fens there is also a decline in the ability of the soil to sustain these qualities and to provide a growing medium for as wide a range of crops as before.

5.4.2. Crop suitability

The suitability of land for particular agricultural crops or farming systems can be determined objectively using standard models developed by the Soil Survey and Land Research Centre.

These concepts take into account climate and relief, as well as soil. Good management is assumed and irrigation can be taken into account where it is available. Social and economic factors which often affect the choice of land use are mainly excluded. Suitability is assessed for *sustained* production in a rational cropping system. The chances of failure to establish, mature or harvest a particular crop must be considered in the assessment and for land to be judged suitable for a crop there must be reasonable confidence that it can be grown regularly and make a predictable contribution to the farm economy.

The models use the concepts of *droughtiness* and *workability* to determine the interactions between soil and climate. The *degree of droughtiness* is used as a measure of the ability of the soils to supply sufficient water for optimum growth and the number of *machinery work days* is used to estimate the time available to cultivate the land and to sow and harvest the crop in good conditions, without causing undue damage to soil structure.

5.4.3. Droughtiness

Droughtiness is an assessment of the ability of a soil to provide a growing crop with water, which reflects a combination of soil and climatic factors.

5.4.4. Soil factors

For annual crops the amount of available water which is generally accessible for plant growth varies with crop type and soil conditions. The depth of rooting under favourable conditions is about 120 cm for cereals, whereas potato roots do not search so deeply and 70-80 cm is the average limit. Sugar beet can root below 120 cm and extract appreciable amounts of water from that depth. Although with increasing depth crop rooting systems are less well developed and their ability to abstract water is diminished, deep roots can provide significant quantities of water during dry summer periods. Thus it is important to break up cultivation pans and any other compaction that might reduce root penetration.

An approximate value for **available water (AP)** for any specified crop growing in any given soil profile can be calculated with existing laboratory data from such properties as texture, stoniness, packing density and depth. This has been done for the main soils in Table 5.2.

Table 5.2:Typical values of crop-available water capacity (AP) of the soils in mm

Soil series	Winter wheat	Spring barley Carrots	Winter barley Oilseed rape	Sugar beet	Potatoes, Beetroot	Permanent grass
Adventurers'	265	265	265	330	200	250
Mendham (60)	135	135	135	135	135	135
Downholland	175	175	175	220	120	155
Wallasea	160	160	160	195	115	145
Duckpit	140	140	140	175	115	140
Peacock	130	130	130	130	115	135
Isleham	125	125	125	125	105	120

The role of organic matter is important in the ability of soil to hold moisture available for plants to use. This is illustrated for a 30 cm soil depth in Table 5.3. It can be seen that as topsoil organic matter levels decline, and as the fibre content of peat (on mineralisation and decomposition) and its thickness in the soil profile also decline, then soils become increasingly less able to supply plants with the required moisture. To avoid yield reductions from drought, the shortfall has to be made up from irrigation, for which there is an increasing demand.

Table 5.3: The amounts of available water held for different organic matter levels and textures.

Organic carbon%	Texture	Plant available water over 30 cm depth
>30%	fibrous peat	165 mm
>30%	semi-fibrous peat	135 mm
>30%	humified peat	90 mm
20-30%	loamy peat (topsoil)	75 mm
12-20%	peaty loam (topsoil)	70 mm
6-12%	humose mineral soil (topsoil)	62 mm
<6%	clay loam (topsoil)	54 mm
<6%	clay, sandy clay loam or sandy loam (topsoil)	51 mm
<6%	sand (topsoil)	36 mm

Where rooting depth is restricted by strong acidity and associated toxicity, biologically available water for crops is considerably reduced compared with physically available water, although different crops have variable sensitivities to acidity. Table 5.4 shows the contrast from measurements of three actual soil profiles at the Arthur Rickwood EHF (Burton 1989).

Table 5.4: The restrictions of rooting depth to biologically available water.

Soil series	Rooting depth	Physically available water	Biologically available water
Mendham	62 cm	391 mm	190 mm
Ireton	58 cm	211 mm	108 mm
Prickwillow	71 cm	208 mm	106 mm

5.4.5. Climatic factors

The climatic factor used in the assessment of droughtiness is the **'moisture deficit' (MD)**. In the April to September period a crop will receive only part of its water needs from rainfall. It will attempt to make up this deficit by drawing on reserves of available water in the soil. If there are not adequate reserves to prevent the crop from coming under stress, then loss of yield and quality can result. It is this balance between the moisture deficit and the soil available water that is the basis of droughtiness assessment.

For arable crops average MD values are calculated for critical periods in the crop growing season. Cereals do not completely cover the ground until the end of April, so moisture losses during this period are less than the potential transpiration under grass. With the onset of ripening in July there is no further uptake of soil water. Root crops such as potatoes or sugar beet and some vegetable crops can be considered as bare ground until mid-May and the crop cover is not complete until the end of June. The crop-adjusted Moisture Deficits typical for the Central Fenland are shown in Table 5.5. In an area of low average annual rainfall (550-600 mm) these moisture deficit figures are amongst the highest for England and Wales

Table 5.5: Typical average crop-adjusted Moisture Deficits (MD) in mm for Central Fenland

Winter wheat	128
Winter barley, oilseed rape	109
Spring barley, linseed	121
Sugar beet, potatoes, spring sown carrots bulb onions, beetroot, spring lettuce (transplanted)	137
Grass	121

Drought risk for individual crops is assessed by subtracting the crop-adjusted moisture deficit from the crop available water capacity of the soil. A value of more than +50 mm indicates that

the soil has appreciable reserves of available water in the average season and provides some additional resistance to drought stress in dry years and is termed **non-droughty**. A value of between 0 and +50 mm indicates a risk of drought stress in dry years and the soil is termed slightly droughty. Moderately droughty soils have a negative value of between 0 and -50 mm, and there is a likelihood of loss of yield due to drought stress in most years on such land. A value of more than -50 mm, termed very droughty, implies severe shortage of water in all but the wettest summers.

For the main soils of the area the calculation of available water (AP) minus moisture deficit (MD) can be expressed in one of the above droughtiness classes (Table 5.6). These are average figures. For the purpose of irrigation scheduling using the 'balance sheet' method more precise calculations can be made on a field-by-field basis. Some of the factors affecting the AP of specific sites are:

texture – increased silt or organic matter contents improve water holding properties; clay soils contain large amounts of water but much is not readily available to plants at usual suctions.

packing density – any densely packed soil will hold less available water and have lower porosity than soil with a medium packing density. Should the soil be compact enough to prevent rooting into a deep, less dense subsoil, then total available water is reduced considerably. Clay soils are most easily damaged structurally by traffic in too wet conditions.

stones – the content of hard, inert stones in a soil will reduce the available water by that percentage. Peat and alluvial soils are naturally stoneless but underlying strata have a varied stone content.

Table 5.6: Drought risk assessment for potatoes on peaty soils and their equivalent skirt and mineral counterparts

Soil series	AP	MD	AP-MD	Droughtiness risk class
Adventurers'	200	137	63	Non-droughty
Mendham	135	137	-2	Moderately to Slightly droughty
Downholland	120	137	-17	Moderately droughty
Wallasea	115	137	-22	Moderately droughty
Duckpit	115	137	-22	Moderately droughty
Isleham	105	137	-32	Moderately droughty

5.4.6. Soil workability

To reduce the risk of soil structural damage it is best to avoid using farm machinery on wet land as moisture content affects the bearing strength of the topsoil. Workability is an assessment of the ease with which a soil can be cultivated and its susceptibility to structural damage. The critical times for cultivation are late autumn and in spring. The days when land can be worked with little risk of damage are called **Machinery Work Days** (MWDs). These represent an interaction between soil and local climate.

The climatic factor is the **field capacity period**, the time during which soil pores are recharged with water and there is no soil moisture deficit. However, differences between soil types means that the length of time over which they are wet varies, so the field capacity period has to be adjusted to account for properties such as texture, subsoil permeability and duration of waterlogging. Each soil type can be given a **'workability rating'** and field capacity data adjusted accordingly.

The main soils in the Central Fenland can be placed in ease of cultivation groups based on soil workability ratings (Table 5.7).

aa-rated soils are very easy to cultivate and have few restrictions during average or dry winters to cultivation within one to three rain-free days;

a-rated soils are easy and are not dependent on frost weathering to produce a tilth;

b-rated soils are moderately easy to cultivate but will require a longer rain-free period (4-7 days) before the surface soil is sufficiently dry to allow working without causing soil structure damage;

c-rated soils are moderately difficult to cultivate; and

d-rated soils are difficult. Cultivation when wet is particularly detrimental to good structure in these soils and damage sustained is not easily rectified. Autumn cultivation is, therefore, desirable to avoid compaction and smearing.

Intermediate categories ab, bc etc, are used where soils fall between the main categories. Soil can straddle two classes where factors such as organic matter content or drainage have a wide range.

Table 5.7: Soil workability ratings for Fenland soils

Workability rating	Soil series
aa	Isleham; Blackwood
a	Adventurers', Mendham, Prickwillow (part); Altcar; Badsey; Chatteris; Fordham; Ireton; Wisbech
ab	Adventurers', Mendham, Prickwillow (part); Clayhythe; Downholland; Duckpit; Wilbraham
b	Downholland (in hollows)
bc	Wallasea (part)
c	Peacock; Wallasea (part)
d	Denchworth

Figure 5.7 gives an indication of autumn (September-December, 122 days max.) and spring (January-April, 120 days max.) MWDs and the periods when landwork is inadvisable. A site in the shadow of woodland has less chance of drying out when the sun is at a low angle, so safe landwork periods can be shortened. It clearly shows that as organic matter levels decline and soil types from peat to skirt to mineral, then the period when the land can be worked is gradually shortened. This affects the range of crops by such factors as the time and ability to prepare spring seedbeds and late autumn harvesting without causing soil structural damage, which then affects succeeding crops and conditions of growth.

5.5. Summary and Conclusions

This section has shown that soil organic matter has an important role in topsoils, where it favourably affects workability, flexibility of cropping, water holding capacity, fertility and, ultimately, productivity of the soil. Peat soils, once effectively drained, form high quality agricultural land with minor or no physical limitations. Yields are consistently high and a wide range of crops can be grown, including the more exacting horticultural crops.

