

FARMER UPTAKE OF DRAINAGE BENEFITS
A REGIONAL STUDY

Report to the Ministry of
Agriculture, Fisheries and Food

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EXECUTIVE SUMMARY

The commitment of public funds to land drainage improvement such as river flood alleviation and improved arterial systems has been an important component of agricultural support in Britain. The economic value of these investments depends on whether private farmers actually exploit the potential benefits afforded. With a view to deriving a more consistent and objective method for benefit assessment, the Severn Trent Water Authority commissioned Silsoe College to evaluate and explain the nature and rate of farmer uptake of benefits on 16 selected agricultural land drainage projects. The STWA study, reporting in 1984, recommended that the analysis of uptake should be extended to cover a small number of non-STWA schemes which reflect the diversity of regional situations with respect to agricultural systems and drainage characteristics. This task, referred to as the Regional study, examined 6 schemes in Lincolnshire, Sussex, Somerset and Cumbria. Using the same methods as the STWA a single visit farm survey covering 67 farmers and 4,810 ha recorded pre-scheme drainage conditions, land use and farming practice, and how these had changed over time. Uptake was assessed in terms of incremental financial benefit, land use change and the installation of field drainage. Investment appraisals of individual projects were also undertaken.

With respect to factors influencing the nature of uptake, the Regional study suggests that common factors are responsible for land use change and field drainage installation. They were both more likely on fields with a poor pre-scheme drainage status, whose drainage condition, especially flood risk, was substantially improved, and where the field formed a contiguous unit with the farmstead. Land use change was also associated with change of occupant since the scheme, and field drainage was greatest where a large proportion of the farm lay within the boundary of a scheme. Benefit uptake on grassland was mainly associated with increased nitrogen use and changes in grass conservation system. Higher nitrogen use was associated with low application rates and undrained fields in the pre-scheme situation and with the move from permanent to temporary grass.

With respect to the timing of benefit uptake, the rate of land use change was more rapid on arable farms, those with large proportions of their

area within the scheme boundary, and those experiencing change of occupancy since the scheme. The timing of field drainage installation was similarly influenced by the latter factors, and was also greatest on the larger farms.

Statistical analysis was carried out to derive mathematical expressions to explain, and possibly predict the nature and rate of uptake. Whilst the expressions for the nature of uptake explain almost 80% of observed variation they contain about 10 variables, none of which are particularly dominant in their influence. The expressions for the rate of uptake have a similar number of variables but explain less than 50% of the observed variation in the timing of uptake.

In many respects the Regional study confirms the findings of the STWA study that land use change and underdrainage are strongly associated with financial benefit uptake, and that the greatest benefits are usually taken up early in project life. Furthermore, the Regional study confirms that a broad complex of field, farm, and farmer variables influences benefit uptake; it is difficult to explain or predict benefit uptake in terms of a small number of dominant factors.

The Regional study derived an aggregate benefit uptake curve with rapid uptake in early years but marginally diminishing throughout its length to a peak at about 20 years. This contrasts with the S-shaped curve of the STWA study which appeared to peak at 13 years. On average for the Regional study, 55% of recorded financial benefits, 80% of land use change, and 50% of field drainage had occurred in the first 5 years of scheme life.

Attempts were made to derive uptake curves for individual independent variables (eg. uptake for farmers below 35 years of age) to determine whether such classifications would give a better description than the aggregate curve. It was concluded that statistically the aggregate uptake curve was as good as any sub-classification.

Compared to the STWA study, the Regional schemes demonstrate better average net benefits per hectare, and higher returns on investment. This is partly because the Regional sample is biased towards the better performers. However, the Regional sample compares well with the better STWA schemes. They

were largely conceived and designed specifically to meet agricultural and farmers' needs. They occurred where for the most part drainage was the biggest remaining constraint. They were mainly large scale pumped schemes offering economies of scale, and perhaps most important contained drainage organisations (IDB's) instrumental in scheme identification, design, and follow-up. Because of these favourable conditions it is not surprising uptake has been greater and more rapid within a sample of (6) regional best performers compared to the broad range of (16) schemes covered within the single STWA region.

The Regional study confirmed that the most suitable approach to predicting the nature of benefit uptake is the development of 'benefit scenarios' or typical budgets for specified field and farm situations, with benefits at scheme level phased over time according to the observed uptake curve.