Arable cropping can lead to a decline organic matter decline over a very long period: in peat soils it is initially rapid where the peats are thickest and in degraded skirt soils where topsoil organic matter levels are still high. Both soil types then suffer a steady exponential depletion until, eventually, all such soils will become similar to mineral soils with topsoil organic matter levels in equilibrium with the inputs and losses of the current management regime. Such levels are between 1-3.5% organic carbon for clays and loams, and 0.5-2.5% for sands.

Soil Series	Rating	Type of Year	MWDs	AUTUMN SEP	OCT	NOV	WINTER DEC	JAN	FEB	SPRING MAR	APR	MWDs
Adventurers' Mendham Altcar Chatteris Ireton	a	Average	122					550 mm annual rainfall				46
		Wet	109									25
Downholland (more organic) Duckpit Wilbraham	ab	Average	117					550 mm annual rainfall				41
		Wet	104									20
Downholland (less organic)	b	Average	112					550 mm annual rainfall				36
		Wet	99									15
Wallasea	bc	Average	107					550 mm annual rainfall				31
		Wet	94									10
Peacock	c	Average	102					550 mm annual rainfall				26
		Wet	89									5
Denchworth	d	Average	92					550 mm annual rainfall				16
		Wet	79									0

MWDs: Number of good Machinery Work Days during the period indicated



Frequent opportunities for Autumn landwork



Little opportunity for landwork



Frequent opportunities for Spring landwork

Figure 5.7. The effects of soil on landwork in the Central Fenland.

As organic matter levels decline, and as the fibre content of peat (on mineralisation and decomposition) and its thickness in the soil profile also decline, then soils become increasingly less able to supply plants with the required moisture. To avoid yield reductions from drought, the shortfall has to be made up from irrigation. Where rooting depth is restricted by strong acidity and associated toxicity, biologically available water for crops is considerably reduced compared with physically available water.

As organic matter levels decline, the periods during late autumn and during spring when landwork can be successfully completed without causing damage to the soil structure, are shortened.

The continued decline of peat soils and organic matter levels is inevitable without fundamental changes in the farming system. Use as grassland with raised water-table levels would slow the decline slightly but not halt it. Some form of rewetting would help maintain current levels for future generations, or in some cases increase the levels.

This section confirms the continued risk of peat degradation in the Fens which questions the sustainability of existing intensive farming practices. This concern was expressed by The Royal Commission on Environmental Pollution which considered that drained peat soils should be regarded as a resource for agriculture and managed in a way that will maintain productivity for as long as possible.

6. REVERSIBLE WETTING OF AGRICULTURAL LAND

The proposed creation of wet fens could involve the reversion of high grade, agricultural land to wetland and a concomitant change of land use from intensive arable to wet grassland or other uses suited to wet conditions. In their drained state, The Fens are an important strategic resource in that they are a major source of the nation's food and agro-industry commodities. There is concern that once returned to wetland, the Fens might be irreversibly lost to agriculture and options on future use would thereby be diminished. Two specific issues arise with respect to the irreversibility of wet fen creation. One is that rewetting of fen soils could lead to the formation of pyrites in soils which could reduce their productivity if returned to agriculture. Another issue is the potential structural damage to fragile silt soils due to wetting and inundation in a wet fen environment. From an agricualtural perspective, this damage could be difficult to recover if the need arose. This section discusses each of these issues in turn.

6.1 Acid Sulphate Soil

Extreme examples of soil acidity occur in so-called acid sulphate soils. The source of the acidity is the release of sulphuric acid by the oxidation of sulphides (iron pyrites) in the soil. The sulphides formed in a reduced environment by anaerobic bacteria in association with a large organic matter content as an energy source and iron in soil material, as shown by the equation:

Desulfovibrio

desulphuricans

at neutral reaction

$Fe_2O3 + 4SO_4 + 8CH_2O + ½O_2 \rightarrow 2FeS_2 + 8HCO_3 + 4H_2O$

iron oxide in sediment	sulphate from sea water	organic matter	dissolved oxygen	iron pyrites	(alkalinity)	water

The sulphates were supplied either during an invasion of the sea (containing sulphate salts) in the past, or from any neighbouring country rock containing sulphides.

While these layers remain waterlogged and anaerobic, pH values remain around neutral (6.5 – 7.5), and these soils are termed '***potential* acid sulphate soils**'. Drainage for agriculture allows air to enter these layers. The following reaction takes place

Thiobacillus

				ferrooxidans at pH<4				
$2FeS_2$	+	$7O_2$	+	$2H_2O$	Ù	$2FeSO_4$	+	$2H_2SO_4$
iron pyrites		oxygen		water		soluble ferrous sulphate		sulphuric acid

Aided by soil bacteria, pH levels fall below 4 and produce '***actual* acid sulphate soils'**. The resulting acidity level and duration will depend on several factors:

- original sulphide content,
- rate of aeration and oxidation,
- whether the sulphide is being replenished,
- whether there is a neutralising capacity present in the deposit, usually in the form of calcium carbonate (lime),

These factors can be very variable. The acid sulphate layers become less productive and the acidity costly to alleviate, if that is at all possible.

Topsoils require frequent lime dressings, especially when ploughing brings to the surface the top of the acid subsoil. To treat the subsoil would require heavy lime dressings of 200 tonnes/ha (80 tons/acre) $CaCO_3$ for every 1% of sulphide to 1 metre (39 in) depth. Soil material commonly contains 5% sulphide, hence this form of treatment would be impractical and uneconomic in the short term. Leaching of lime from the topsoil neutralises the subsoil acidity to some extent, producing sugar-like crystals of gypsum ($CaSO_4$), but this is a very slow process. Only when the sulphide reserves are completely depleted can this source of lime begin to build up the pH level slowly. Deep placement of lime to encourage deep root growth has been investigated at the Arthur Rickwood EHF (Annual Review 1981, 1982) but responses were small and mainly negative (Annual Review 1985).

Former or '***fossil* acid sulphate soils'** occur where all of the pyrite has been exhausted within the soil profile and pH levels have been raised throughout, usually from surface applications of lime. The situation requires a stable land surface, i.e. without a peat cover, and no likelihood of deeper drainage causing aeration of buried potential acid sulphate soil material.

Reflooding of the subsoil on a permanent basis to recreate anaerobic conditions reverses the acidification process. This may be by sub-irrigation with continued agricultural use, or by large-scale reflooding. The reversal proved successful where lake acidification and associated fish kills had been short-lived, as reported by Gosling and Baker (1980) at Calthorpe Broad, in Norfolk. Water management and periodic reflooding are techniques used as a means of improving yields in rice paddy and oil palm cultivation on acid sulphate soils in the tropics (e.g.

Poon and Bloomfield 1977). However, there seem to be no reports of the fate of reflooding well developed actual acid sulphate soils in temperate parts of the world, but it is stated that the bacterial reduction of sulphates to sulphide is confined to the pH range 6.5-8.5, with pH5 about the lowest value at which anaerobic sulphate reducers are active (Bloomfield and Coulter 1973). The Wet Fens project would offer that opportunity by careful monitoring of any such rewetted sites, and, indeed, such sites with low quality agricultural soil, would be good candidates for consideration.

6.1.2. Serious effects associated with acid sulphate soils

Aluminium toxicity. At low pHs (below 4) toxic aluminium becomes increasingly soluble and available to plants. In mineral soil material (like the Fen Clay) aluminium concentration increases roughly ten-fold per unit pH decrease. It accumulates in root tissues, preventing cell division and elongation, producing a stunted, deformed root system. Soluble aluminium can also pass into drainage waters so that the quality of ditch water that might be used for irrigation can be poor at certain times of the year. The most common symptom of acidity and metal toxicity is severe susceptibility to water stress that cannot be fully compensated for by irrigation.

Crop tolerance. Acidity combined with aluminium toxicity can prevent root development, thus reducing the amount of soil water available to plants, and eventually crop yield. Agricultural crops have preferred pH ranges. Mason (1975, p. K-3) lists the tolerances to soil acidity of crops grown in organic soils*:

CROP	pH	CROP	pH
Lettuce	5.8	Onions	5.4
Beans	5.6	Celery	5.3
Barley	5.5	Wheat	5.1
Sugar beet	5.5	Parsnips	5.1
Peas	5.5	Oats	4.9
Carrots	5.4	Potatoes	4.5
Red beet	5.4	Rye	4.3

* Increase by half a pH unit for mineral soils

Nutrient uptake. Acidity affects the ease with which plants can extract nutrients from the soil. Manganese availability is increased but uptake of phosphate is inhibited by absorption by

aluminium, both within the root and in the soil. Activity of micro-organisms which convert ammonium nitrogen to available nitrate nitrogen is reduced.

Ochre Release. At low pHs the soluble ferrous sulphate (see above equation) is mobilised in the soil forming a precipitate of iron oxide (Fe_2O_3) in drainage pipes and ditches and cementing any permeable fill. Ochre production is particularly prolific for the first few years following installation of a new drainage scheme and lasts until the iron sulphide content of the soil is exhausted. Drain jetting to clear the offending clogging material may be necessary if the underdrainage system is to remain effective and not require early replacement. Sacrificial mole channels in clay subsoils may be effective as an initial measure to supplement drainage by ditches.

'Drummy' Peat. This is a term used in the Fenland for the layer up to 10-15 cm (4-6 in) thick that often occurs immediately below the plough layer. It is a hard, dry, either very fine platy (flaky) or fine blocky peat that is irreversibly dried and rewets with difficulty due to iron and aluminium coatings. It usually contains many very fine roots that show stress symptoms (short, branching with horizontal growth). Drummy peat is frequently strongly acid but pH values above 5 have been recorded as well.

Acid sulphate soils represent a small proportion of the agricultural land in England & Wales. Where they occur they can present considerable difficulties to agricultural management, in both technical and financial terms.

6.1.3. Existing acid sulphate conditions in Fenland

Acid sulphate soils are common in the Fenland study area. Inundation by brackish water during the marine transgressions caused sulphides to accumulate in the thin, marginal areas of the clayey marine alluvium, in the reedswamp peat and in the fen-carr peat beneath, and in the upper horizons of the underlying mineral soil material. In nearly all cases the affected soils have been drained and reclaimed for agriculture (i.e. they are *actual* acid sulphate soils) and are generally moderately productive with good management.

In many instances, further potentially acid layers underlie the already acidified soil profile and will also release sulphuric acid should deeper drainage be undertaken (whether by design or by necessity with loss of surface peat through wastage). This process is only halted when the peat has almost entirely disappeared and the ground surface becomes stabilised. After a long period, the sulphides contained in the soil are completely weathered and the pH can be increased, usually by lime leached from surface applications, to form *fossil* acid sulphate soils.

The National Lowland Peat Inventory (Burton and Hodgson 1987) shows that nearly a third (7,000 ha) of the remaining **peat soils** in the Fenland have a strongly acid, sulphuric horizon (Avery 1980) within 80 cm depth. These soils belong to *Mendham* or *Prickwillow series*, soil types identified in the national scheme of soil classification administered by the Soil Survey and Land Research Centre. The most acid conditions tend to occur in the latter soil type at the feather edge of the marine alluvium.

Further to this and as yet unquantified in detail, many **skirt soils** formed in both alluvium and solid and drift deposits have sulphuric subsoils. The majority occur around the edge of the Fen Clay, both landward with a thin peaty surface covering (as sulphuric phases of most skirt soil series), and seaward in alluvium with organic bands through the subsoil (e.g. *Tydd* and *Normoor series*). This distribution is mostly limited to land at or below modern sea level, to where brackish water influences were concentrated.

Land north of Witcham (TL460820), at Pymore (TL495857) and around Manea (TL474896) mapped as *Manea series* by Seale (1975) consists of acid sulphate soils developed mainly in the Ampthill Clay country rock, with a pyrite source dating from Jurassic times.

In Figure 6.1, 315 1x1 kilometre squares have been identified where actual acid sulphate soil conditions occupy at least a quarter of that square (25 ha). The northern Fenland has 35 squares and southern Fenland 280 squares. The main areas of occurrence of *actual* acid sulphate soils (with Ordnance Survey Sheet No.), as illustrated in Figure 5.1, are:

Witham Fens (TF06, 07, 16, 17)
East Fen (TF35, 45)
Bourne Fen (TF11, 12)
(TF41)
Newborough Fen (TF10, 20)
Flag Fen and King's Delph (TL29)
Farcet Fen (TL29)
Conington and Wood Walton Fens (TL18, 28)
West Moor, Chatteris and Pidley Fen (TL38)
Mepal Fen and Arthur Rickwood EHF (TL48)
Wimblington Fen and Bedlam (TL49)
Haddenham and Sutton Fens (TL47)Tydd Fen
Cam valley (TL56, 57)
Isle of Ely margins (TL58)
Shippea Hill Station area (TL68)
Methwold Fens (TL69)
Nar valley (TF61)

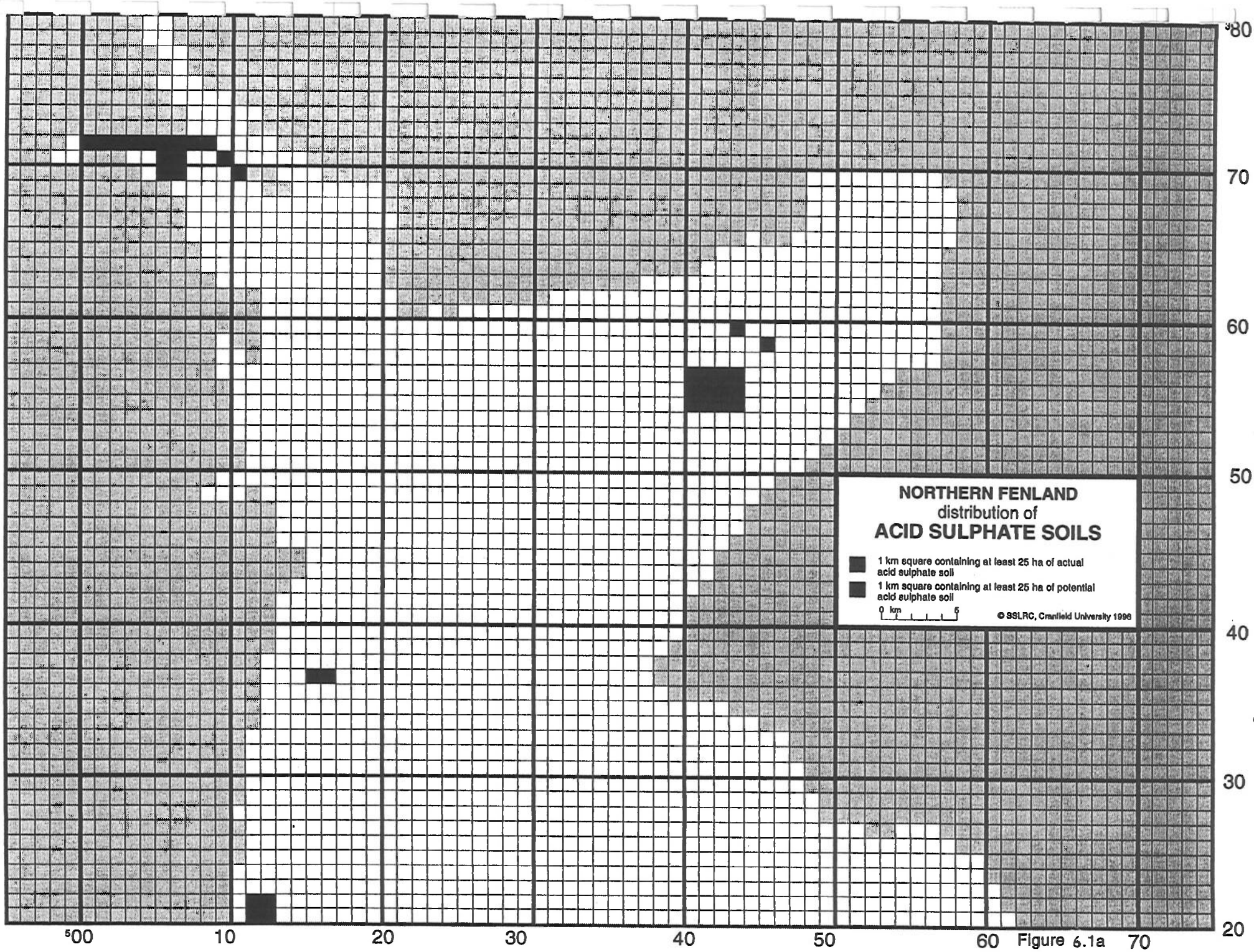

NORTHERN FENLAND
distribution of
ACID SULPHATE SOILS
1 km square containing at least 25 ha of actual acid sulphate soil
1 km square containing at least 25 ha of potential acid sulphate soil
0 km 5
© SSLRC, Cranfield University 1996
80
70
60
50
40
30
20
00
10
20
30
40
50
60
70

Figure 6.1a


SOUTHERN FENLAND
distribution of
ACID SULPHATE SOILS
1 km square containing at least 25 ha of actual acid sulphate soil
1 km square containing at least 25 ha of potential acid sulphate soil
0 km
5
© SSLRC, Cranfield University 1996
320
10
00
90
80
70
260
500
10
20
30
40
50
60
70
80

Figure 4.1b

Most areas conform to the pattern of intense acid sulphate soil development around the margins of the Fen Clay deposit, or where thin intercalations of marine clayey alluvium and peat occur. However, there are exceptions in that peat can be affected some distance beyond the former marine limit, as in Conington and Wood Walton Fens. The chemical conditions there are similar and the source may be by sufficient brackish water seepage without deposition of any Fen Clay, but there is also the possibility that the pyrite source was derived from the country rock.

The narrow strip of Fenland in the west between Bourne and Billinghay (TF12, 13, 14, 15) has small pockets of acid sulphate soils in low places, where alluvial clays have buried thin layers of peat at shallow depth.

In other instances, acid sulphate peats occur directly beneath the thin spreads of non-calcareous riverine alluvium associated with the rivers entering the Fenland along its western and southern edges, without evidence of brackish water influence from a marine source. Examples include the Welland alluvium west of Crowland (TF20, 21), that of the Nene at Flag Fen (TF20, TL29), Kings Delph and Milby, south of Whittlesey (TL29), and of the Gt Ouse east of Earith (TL37, 47). The alluvium represents a period with suspension of clay-size particles in the river waters spreading over the fens instead of the relatively sediment-free freshwater forming peat. Further research would be needed to establish the reasons for acid sulphate soil formation in these locations.

The Ouse Washes have been flooded annually since their construction 350 years ago. The peat within the middle section of the flood-relief reservoir has been conserved to some extent by a cover of riverine alluvium from 25 to 40 cm thick and calcareous in places. However, unlike the older deposits of the Welland, Nene and Ouse, from a systematic survey of the buried deposits (Burton and Hodgson 1987), no actual or potential acid sulphate soils are known to have developed beneath this alluvial layer. The only acid sulphate soils within the Ouse Washes occur in association with the usual marginal marine conditions around National Grid Ref TL525925 (mapped as Prickwillow series in Seale 1975).

The main areas of occurrence of *potential* acid sulphate soils, where acidity will develop in the future with continued agriculture and peat wastage, as illustrated in Figure 6.1 by kilometre square, are:

- Methwold Severals (TL69, 79 with 15 kilometre squares), where because of late reclamation during World War II the sedge peat is still around a metre thick overlying potentially acid layers which will eventually emerge.

6.2. Soil Structure and Stability

There are two distinct types of mineral soil in the fenland area: silty soils and clay soils. They behave very differently with changes in water regime and surface management. The critical physical factor influencing soil quality for agriculture is structure. It is therefore necessary to look at the possible structural changes to assess the likely long-term influence on soil quality if the re-created wetlands were returned to agriculture.

There are differences in structure between the topsoils and subsoils of the Fens. Topsoil structure is currently influenced by farming operations whereas subsoil structure is influenced by drainage. The structure of some of these soils is formed by the presence of macropores. These are stabilised vertical root channels of 1 - 3 mm diameter formed hundreds of years ago (Spoor and Fry, 1983a). Loss of these channels would be very serious to the permeability of the soil. In order to be able to judge whether macropore loss is likely on conversion from agriculture to wetland it is necessary to know what soil types occur in the fenlands.