The Regional study further emphasised the importance of bringing together at the planning stage representatives of the parties responsible for scheme identification, design, implementation and successful completion, namely, the Water Authority, ADAS, Local Authorities, IDB's, and farmers. The strong presence of IDB's and/or active support from advisory services were key determinants of scheme success.

The study concludes with a recommendation for further work involving the on-going monitoring of schemes concentrating on an in-depth, case study monitoring of selected farms representing important benefit situations. It recommends continued work on the development of consistent guidelines and procedures for data collection, analysis, planning and evaluation methods for the appraisal of agricultural land drainage capital and maintenance programmes.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The commitment of public funds to land drainage improvement such as river flood alleviation and improved arterial systems, has been an important component of agricultural support in Britain. The economic performance of these investments depends on whether private farmers actually exploit the potential benefits afforded. Pre-investment appraisals of agricultural land drainage schemes have been criticised for their often arbitrary and optimistic predictions of benefit uptake whilst the great variation in benefit uptake between schemes and farmers has hitherto remained unexplained. More recently, in the face of changes in agricultural policy, pressure on public funds, and competition from other land users, there has been a call for a more consistent and objective method for evaluating public sector land drainage investments (HMSO, 1985).

In this context, the Severn Trent Water Authority (STWA) commissioned Silsoe College to evaluate and explain the nature and rate of farmer uptake of benefits on selected agricultural land drainage projects, with a view to improving the accuracy of benefit assessment for pre-investment appraisal. The STWA study (Morris et al, 1984) examined 16 publicly financed projects involving flood alleviation and improved arterial drainage within the STWA region of Central England. A total of 177 farmers, 880 blocks of land, and 5,500 hectares were surveyed with data collected on changes over time in drainage status, land use, and farming system and performance, attributable to the improvement schemes. Statistical analysis identified factors influencing the nature and rate of farmer response, in terms of benefit uptake, and an S-shaped aggregate uptake curve was derived (Morris and Hess, 1986). Assessments were made of individual scheme financial performances, and factors influencing the latter were identified.

The results of the STWA study were presented at the 1984 MAFF River Engineers Conference (Morris and Hess, 1984). The question was raised in conference whether the STWA results were generally applicable to other regions within England and Wales, and to schemes which had different characteristics

to those found in the STWA sample. In this context Silsoe College submitted an application to MAFF to extend the investigation of farmer uptake of agricultural land drainage benefits, to a non-STWA sample of schemes, and compare the STWA and Regional results. The research proposal was for 7 months to be completed over a calendar period of 12 months beginning November 12th 1985.

1.2 OBJECTIVES AND METHODS

The overall objectives of the study are as follows:

- (i) To evaluate the actual nature and rate of farmer uptake of agricultural benefits on 4 selected non-STWA land drainage improvement schemes which reflect a diversity of regional situations with respect to agricultural systems and drainage characteristics.
- (ii) To identify, on the basis of (i), the factors which determine and explain the nature and rate of farmer uptake of agricultural benefits from land drainage schemes.
- (iii) To evaluate the overall technical, agricultural and financial performance of the selected schemes.
- (iv) To compare the findings of the regional results with those of the STWA study, and consider the implications for future benefit assessment and scheme appraisals.

The methods used in the Regional study followed exactly those used in the STWA enquiry in order to ensure consistency. These are discussed in Chapter 2.

1.3 ACKNOWLEDGEMENTS

During the study the Silsoe team received cooperation and assistance from many individuals and organisations, and especially the 67 farmers interviewed. Attention is drawn to the list given in Appendix I.

1.4 THE STRUCTURE OF THE REPORT

Chapter 2 of this report briefly enumerates the benefits of agricultural drainage and the methodology for benefit assessment used in the study. These topics, together with an extensive literature review are dealt with fully in Morris et al (1984) to which the reader is referred.

Chapter 3 describes the location and characteristics of the schemes studied and evaluates their financial performance. Detailed case studies of the individual schemes are contained in the Annexes.

The results of the analysis of factors influencing the nature and rate of benefit uptake are given in Chapter 4. Reference is made in both Chapters 3 and 4 to the STWA results for comparison. Chapter 5 considers the implications of the study's findings for land drainage policy.

A Glossary of terms used in the report is given in Appendix II.

CHAPTER 2

AGRICULTURAL DRAINAGE BENEFITS AND METHOD FOR ASSESSMENT

2.1 INTRODUCTION

This Chapter reviews the benefits of improved agricultural drainage, the context of benefit uptake on the farm, and the methods used for benefit assessment.