6.2.1. Representative soil profiles and properties of Fen soils

The main soil types in the fen region are as follows (from Hodge *et al*, 1984; Reeve and Thomasson, 1981)

i) Wisbech Series Silt loam

Profile (depths in metres)

0
topsoil
0.3
platy structure
12% clay
many roots
0.6
platy loamy fine sand
5% clay
few roots
1.2

Properties

Few macropores
5 - 7% $CaCO_3$
0.2 - 0.4% organic matter

If this soil were to become compacted so that structural pores were lost, it could be loosened mechanically. Any loss in macropores could not be recovered in this way but since

the soil contains very few macropores the loss of these would not have a large effect on the permeability of the soil.

ii) Agney Series *silty clay loam*

Profile (depths in metres)
0
topsoil
0.3
coarse angular blocky structure
macropores
30% clay
0.5
medium prismatic
macropores
30% clay
1.0

Properties
Many macropores
4 - 7% $CaCO_3$
1% organic matter
The main factor influencing the hydraulic conductivity of this soil is the distribution of macropores (Spoor and Fry, 1983b). If the macropores were lost they could not be re-created by mechanical means.

iii) Romney Series Silt loam

Profile (depths in metres)
0
topsoil
0.3
fine subangular blocky structure
macropores
15% clay
0.45
fine angular blocky
macropores
15% clay
1.5

Properties
Many macropores
10 - 12% $CaCO_3$
1% organic matter

The main factor influencing the hydraulic conductivity of this soil is the distribution of macropores (Spoor and Fry, 1983b). If the macropores were lost they could not be re-created by mechanical means.

v) Wallasea Series silt clay

Profile (depths in metres)
0
topsoil
0.3
medium angular blocky structure
many roots
50% clay
0.5
coarse prismatic
many roots
50% clay
1.1

Properties
0% $CaCO_3$
1% organic matter
Soil very prone to swelling and shrinking with changes in water content.

6.2.3. Soil Structure

Topsoils

The topsoils are likely to vary depending on the farming system and management. The calcareous nature of the Wisbech, Agney and Romney soils is an aid to their structural recovery if damaged. However, Wallasea is non-calcareous and therefore more susceptible to structural breakdown during cultivations or due to compaction associated with heavy machinery.

Wisbech soils

These have a platy structure with few macropores. The permeability in the layer between 0.3 and 0.5 m depth is influenced by the macropores but these have less influence at depths below this where permeability is controlled more by the platy structure. Compaction in this soil can be remedied by mechanical loosening.

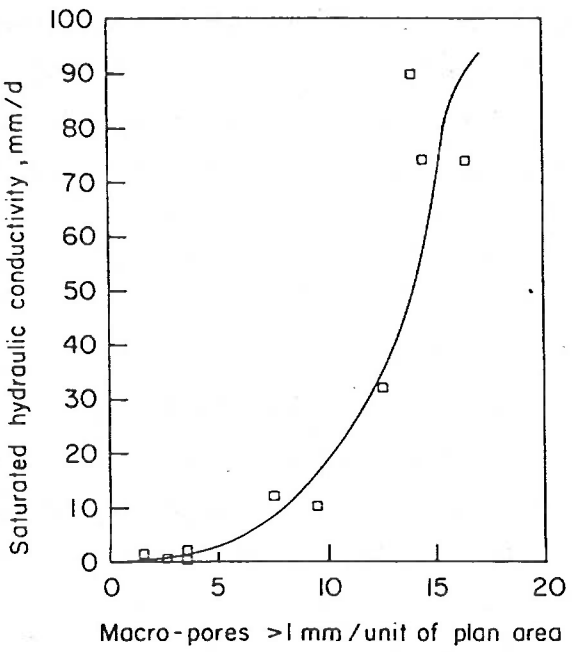
Agney and Romney soils

Hydraulic conductivity depends on the density of macropores(see Figure 6.1). The loss of macropores in these soils is very serious since they cannot be reformed mechanically. Their

low clay content means that very little swelling and shrinking occurs on drainage hence improvement to their inherent blocky prismatic structure to increase permeability would be very slow. It is therefore important not to loose the macropores form these soils.

Macropores have been stabilised over the centuries by organic compounds, iron and other concretions and the generally high calcium status of the soil. They are physically very stable and cannot be easily destroyed by vertical loads. They can only be damaged by mechanical loads causing shear and sliding at depth such as ploughing. Observations at the interface between the completely saturated and the fluctuating water table zone shows no significant difference in macropores suggesting a period of aeration followed by flooding had no significant effect on their stability.

Figure 6.1: Variation in hydraulic conductivity with number of macropores per unit of plan area (sample area 0.004 m^2)



Taken from Spoor and Fry (1983b)

Wallasea

These have a blocky prismatic structure and reasonably high permeability when well drained. Deep rooting occurs allowing numerous wetting and drying cycles. Continuous waterlogging

induces significant soil swelling, particularly in the absence of calcium, reducing the size of structural pores and hence permeability.

6.2.4. Potential changes to soil structure when converting from agricultural land to wetland

The conversion of land from agriculture to wetland leads to a number of changes in the soil which affect soil structure. These are as follows:

- Higher water table or continuous waterlogging causes reduced aeration
- Downward water movement is reduced or eliminated
- Minimal or zero soil disturbance
- Reduced soil loadings limited largely to grazing animals
- Build-up of root mat

In the case of topsoils the main impact of a high water table will be to increase the risk of soil surface damage by grazing animals. Where soils are loaded at high moisture contents the structure is more vulnerable to damage. Poor grazing management and water table control could cause poaching leading to significant structural deterioration to the top 0.15 m. Damage could be reduced by good management. Any damage in the topsoil will be reversible when returned to arable agriculture and is unlikely to be any worse than damage caused when harvesting sugar beet and potatoes under wet conditions. Tillage operations and cropping will rectify any damage caused by grazing.

Initial flooding of silt topsoils may give rise to slurrying. This will be reduced over time by the proliferation of roots giving more structure to the topsoil. The risk of clay dispersion is much higher on clay soils than on silts. This increases the chances of the drains becoming blocked. If no grazing occurs on the newly created wetlands then no mechanical damage will result. Root development should maintain or improve the structure of the soil and the organic content of the wetland soils will gradually increase over time due to the cessation of tillage.

In the case of silt subsoils the platy structure will be unaffected by surface loads and therefore will not change following the change of land use. Macropores will not be damaged by surface loadings and remain stable under waterlogged conditions. The risk of blockage by chemical leaching is much reduced compared with the situation under agricultural management since downward water flow is markedly reduced or eliminated. Existing pipe systems would most probably block under wetland conditions unless they are used for sub-irrigation, particularly in soils such as Wisbech. It is likely that new pipe installation would be necessary if the land is

returned to arable agriculture, although some of the original pipes may be regenerated by flushing.

In the case of clay subsoils, the prismatic structure will be affected by continuous waterlogging. The clay will swell, effectively closing off the majority of structural pores, resulting in a loss of permeability. On returning to agriculture it may be necessary to install a new drainage system due to the blockage of existing pipes. This new system supplemented by mole drainage would enable dewatering to commence, leading to soil shrinkage and the reopening of structural pores. The soil is likely to swell when waterlogged thus closing all the structural pores. However, planes of weakness at the interface between original structural units would remain and these would be the areas where the first cracking occurs on shrinkage. It is estimated that it could take 5 to 7 years to return subsoils into a good working state for agriculture, depending on weather conditions. Dry conditions would speed up the process.

6.2.5. Summary and Conclusions

This section has reviewed the research evidence relating to possible soil management problems in the event of returning wet fen land back into arable farming should the need arise. The conclusion is that whilst amelioration actions might be required to address possible build up of acid sulphates or structural change under wetland conditions, the wet fen creation is not irreversible. In this respect, options to use the fens for agriculture remain open. This is important from the viewpoint of strategic resource management.

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APPENDIX I

SCADE (Silsoe College Agricultural Drainage Evaluation Model)

The overall approach to assessing the effects of changes in land drainage on agricultural performance involves a comparison of the value-added by agriculture under different drainage conditions. The extra net benefit (value-added) due to changes in drainage condition and the consequent impacts on enterprises may be used to determine the MII and net margin associated with different enterprises and farming systems.

The Silsoe College Drainage Evaluation Model (SCADE) incorporates this approach and assesses the agricultural benefits associated with a given standard of, or change in, land drainage condition (Hess and Morris, 1985). Data describing farming practice and drainage conditions are combined in the model with a database containing relevant agricultural economic and management data. The model was adapted to simulate changes in drainage status, productivity and agricultural enterprises as a result of altering the water level regime.

The impact of waterlogging on grassland is assessed in the model through energy from grass and stocking rates. Stocking rates are converted into gross margins and fixed costs per hectare, with adjustment for the value of extra grazing days and forage production costs. Reduced energy from grass due to a deterioration in drainage status may be used to decrease stocking rates, or result in the transferral of cropped areas to pasture.

Estimates of net agricultural benefits are sensitive to assumptions regarding the need for additional farm expenditure on regular labour, power and machinery, buildings, storage and drying. These fixed costs are often equivalent to 70 - 80 % of total farm gross margins. The SCADE model distinguishes between the need for extra recurrent expenditure on these items (e.g. machinery running costs) and extra capital expenditure (e.g. depreciation of machinery). Any net increase in fixed costs 'before' and 'after' a change in drainage condition is identified.

The model may be run with financial and economic prices for agricultural commodities. These take into account 1996 farm gate prices, current levels of subsidy, agricultural legislation and requirements of set-aside. Financial values show the return to the farmers. Economic values show the return to the nation after removing government price support.

APPENDIX II

This Appendix contains the financial and economic analysis of alternative farming systems. The estimates are based on a range of data sources which include the published results of the Regional Farm Business Surveys, especially Farming in the Eastern Counties (Murphy 1996), and farm management source books such as Nix (1996) and ABC (1996).

The analysis works through a number scenarios which represent farming systems/policy combinations. These include:

Scenario	Farming System	Policy
1	Arable - cereals, root crops, set aside	Current Situation
2	Arable - cereals, root crops, set aside	Free Market
3	Intensive grass - beef cows and sucklers, overwintered/finished beef, sheep and fat lambs	Cross-compliance
4	Extensive grass - beef cows and sucklers, sheep and fat lambs	Management Agreement Tier 1
5	Very extensive grass - beef cows and sucklers, medium store cattle	Management Agreement Tier 2

The analysis of the scenarios follows a common format. Two farm perspectives are taken.

- A whole farm budget is compiled for each of the scenarios showing the average annual income and expenditure and net return per ha (defined as management and investment income (MII) in accordance with farm management accounting convention). The whole farm budget shows the average net returns per ha which would be gained or lost in the event of a switch into or out of the farming system concerned respectively. Variable costs are based on standard estimates which reflect yield performance, checked against regional statistics for consistency. Fixed costs are based on regional farm management survey sources. In the case of arable farms, fixed costs are based on data for fen farms, whereas for livestock, fixed cost data are drawn from livestock rearing and fattening farms in various parts of the country.

- A partial budget is compiled for each of the scenarios showing the extra income and expenditure and net margin per ha associated with substitution of farming activities at the margin, without changing the predominant farming system. There are some changes in labour requirements and operating costs of machinery but the majority of fixed costs on the farm remain unchanged.

Two price perspectives are taken for farm outputs:

- Financial prices are used to reflect the prices paid and received by farmers, including relevant taxes and subsidies, such as area payments and livestock premia. !996 prices are used throughout. The financial analysis uses estimates of short term (year 2000) prices. These are lower than recent prices which are considered high relative to the long term trend of declining real prices for farm output. For example wheat prices averaged £115 to £120/t in1995/6, whereas the short term prediction (2 to 3 years) is about £105/t. The medium term prediction, given the commitment to move prices to world market levels, is about £90/t. The latter is used in the economic analysis (see below). The market in livestock products has recently been upset by the impact of BSE. The financial analysis adopts pre BSE prices (based on 1994 to 1995).

- Economic prices are used to reflect the value of agricultural inputs and outputs to the national economy once the costs of support have been taken out. The value of internationally traded commodities, for example should reflect international , ie world market, prices. For this reason, the economic price of wheat at £90/t reflects a medium term (5 years) international price prediction. Futher adjustments to take out Government subsidies follow the methods advised by MAFF (1993) for the appraisal of flood defence projects. These methods are open to some debate. They tend to reflect the net costs to the Exchequer after reimbursement of some the costs of support, such as set aside payments, from the EU, rather than the economic resource costs involved in supporting the sector. The methods, whilst still in place, are reportedly under review by MAFF.

Budgeting Routine

For the purpose of analysis, data from the sources referred to above, were used to compile standard crop and livestock budgets which reflect local circumstances which were fed into a spreadsheet routine. This follows methods incorporated in SCADE (Silsoe College Agricultural Land Drainage Evaluation Model) which, as the name suggests, was designed to appraise the impact of changes in farming system associated with changes in land drainage. The model is particularly useful for determining the productivity of grassland systems under wet fen regimes. Box II.1 contains a glossary of the terms used in the analysis

Box II.1 Glossary of terms

Gross output is the revenue from sales and subsidies plus the value of produce kept on the farm for future or that which remains unsold (yield * price). In the case of livestock enterprises, the cost of purchased or retained livestock must be taken into account and provision made for breeding livestock replacements. Gross output also includes the value of area payments and livestock premia such as those for suckler beef cows.

Variable costs are those which usually change proportionally according to the size of the enterprise. For arable production, variable costs include the cost of seed, fertilisers, sprays, contract work or casual labour and transport. With livestock enterprises, the primary variable costs are concentrate feeds (including home-grown), forage costs (seeds, fertilisers, sprays, casual labour and contractors' charges) and miscellaneous items such as veterinary expenses.

The *Gross Margin* of an enterprise is this gross output less the variable costs. Gross margins are usually expressed per unit of limiting resource such as £per ha of land. Gross margin is not a profit but a contribution to fixed costs and profitability.

Fixed Costs may be defined as those costs which are incurred for the farm as a whole and are not normally affected by minor changes in the size of an enterprise. According to UK farm accounting convention, regular labour, machinery, power, buildings, rent and general expenses are examples of fixed costs. In practice of course, substitution of enterprises can affect the size and composition of fixed costs at farm level. As fixed costs vary by size and type of farm, caution is needed in using an average of fixed costs. Fixed Costs may include charges to reflect resource costs such as rent for owned land and wages for unpaid family labour, even though these may not be actually paid out.

In some cases it is useful to identify *Semi Fixed Costs* which are items of recurrent expenditure per unit of activity (such as machinery operating and repair expenses, building maintenance and crop drying/storage costs) associated with the use of existing fixed resources. The term *Net Margin* is used to denote the difference between gross margin and semi-fixed costs, as for example when a small area of land changes from arable to grazing without affecting the major cost structure of the farm.

Management and Investment Income (MII) is the value of Gross Output less total fixed and variable costs. This is an estimatate of profitability before interest charges and shows the return to ing for any interest the balance available to meet interest charges and for investment and to reward the management of the farm.

Scenario 1

Table II.1 contains the whole farm budgets for Scenarios 1a, 1b and 1c using financial prices. Scenario 1a represent a typical average farm of 130 ha (Type 7, Murphy 1996) based on a survey of 46 farms in the fens. Following discussions with the Farm Business Survey of the Department of Land Economy at Cambridge University, two other typical farm models have been compiled. Scenario 1b represents the relatively small, less intensive farms occupying relatively poor soils. Scenario 1c represents the relatively large, intensive, high performance farms with a relatively large proportion of their area in roots and field vegetables. Estimated MII for the farms are £ 175, £ 55 and £ 240 per ha respectively in 1996 prices.

Table II.2 applies the MAFF economic adjustment methodology. This involves reducing the gross output (the value of yield plus area payments) by 10 % for cereals, grain legumes and oil seeds. Quota crops such as potatoes and sugar beet and high value field vegetables are treated as equivalent to wheat on the grounds that their production would switch elsewhere (and displace wheat) in the event of a move to wet fen. Set aside, because it is a transitional arrangement, is also regarded as wheat. Estimated MII for the farms are £ 76, £ 0 and £ 116 per ha respectively in 1996 prices. The economic value-added is less than that accruing to farmers.

Tables II.3 and II.4 adopt the perspective of the partial budget. Table II.3 examines the marginal impact on farm income of a hectare increase or decrease in the given farming system. The net margins are £ 726, £ 610 and £ 1060 for Scenarios 1a, 1b and 1c respectively. Table II.4 expresses these marginal changes in economic prices. Net margins are £ 452, £ 388 and £ 489 respectively. These marginal returns are much higher than the average MII derived above. Income loss from switching out of arable is considerable if their are no concomitant savings in fixed costs.

Scenario 2

Scenario 2 estimates the value added of existing farming systems in the absence of Government support and the operation of free market conditions where prices approximate to world market prices (inclusive of transaction costs).

Table II.5 reflects the impact on farm incomes. There are substantial reductions relative to the current case (Scenario 1). MII is -£ 107, -£ 222 and £ 13 for Scenarios 2a, 2b and 2c respectively. These estimated returns are unlikely to prevail in practice. In the face of

declining prices, farmers are likely to adjust their cropping patterns and to reduce inputs in an attempt to reduce costs. These indicate the dependency of current farming systems on Government support.

Table II.6 shows the marginal value added for Scenario 2, assuming financial prices based on zero support and free market conditions. Net margins are £ 431, £. 322 and £ 820 for Scenarios 2a, 2b and 2c respectively.

The estimates of economic value for Scenario 2 are taken to be the same as those for Scenario 1, in that the same cropping pattern and Government guidelines apply.

Scenarios 3, 4 and 5

These involve the rearing and fattening of livestock. The scenarios differ in terms of degree of wetness which in turn affects the productivity, carrying capacity and hence profitability of the farming systems. The method estimates energy from grass associated with drainage condition, nitrogen use, grass cutting/grazing regime. Standard budgets (£/head) are compiled for relevant livestock systems, together with estimates of energy from grass per head of stock. Stocking rates (head/ha) are derived according to energy supply (MJ/ha) and requirements (MJ/head). Returns (£/ha) reflect stocking rates. Allowance is made for variation in the length of the grazing season.

Whilst increased wetness reduces farming profits, it is assumed to increase the delivery of wet fen environmental benefits.

Table II.7 contains the whole farm budget in financial prices for Scenarios 3, 4 and 5.

Scenario 3 represents a moderately intensive livestock system on reasonably well drained land involving suckler beef, grass finished store cattle and lowland fat lamb production. The system is based on the practices associated with Tier 1 of ESA management agreements. In this respect, the Scenario involves 'cross-compliance'. Overall stocking rates are about 2 livestock units per ha. Headage payments are assumed to apply (see Section 2.3.1). Financial MII is £ 64/ha.

Scenario 4 represents a low input grassland system producing sucker calves and lambs. The system is indicative of Tier 2 arrangements. Overall stocking is about 1 livestock unit per ha and therefore additional extensification premia apply. Financial MII is -£ 155/ha.

Scenario 5 is an extensive wet fen system. Beef cows and store cattle are summer grazed. It is too wet for sheep. Stocking rates are less than 1 livestock unit per ha. Financial MII is -£ 218/ha.

Table II.7 also gives the economic value added from Scenarios 3, 4 and 5. This follows MAFF guidelines on the reductions of beef and sheep gross output to reflect headage payments. Economic value added is -£ 213/ha, -£ 271/ha and -£ 280/ha respectively.

The analysis suggests that Scenario 3 is in itself financially viable, but not economically attractive given the degree of support involved. Scenarios 4 and 5 are not financially viable unless incentives are paid to farmers. They are result in negative economic returns.

Table II.8 examines the partial budget aspects of Scenarios 3, 4 and 5 after charging for the marginal costs of livestock production. These represent the extra benefits and costs of adding or reducing the grassland area on the farm without affecting the majority of fixed costs. The financial returns from grassland are £ 372/ha, £ 58/ha and £ 45/ha for the three Scenarios respectively. Thus small changes at the margin are financially viable. In economic terms, however, value added is negative at -£ 184/ha, -£ 172/ha and -£ 78/ha respectively.

The difference in financial returns shows the order of incentives that may be necessary to get farmers to participate in an arable reversion scheme. For example, a whole farm switch from arable Scenario 1a to relatively intensive grass Scenario 3 involves an income loss of £ 112/ha, and a switch to extensive grass Scenario 5 a loss of £ 394/ha.

The income losses associated with switching small parts of the farm are greater if there are not concomitant savings in fixed costs for the farm as a whole. In practice, however, these income losses are likely to overestimate the cost of transferring small, fragmented or less productive parts of the farm from arable to grassland.