2.2 AGRICULTURAL DRAINAGE BENEFITS

2.2.1 The Objectives of Improved Agricultural Drainage

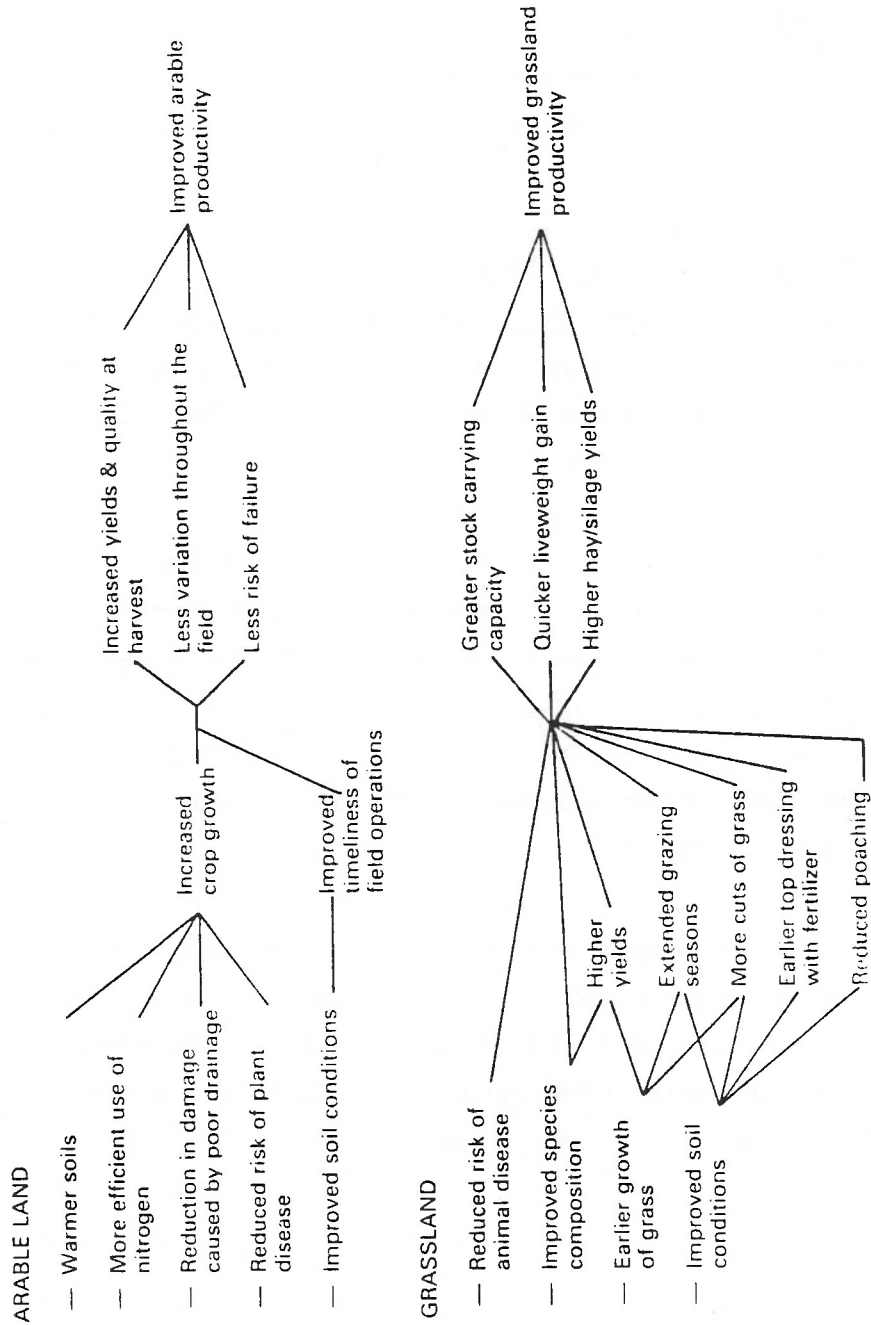
The basic aim of agricultural drainage is to alleviate or prevent the problems caused by excess water in order to facilitate crop growth and greater cropping opportunities.

The agricultural drainage problem may be due to coastal or fluvial flooding, and/or the presence of seasonally or permanently high watertables. Poor drainage due to flood inundation often calls for river re-channelling and embanking works. Where poor drainage is due to waterlogging, the preoccupation is with improving arterial watercourses, installing piped underdrainage, and other measures such as subsoiling which improve the movement of water in the soil.