Summary of Scenarios

Table II.9 summarises the financial and economic analysis and compares possible future wet fen land uses (Scenarios 3,4,5) with the dominant existing land use (Scenario 1a). The analysis assumes that farm systems are perfectly substitutable.

Table II.1 **Whole farm budgets**
Financial prices

		Scenario 1a						Scenario 1b				Scenario 1c						
Farm Size	ha	130						63.8				524						
Drainage Condition	class	Good						Good				Good						
Crop		Winter wheat	Oil seed rape	Potatoes	Sugar beet	Field beans	Set-aside	Winter wheat	Combine peas	Sugar beet	Set-aside	Winter wheat	Combine peas	Sugar beet	Set-aside	Spring wheat	Potatoes	Field veg
Yield	t/ha	7.90	2.60	42.00	40.00	3.10	0.00	6.00	4.20	36.00	0.00	8.30	4.90	45.00	0.00	5.30	47.00	40.00
Price	£/t	105.00	175.00	91.00	40.00	115.00	0.00	105.00	140.00	40.00	0.00	105.00	140.00	40.00	0.00	115.00	91.00	120.00
Gross Output	£/ha	829.50	455.00	3822.00	1600.00	356.50	0.00	630.00	588.00	1440.00	0.00	871.50	686.00	1800.00	0.00	609.50	4277.00	4800.00
Area Payment	£/ha	269.00	476.00	0.00	0.00	390.00	341.00	269.00	390.00	0.00	341.00	269.00	390.00	0.00	341.00	269.00	0.00	0.00
Gross Output incl. Area Payment		1098.50	931.00	3822.00	1600.00	746.50	341.00	899.00	978.00	1440.00	341.00	1140.50	1076.00	1800.00	341.00	878.50	4277.00	4800.00
Variable Cost	£/ha	275.28	243.40	1743.12	555.75	127.60	10.00	230.25	245.00	517.25	10.00	284.78	255.00	603.65	10.00	141.90	1916.42	900.00
Gross Margin	£/ha	823.22	687.60	2078.88	1044.25	618.90	331.00	668.75	733.00	922.75	331.00	855.74	821.00	1196.35	331.00	736.60	2360.58	3900.00
Total Fixed Costs																		
labour	£/ha	169						189				334						
machinery	£/ha	299						260				405						
rent and rates	£/ha	137						148				172						
other	£/ha	112						92				131						
Total Fixed Costs	£/ha	717						689				1042						
Area under crop	ha	63.70	10.40	10.40	23.40	10.40	11.70	24.09	12.60	22.17	4.94	190.00	52.00	117.00	47.00	15.00	66.00	37.00
Total Gross Margin /crop	£	52439.11	7151.04	21620.35	24435.45	6436.56	3872.70	16110.19	9235.80	20457.37	1635.14	162590.60	42692.00	139972.95	15557.00	11049.00	155798.28	144300.00
Total Gross Output	£/ha	1297						1059				1856						
Total Gross Margin	£/ha	892						744				1282						
Total Fixed Costs	£/ha	717						689				1042						
Management & Investment Income	£/ha	176						55				240						

Data sources: Yield (Murphy, 1996), Price and Variable Costs (SCADE), Fixed Costs (1a, Murphy, 1996, 1b and 1c, FBS)

Table II.2 **Whole farm budgets**

Economic prices

		Scenario 1a						Scenario 1b				Scenario 1c						
Farm Size	ha	130						63.8				524						
Drainage Condition	class	Good						Good				Good						
Crop		Winter wheat	Oil seed rape	Potatoes (wheat)	Sug Beet (wheat)	Field beans	Set-aside (wheat)	Winter wheat	Combine peas	Sug Beet (wheat)	Set-aside (wheat)	Winter wheat	Combine peas	Sug Beet (wheat)	Set-aside (wheat)	Spring wheat	Potatoes (wheat)	Field Veg (wheat)
Yield	t/ha	7.90	2.60	7.90	7.90	3.10	7.90	6.00	4.20	6.00	6.00	8.30	4.90	8.30	8.30	5.30	8.30	8.30
Price	£/t	90.00	150.00	90.00	90.00	88.00	90.00	90.00	125.00	90.00	90.00	90.00	125.00	90.00	90.00	100.00	90.00	90.00
Gross Output	£/ha	711.00	390.00	711.00	711.00	272.80	711.00	540.00	525.00	540.00	540.00	747.00	612.50	747.00	747.00	530.00	747.00	747.00
Area Payment	£/ha	269.00	476.00	269.00	269.00	390.00	269.00	269.00	390.00	269.00	269.00	269.00	390.00	269.00	269.00	269.00	269.00	269.00
Gross Output incl. Area Payment (adjusted)		882.00	779.40	882.00	882.00	596.52	882.00	728.10	823.50	728.10	728.10	914.40	902.25	914.40	914.40	719.10	914.40	914.40
Variable Cost	£/ha	275.28	243.40	275.28	275.28	127.60	275.28	230.25	245.00	230.25	230.25	284.76	255.00	284.76	284.76	141.90	284.76	284.76
Gross Margin	£/ha	606.72	536.00	606.72	606.72	468.92	606.72	497.85	578.50	497.85	497.85	629.64	647.25	629.64	629.64	577.20	629.64	629.64
Total Fixed Costs																		
labour	£/ha	100						100				100						
machinery	£/ha	216						216				216						
rent & rates	£/ha	121						121				121						
other	£/ha	77						77				77						
Total Fixed Costs	£/ha	514						514				514						
Area under crop	ha	63.70	10.40	10.40	23.40	10.40	11.70	24.09	12.60	22.17	4.94	190.00	52.00	117.00	47.00	15.00	66.00	37.00
Total Gross Margin /crop	£	38648.06	5574.40	6309.89	14197.25	4876.77	7098.62	11993.21	7289.10	11037.33	2459.38	119631.60	33657.00	73667.88	29593.08	8657.94	41556.24	23296.68
Total Gross Output	£/ha	851						747				908						
Total Gross Margin	£/ha	590						514				630						
Total Fixed Costs	£/ha	514						514				514						
Management & Investment Income	£/ha	76						0				116						

NB: Gross Output of cereals, oil seeds and peas/beans reduced by 10 %, enterprises subject to quota and set aside are treated as winter wheat equivalent

Data sources: Yield (Murphy, 1996), Price and Variable Costs (SCADE), Fixed Costs (1a, Murphy, 1996, 1b and 1c, FBS)

Table II.3 **Partial budgets**
Financial prices

		Scenario 1a						Scenario 1b				Scenario 1c						
Farm Size	ha	130						63.8				524						
Drainage Condition	class	Good						Good				Good						
Crop		Winter wheat	Oil seed rape	Potatoes	Sugar beet	Field beans	Set-aside	Winter wheat	Combine peas	Sugar beet	Set-aside	Winter wheat	Combine peas	Sugar beet	Set-aside	Spring wheat	Potatoes	Field veg
Yield	t/ha	7.90	2.60	42.00	40.00	3.10	0.00	6.00	4.20	36.00	0.00	8.30	4.90	45.00	0.00	5.30	47.00	40.00
Price	£/t	105.00	175.00	91.00	40.00	115.00	0.00	105.00	140.00	40.00	0.00	105.00	140.00	40.00	0.00	115.00	91.00	120.00
Gross Output	£/ha	829.50	455.00	3822.00	1600.00	356.50	0.00	630.00	588.00	1440.00	0.00	871.50	686.00	1800.00	0.00	609.50	4277.00	4800.00
Area Payment	£/ha	269.00	476.00	0.00	0.00	390.00	341.00	269.00	390.00	0.00	341.00	269.00	390.00	0.00	341.00	269.00	0.00	0.00
Gross Output incl. Area Payment		1098.50	931.00	3822.00	1600.00	746.50	341.00	899.00	978.00	1440.00	341.00	1140.50	1076.00	1800.00	341.00	878.50	4277.00	4800.00
Variable Cost	£/ha	275.28	243.40	1743.12	555.75	127.60	10.00	230.25	245.00	517.25	10.00	284.76	255.00	603.65	10.00	141.90	1916.42	900.00
Gross Margin	£/ha	823.22	687.60	2078.88	1044.25	618.90	331.00	668.75	733.00	922.75	331.00	855.74	821.00	1196.35	331.00	736.60	2360.58	3900.00
Semi Fixed Costs																		
labour	£/ha	45.69	31.71	132.83	83.02	29.44	0.00	45.69	30.94	83.02	0.00	45.69	30.94	83.02	0.00	33.82	132.83	160.00
machinery	£/ha	58.51	40.73	218.27	108.35	41.63	0.00	58.51	37.58	108.35	0.00	58.51	37.54	108.35	0.00	42.41	218.27	216.00
buildings (dry & store)	£/t	5.35	7.50	5.00	0.00	6.76	0.00	5.35	3.00	0.00	0.00	5.35	3.00	0.00	0.00	5.35	5.00	5.00
Total Semi Fixed Costs	£/ha	146.47	91.94	561.10	191.37	92.03	0.00	136.30	81.12	191.37	0.00	148.61	83.18	191.37	0.00	104.59	586.10	576.00
Net Margin/crop	£/ha	676.76	595.66	1517.78	852.88	526.87	331.00	532.45	651.88	731.38	331.00	707.14	737.82	1004.98	331.00	632.02	1774.48	3324.00
Area under crop	ha	63.70	10.40	10.40	23.40	10.40	11.70	24.09	12.60	22.17	4.94	190.00	52.00	117.00	47.00	15.00	66.00	37.00
Total Gross Margin /crop	£	52439	7151	21620	24435	6437	3873	16110	9236	20457	1635	162591	42692	139973	15557	11049	155798	144300
Total Semi Fixed Costs/crop	£	9330	956	5835	4478	957	0	3283	1022	4243	0	28235	4325	22390	0	1569	38683	21312
Total Farm Net Margin /crop	£	43109	6195	15785	19957	5479	3873	12827	8214	16215	1635	134356	38367	117583	15557	9480	117116	122988
Total Gross Output	£/ha	1297						1059				1856						
Total Gross Margin	£/ha	892						744				1282						
Total Semi Fixed Costs	£/ha	166						134				222						
Net Margin	£/ha	726						610				1060						

Data sources: Yield (Murphy, 1996), Price, Variable Costs and Semi Fixed Costs (SCADE)