Figure 2.1 summarises the principal benefits of improved drainage for grass and arable enterprises. They can be generalised in terms of improvements in the soil/plant/water growing environment and in the 'trafficability' of soils which allow more timely access for field activities, together with a reduction in crop damage caused by inundation.

A review of relevant agricultural drainage literature is contained in Morris et al (1984). Much research into crop response to drainage has measured soil wetness in terms of depth to watertable and has related yields to this parameter (Visser, 1958; Sieben, 1964; Scaggs, 1975). Experimental results show a wide difference in the tolerance of crops to the timing and duration of waterlogging or inundation (Trafford, 1972, 1974). Recent U.K. research has examined the yield effects of waterlogging at different stages of crop development concluding that watertable control to 0.5 m is adequate

Figure 2.1
The benefits of improved drainage for arable and grassland uses



providing incursions above this level are brief (Cannell and Belford, 1982). With respect to trafficability and field work day probability, soil strength and load bearing capacity vary inversely with water content and watertable height (Godwin and Spoor, 1977; Spoor and Godwin, 1979; Jarvis, 1979). Better drainage reduces the risk of untimeliness yield penalties for critical operations such as seedbed preparation or fertilising (Smith, 1972; Armstrong, 1977; Wendte et al, 1978). In many respects requirements for trafficability and workability may impose stricter conditions than the crop itself. In grassland systems, improved drainage can reduce 'poaching' liability, allow earlier access for grazing stock, and the timely application of nitrogen fertiliser, and facilitate a move to more intensive and predictable silage making systems (Parker, 1983).

2.3 FARMER UPTAKE OF DRAINAGE BENEFITS

2.3.1 The Nature, Rate and Context of Benefit Uptake

In situations where, say, a Water Authority undertakes a land drainage project involving flood alleviation works and lowering of water levels in the arterial system, 2 types of benefit are apparent. Firstly, there are those automatic benefits which are realised on the completion of a scheme such as flood damage reduction, and secondly, there are those potential benefits which require a subsequent investment or change of practice by the farmer and therefore may or may not be realised over time. A major concern of pre-investment appraisal is with identifying the type of potential benefits which are likely to be taken up by farmers (the nature of uptake) and the time over which they will be realised in relation to the commencement of the scheme (the rate of uptake). The value of benefits at full development and how long it takes to get there critically influence investment feasibility particularly when discounting methods are used.

For the farm business, the physical benefits of land drainage may occur in a number of ways. Drainage may allow the reclamation of land previously unsuited to commercial agriculture. Improved drainage could allow the intensification of existing enterprises particularly arising from the use of yield increasing inputs and practices, such as improved forage conservation. Alternatively, better drainage could facilitate land use change and a switch to new, more profitable enterprises, such as a move from permanent pasture to an arable/ley rotation. Furthermore, reduced production

costs could result due to improved working conditions or savings in forage conservation costs due to extended grazing seasons. Where drainage incorporates a significant part of the farm, there may be benefits for activities on other parts of the farm such as where increased stocking on lowland pastures may release upland areas for arable production whilst maintaining herd size.

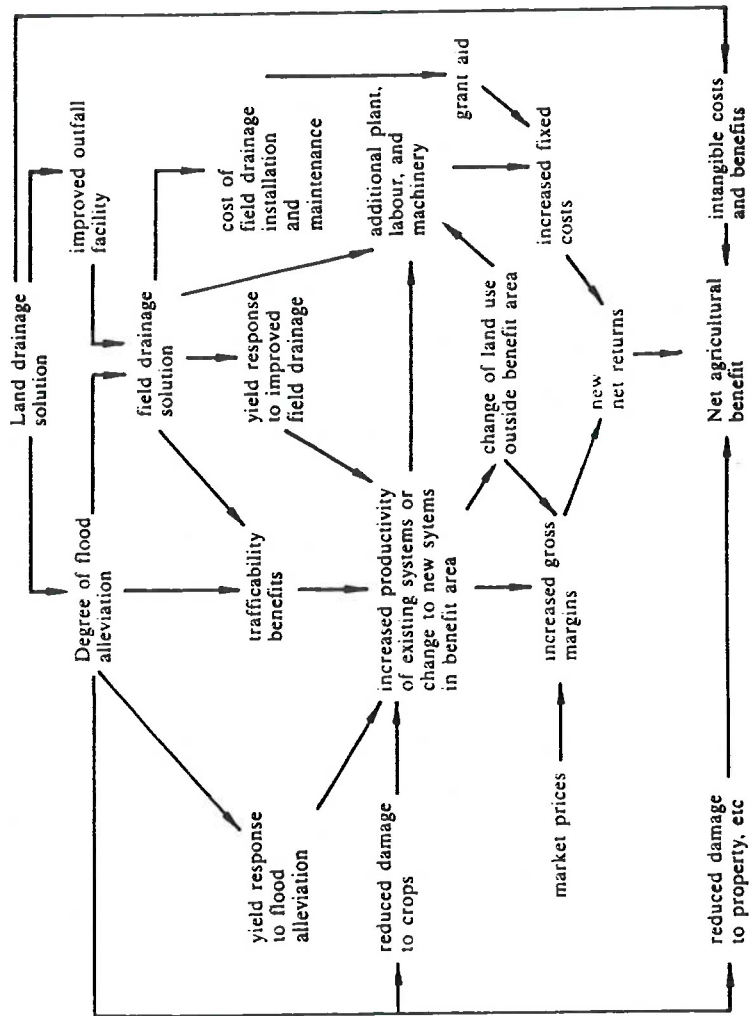
Figure 2.2 provides a basic framework for agricultural drainage benefit assessment. Improved land drainage offers a degree of flood alleviation and/or an improvement in outfall levels in the arterial drainage system. The extra value of intensifying existing, or moving to new farming systems, can be expressed in terms of changes in enterprise gross margins and farm-level fixed costs.

2.3.2 Estimating Farmer Uptake of Benefits

Whilst numerous studies have assessed the economics of agricultural drainage (Trafford, 1971; Hunter and Traffod, 1979; Bailey, 1979), few have considered actual farmer uptake of drainage benefits (McDonald, 1975; Lukehurst, 1981; Morris et al, 1984).

Most land drainage scheme evaluation has been pre-investment and estimates of farmer uptake have often been accused of optimistic bias (Bowers, 1983; R.S.P.B., 1983). For instance, there has been a tendency to generalise benefits when sub-areas within a scheme offer very different potential benefits. Estimates of potential benefit have sometimes been made on purely technical 'land capability' grounds without due regard to farm/farmer characteristics, eg. some assessments have assumed a move from grass to cereals and the necessary installation of field drains, when farmers are clearly committed to livestock production. Where benefit assessments rely on farmer or local advisory officer views, these sources, as potential beneficiaries, may be subject to optimistic, 'free rider' bias. With respect to predicting the timing of uptake, drainage is often seen as the only constraint, which when alleviated precipitates a local agricultural revolution. The fact that many farmers do not fully exploit pre-scheme potential is often overlooked. In the mid 1970's ADAS advocated a linear phasing with full benefits in year 15. Others have advocated phasing based on observations of actual uptake (Penning-Rowse and Chatterton, 1977; LGORU,

Figure 2.2
Determination of drainage benefits at farm level



1978). Predictions based on past experience on similar schemes would provide a rational basis for benefit assessment. However, a general lack of post-scheme evaluation data and a lack of consistency in the definition of agricultural drainage benefits has until recently precluded such an approach.

In addition to criticism regarding uptake assumptions, scheme appraisal has been criticised for using financial rather than economic prices, ignoring secondary, mainly environmental effects, and making insufficient sensitivity analysis of important cost and benefit assumptions.

2.4 METHOD FOR BENEFIT AND UPTAKE ASSESSMENT

The data needs, sources, collection methods, and analytical procedures used in the Regional study are the same as those used in the STWA study.