Table II.4 **Partial budgets**

Economic prices

		Scenario 1a						Scenario 1b				Scenario 1c						
Farm Size	ha	130						63.8				524						
Drainage Condition	class	Good						Good				Good						
Crop		Winter wheat	Oil seed rape	Potatoes (wheat)	Sug Beet (wheat)	Field beans	Set-aside (wheat)	Winter wheat	Combine peas	Sug Beet (wheat)	Set-aside (wheat)	Winter wheat	Combine peas	Sug Beet (wheat)	Set-aside (wheat)	Spring wheat	Potatoes (wheat)	Field Veg (wheat)
Yield	t/ha	7.90	2.60	7.90	7.90	3.10	7.90	6.00	4.20	6.00	6.00	8.30	4.90	8.30	8.30	5.30	8.30	8.30
Price	£/t	90.00	150.00	90.00	90.00	88.00	90.00	90.00	125.00	90.00	90.00	90.00	125.00	90.00	90.00	100.00	90.00	90.00
Gross Output	£/ha	711.00	390.00	711.00	711.00	272.80	711.00	540.00	525.00	540.00	540.00	747.00	612.50	747.00	747.00	530.00	747.00	747.00
Area Payment	£/ha	269.00	476.00	269.00	269.00	390.00	269.00	269.00	390.00	269.00	269.00	269.00	390.00	269.00	269.00	269.00	269.00	269.00
Gross Output incl. Area Payment		882.00	779.40	882.00	882.00	596.52	882.00	728.10	823.50	728.10	728.10	914.40	902.25	914.40	914.40	719.10	914.40	914.40
Variable Cost	£/ha	275.28	243.40	275.28	275.28	127.60	275.28	230.25	245.00	230.25	230.25	284.76	255.00	284.76	284.76	141.90	284.76	284.76
Gross Margin	£/ha	606.72	536.00	606.72	606.72	468.92	606.72	497.85	578.50	497.85	497.85	629.64	647.25	629.64	629.64	577.20	629.64	629.64
Semi Fixed Costs																		
labour	£/ha	45.69	31.71	45.69	45.69	29.44	45.69	45.69	30.94	45.69	45.69	45.69	30.94	45.69	45.69	33.82	45.69	45.69
machinery	£/ha	58.51	40.73	58.51	58.51	41.63	58.51	58.51	37.58	58.51	58.51	58.51	37.58	58.51	58.51	42.41	58.51	58.51
buildings (dry & store)	£/t	5.35	7.50	5.35	5.35	6.76	5.35	5.35	3.00	5.35	5.35	5.35	3.00	5.35	5.35	5.35	5.35	5.35
Total Semi Fixed Costs	£/ha	146.47	91.94	146.47	146.47	92.03	146.47	136.30	81.12	136.30	136.30	148.61	83.18	148.61	148.61	104.59	148.61	148.61
Net Margin/crop	£/ha	460.26	444.06	460.26	460.26	376.89	460.26	361.55	497.38	361.55	361.55	481.04	564.07	481.04	481.04	472.62	481.04	481.04
Area under crop	ha	63.70	10.40	10.40	23.40	10.40	11.70	24.09	12.60	22.17	4.94	190.00	52.00	117.00	47.00	15.00	66.00	37.00
Total Gross Margin /crop	£	38648	5574	6310	14197	4877	7099	11993	7289	11037	2459	119632	33657	73668	29593	8658	41556	23297
Total Semi Fixed Costs/crop	£	9330	956	1523	3427	957	1714	3283	1022	3022	673	28235	4325	17387	6984	1569	9808	5498
Total Farm Net Margin /crop	£	29318	4618	4787	10770	3920	5385	8710	6267	8016	1786	91397	29332	56281	22609	7089	31748	17798
Total Gross Output	£/ha	851						747				908						
Total Gross Margin	£/ha	590						514				630						
Total Semi Fixed Costs	£/ha	138						125				141						
Net Margin	£/ha	452						388				489						

NB: Output of cereals, oil seeds and peas/beans reduced by 10 %, enterprises subject to quota and set aside are treated as winter wheat equivalent

Data sources: Yield (Murphy, 1996), Price, Variable Costs and Semi Fixed Costs (SCADE)

Table II.5 **Whole farm budgets**
Financial prices

		Scenario 2a						Scenario 2b				Scenario 2c						
Farm Size	ha	130						63.8				524						
Drainage Condition	class	Good						Good				Good						
Crop		Winter wheat	Oil seed rape	Potatoes	Sugar beet	Field beans	Set-aside (wheat)	Winter wheat	Combine peas	Sugar beet	Set-aside (wheat)	Winter wheat	Combine peas	Sugar beet	Set-aside (wheat)	Spring wheat	Potatoes	Field veg
Yield	t/ha	7.90	2.60	42.00	40.00	3.10	7.90	6.00	4.20	36.00	6.00	8.30	4.90	45.00	8.30	5.30	47.00	40.00
Price	£/t	90.00	160.00	91.00	36.00	115.00	90.00	90.00	125.00	36.00	90.00	90.00	125.00	36.00	90.00	100.00	91.00	120.00
Gross Output	£/ha	711.00	416.00	3822.00	1440.00	356.50	711.00	540.00	525.00	1296.00	540.00	747.00	612.50	1620.00	747.00	530.00	4277.00	4800.00
Area Payment	£/ha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gross Output		711.00	416.00	3822.00	1440.00	356.50	711.00	540.00	525.00	1296.00	540.00	747.00	612.50	1620.00	747.00	530.00	4277.00	4800.00
Variable Cost	£/ha	275.28	243.40	1743.12	555.75	127.60	275.28	230.25	245.00	517.25	230.25	284.76	255.00	603.65	284.76	141.90	1918.42	900.00
Gross Margin	£/ha	435.72	172.60	2078.88	884.25	228.90	435.72	309.75	280.00	778.75	309.75	462.24	357.50	1016.35	462.24	388.10	2360.58	3900.00
Total Fixed Costs																		
labour	£/ha	169						189				334						
machinery	£/ha	299						260				405						
rents and rates	£/ha	137						148				172						
other	£/ha	112						92				131						
Total Fixed Costs	£/ha	717						689				1042						
Area under crop	ha	63.70	10.40	10.40	23.40	10.40	11.70	24.09	12.60	22.17	4.94	190.00	52.00	117.00	47.00	15.00	66.00	37.00
Total Gross Margin /crop	£	27755.36	1795.04	21620.35	20691.45	2380.56	5097.92	7461.88	3528.00	17264.89	1530.17	87825.60	18590.00	118912.95	21725.28	5821.50	155798.28	144300.00
Total Gross Output	£/ha	1039						800				1663						
Total Gross Margin	£/ha	610						467				1055						
Total Fixed Costs	£/ha	717						689				1042						
Management & Investment Income	£/ha	-107						-222				13						
Saving in cost required to breakeven		-9%						-22%				1%						

NB: Land under set-aside is treated as winter wheat.
Data sources: Yield (Murphy, 1996), Price and Variable Costs (SCADE), Fixed Costs (1a, Murphy, 1996, 1b and 1c, FBS)

Table II.6 **Partial budgets**
Financial prices

		Scenario 2a						Scenario 2b				Scenario 2c						
Farm Size	ha	130						63.8				524						
Drainage Condition	class	Good						Good				Good						
Crop		Winter wheat	Oil seed rape	Potatoes	Sugar beet	Field beans	Set-aside (wheat)	Winter wheat	Combine peas	Sugar beet	Set-aside (wheat)	Winter wheat	Combine peas	Sugar beet	Set-aside (wheat)	Spring wheat	Potatoes	Field veg
Yield	t/ha	7.90	2.60	42.00	40.00	3.10	7.90	6.00	4.20	36.00	6.00	8.30	4.90	45.00	8.30	5.30	47.00	40.00
Price	£/t	90.00	160.00	91.00	36.00	115.00	90.00	90.00	125.00	36.00	90.00	90.00	125.00	36.00	90.00	100.00	91.00	120.00
Gross Output	£/ha	711.00	416.00	3822.00	1440.00	356.50	711.00	540.00	525.00	1296.00	540.00	747.00	612.50	1620.00	747.00	530.00	4277.00	4800.00
Area Payment	£/ha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gross Output		711.00	416.00	3822.00	1440.00	356.50	711.00	540.00	525.00	1296.00	540.00	747.00	612.50	1620.00	747.00	530.00	4277.00	4800.00
Variable Cost	£/ha	275.28	243.40	1743.12	555.75	127.60	275.28	230.25	245.00	517.25	230.25	284.76	255.00	603.65	284.76	141.90	1916.42	900.00
Gross Margin	£/ha	435.72	172.60	2078.88	884.25	228.90	435.72	309.75	280.00	778.75	309.75	462.24	357.50	1016.35	462.24	388.10	2360.58	3900.00
Semi Fixed Costs																		
labour	£/ha	45.69	31.71	132.83	83.02	29.44	45.69	45.69	30.94	83.02	45.69	45.69	30.94	83.02	45.69	33.82	132.83	160.00
machinery	£/ha	58.51	40.73	218.27	108.35	41.63	58.51	58.51	37.58	108.35	58.51	58.51	37.54	108.35	58.51	42.41	218.27	216.00
buildings (dry & store)	£/t	5.35	7.50	5.00	0.00	6.76	5.35	5.35	3.00	0.00	5.35	5.35	3.00	0.00	5.35	5.35	5.00	5.00
Total Semi Fixed Costs	£/ha	146.47	91.94	561.10	191.37	92.03	146.47	136.30	81.12	191.37	136.30	148.61	83.18	191.37	148.61	104.59	586.10	576.00
Net Margin/crop	£/ha	289.26	80.66	1517.78	692.88	136.87	289.26	173.45	198.88	587.38	173.45	313.64	274.32	824.98	313.64	283.52	1774.48	3324.00
Area under crop	ha	63.70	10.40	10.40	23.40	10.40	11.70	24.09	12.60	22.17	4.94	190.00	52.00	117.00	47.00	15.00	66.00	37.00
Total Gross Margin /crop	£	27755.36	1795.04	21620.35	20691.45	2380.56	5097.92	7461.88	3528.00	17264.89	1530.17	87825.60	18590.00	118912.95	21725.28	5821.50	155798.28	144300.00
Total Semi Fixed Costs/crop	£	9329.82	956.18	5835.44	4478.06	957.07	1713.64	3283.47	1022.11	4242.67	673.32	28234.95	4325.36	22390.29	6984.44	1568.78	38682.60	21312.00
Total Farm Net Margin /crop	£	18425.54	838.86	15784.91	16213.39	1423.49	3384.28	4178.41	2505.89	13022.21	856.84	59590.65	14264.64	96522.66	14740.85	4252.73	117115.68	122988.00
Total Gross Output	£/ha	1039						800				1653						
Total Gross Margin	£/ha	610						467				1055						
Total Semi Fixed Costs	£/ha	179						145				236						
Net Margin	£/ha	431						322				820						

NB: Land under set-aside is treated as winter wheat.
Data sources: Yield (Murphy, 1996), Price, Variable Costs and Semi Fixed Costs (SCADE)

Table II.7 **Whole farm budgets - Scenario 3, 4 and 5**
Financial prices and economic prices

		Scenario 3			Scenario 4			Scenario 5		
Farm Size	ha	130			130			130		
Drainage Condition	class	Good			Bad			Very Bad		
Nitrogen	Kg/ha	100			44			0		
Energy From Grass	Mj/ha	54000			29300			16800		
Grazing Season										
Extra grazing cf norm										
Days spring		14			0			-28		
autumn		28			0			-28		
Grass Conservation	type	Graze 50% ,silage 50%			Graze 50% , hay /silage 50%			Graze with cut hay when possible (<25% area)		
Livestock Type		Beef Cows and Sucklers (spring calving)	Overwintered and grass finished Beef	Sheep and Fat Lambs	Beef Cows and Sucklers (spring calving)	Overwintered and grass finished Beef	Sheep and Fat Lambs	Beef Cows and Sucklers (spring calving)	Medium Store Cattle	Sheep and Fat Lambs
Gross Output		360.00	343.00	66.70	388.00	343.00	59.30	388.00	99.00	59.30
Variable Cost	£/hd	122.00	90.00	15.50	122.00	90.00	15.50	122.00	23.00	15.50
Gross Margin	£/hd	238.00	253.00	51.20	266.00	253.00	43.80	266.00	76.00	43.80
Energy Requirements	Mj/hd	23300	15000	4700	23300	15000	4500	23300	11800	4500
Energy Available	Mj/ha									
Stock Numbers / ha	hd/ha	2.32	3.60	11.49	1.26	1.95	6.51	0.72	1.42	3.73
Livestock Units (MAFF)	lu/ha	2.32	2.16	1.72	1.26	1.17	0.98	0.72	0.85	0.56
Gross Margin / ha (before forage costs)	£/ha	551.59	910.80	588.26	334.50	494.19	285.19	191.79	108.20	163.52
Proportion of Grass Allocation	%	25	25	50	25	0	75	25	75	0
No of ha allocated	ha	32.5	32.5	65	32.5	0	97.5	32.5	97.5	0
Stock Numbers / farm	hd	75	117	747	41	0	635	23	139	0
Total Enterprise Gross Margin	£/enterprise	17927	29601	38237	10871	0	27806	6233	10550	0
Adjustment for grazing season	£/enterprise	2794	2195	3346	0	0	0	-1247	-3731	0
Total Livestock Units	lu/farm	258			136			107		
Average Stocking Rate	lu/ha	1.98			1.05			0.82		
		£/ha	£/farm		£/ha	£/farm		£/ha	£/farm	
Total Farm Gross Margin		660	85764		298	38677		129	16783	
Forage Variable Costs		65	10400		33	4290		9	1170	
Grazing Season Adjustment		64	8335		0	0		-38	-4978	
Total Farm Gross Margin (after forage costs)		659	83699		265	34387		82	10635	
Farm Fixed Costs										
Labour		230	29900		170	22100		115	14950	
Power and Machinery		175	22750		110	14300		80	10400	
Rent and Rates		120	15600		90	11700		65	8450	
Other Expenses		70	9100		50	6500		40	5200	
Total		595	77350		420	54600		300	39000	
Management and Investment Income		64	6349		-155	-20213		-218	-28365	

Economic Analysis

Reduction in Gross Output to adjust from financial to economic prices

		Scenario 3			Scenario 4			Scenario 5		
Reduction per Livestock Type	% of GO	35%	35%	25%	35%	35%	25%	35%	35%	25%
	£/head	126	120	17	136	120	15	136	35	15
	£/enterprise	9491	14046	12453	5550	0	9411	3182	4810	0
	£/farm	35989			14961			7992		
	£/ha	277			115			61		
Adjusted Econ Gross Margin	£/ha	382			149			20		
Adjusted Econ Man & Inv Inc	£/ha	-213			-271			-280		

NB Assumed Livestock quota available from national reserve for arable reversion schemes. Premium included on beef cows, special beef premium, ewe premium.
All farm systems below 2 livestock units per ha qualify, with extra extensification payment for stocking rates less than 1.4lu/ha.
Data sources: SCADE

Table II.8 **Partial budgets - Scenario 3, 4 and 5**

Financial and economic prices

		Scenario 3			Scenario 4			Scenario 5		
Farm Size	ha	130			130			130		
Drainage Condition	class	Good			Bad			Very Bad		
Nitrogen	Kg/ha	100			44			0		
Energy from Grass	Mj/ha	54000			29300			16800		
Grazing Season										
Extra grazing cf norm										
Days spring		14			0			-28		
autumn		28			0			-28		
Grass Conservation	type	Graze 50%, silage 50%			Hay /silage			Graze, with one cut hay when possible (<25% area		
Livestock Type		Beef Cows and Sucklers (spring calving)	Overwintered and grass finished Beef	Sheep and Fat Lambs	Beef Cows and Sucklers (spring calving)	Overwintered and grass finished Beef	Sheep and Fat Lambs	Beef Cows and Sucklers (spring calving)	Medium Store Cattle	Sheep and Fat Lambs
Gross Output		360.00	346.00	66.70	388.00	346.00	59.30	388.00	99.00	59.30
Variable Cost	£/hd	122.00	90.00	15.50	122.00	90.00	15.50	122.00	23.00	15.50
Gross Margin	£/hd	238.00	256.00	51.20	266.00	256.00	43.80	266.00	76.00	43.80
Semi fixed Costs										
Labour	£/hd	22.80	17.80	7.80	22.80	17.80	7.60	22.80	2.90	7.60
Machinery	£/hd	34.70	17.20	8.40	34.70	17.20	8.30	34.70	9.90	8.30
Buildings	£/hd	20.00	4.50	2.50	20.00	4.50	2.50	20.00	0.00	2.50
Total Semi Fixed Costs	£/hd	77.50	39.50	18.70	77.50	39.50	18.40	77.50	12.80	18.40
Net Margin	£/hd	160.50	216.50	32.50	188.50	216.50	25.40	188.50	63.20	25.40
Energy Requirements	Mj/hd	23300	15000	4700	23300	15000	4500	23300	11800	4500
Energy Available	Mj/ha									
Stock Numbers / ha	hd/ha	2.32	3.60	11.49	1.26	1.95	6.51	0.72	1.42	3.73
Livestock Units (MAFF)	lu/ha	2.32	2.16	1.72	1.26	1.17	0.98	0.72	0.85	0.56
Net Margin / ha										
(before forage costs)	£/ha	371.97	779.40	373.40	237.04	422.90	165.38	135.91	89.98	94.83
Forage Semi Fixed Costs										
ley establishment	£/ha	12.00			12.00			6.00		
grass production	£/ha	65.20			65.20			0.00		
grass conservation	£/ha	89.74			47.80			12.60		
Total Forage Semi Fixed Costs	£/ha	166.94			125.00			18.60		
Net Margin after Forage Costs	£/ha	205.03	612.46	206.46	112.04	297.90	40.39	117.31	71.38	76.23
Adjustment for grazing season	£/ha	86	68	51	0	0	0	-38	-38	-26
Net Margin after Forage										
(and grazing adjustment)	£/ha	291	680	258	112	298	40	79	33	50
	%	25	25	50	25	0	75	25	75	0
No of ha allocated	ha	32.5	32.5	65	32.5	0	97.5	32.5	97.5	0
Stock Numbers / farm	hd	75	117	747	41	0	635	23	139	0
Farm Total Livestock Units	lu/farm	258			136			107		
Average farm Stocking Rate	lu/ha	1.98			1.05			0.82		
Total Enterprise Net Margin	£/enterprise	9458	22100	16766	3641	0	3938	2566	3228	0
		£/ha	£/farm		£/ha	£/farm		£/ha	£/farm	
Total Farm Net Margin		372	48323		58	7579		45	5794	

Economic Analysis

Reduction in Gross Output to adjust from financial to economic prices

		Scenario 3			Scenario 4			Scenario 5		
Reduction per Livestock type	% of GO	35%	35%	25%	35%	35%	25%	35%	35%	25%
	£/head	126	121	17	136	121	15	136	35	15
	£/enterprise	9491	14169	12453	5550	0	9411	3182	4810	0
	£/farm	36112			14961			7992		
	£/ha	278			115			61		
Adjusted Econ Net Margin	£/ha	-184			-172			-78		

NB: Assumption: beef cow, beef special premium, and ewe premium all available and included, assumed that quota provided to farms out of national reserve associated with arable reversion scheme. If not, quota would need to be purchased. Additional beef cow premium on stocking rates below 1.4lu/ha.

Data sources: SCADE

Table II.9 Summary of MII and Net Margins per ha by Scenario

Scenarios	1a	1b	1c	2a	2b	2c	3	4	5
Financial Prices (£/ha)									
Whole farm budget	175	55	240	-107	-222	13	64	-155	-218
Difference compared to Scenario 1a							-111	-330	-393
Partial budgets	726	610	1060	431	322	820	372	58	45
Difference compared to Scenario 1a							-354	-668	-681
Economic Prices (£/ha)									
Whole farm budget	76	0	116	76	0	116	-213	-271	-280
Difference compared to Scenario 1a							-289	-347	-356
Partial budgets	452	388	489	452	388	489	-184	-172	-78
Difference compared to Scenario 1a							-636	-624	-530



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Wet fens for the future: Feasibility study phase 2 - a study of the economic and social implications of creating new wetlands in Fenland

Morris, Joe

1996-11
Cranfield University
https://dspace.lib.cranfield.ac.uk/handle/1826/21177
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