2.4.1 Data Needs, Sources and Collection Methods

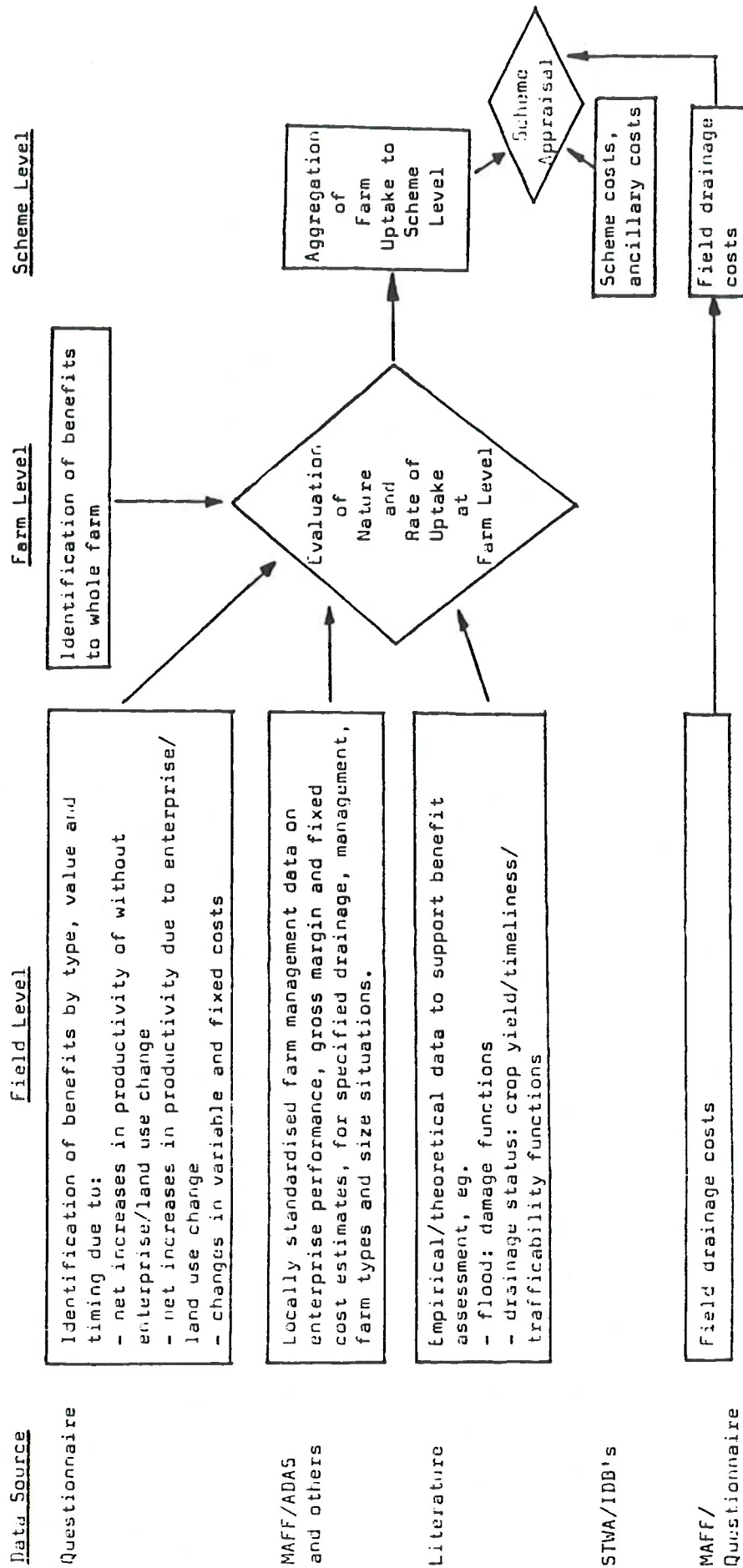
The data requirements and sources for drainage benefit assessment and scheme appraisal are summarised in Figure 2.3. Basically, they relate to a description of pre-scheme and post-scheme drainage conditions, farming and land use practices, with a view to assessing changes attributable to land and/or field drainage improvements. A detailed farm survey has been the major source of physical farm level data, which for reasons of practicality, has been converted to net financial benefit using standardised enterprise budgets.

2.4.2 Selection of Schemes and Farm Survey

Six schemes in 4 geographical locations were selected according to the criteria given in Section 3.3 below. A single visit survey of 67 farmers covering 4,810 ha within the benefit areas of these schemes was carried out using a structured questionnaire. Information was collected by interview on pre-scheme and post-scheme drainage conditions, the nature and rate of benefit uptake, and farm and farmer characteristics. The questionnaire was supported by field survey, and in the case of field drainage installations by reference to MAFF files. The main sources of data on scheme technical design standards, implementation schedules, and capital and maintenance costs were the files of Water Authorities and IDBs.

Figure 2.3

Data sources for the evaluation of uptake and scheme appraisal



2.4.3 MAFF Drainage Files

Permission was obtained from farmers and MAFF to examine MAFF's files on grant aided field drainage works carried out during the life of the projects concerned. This removed the need for farmer recall. The data provided design characteristics, timing and cost of installations used in the assessment of uptake.

2.4.4 Method for Benefit Assessment and Scheme Performance

The method adopted for assessing the nature and rate of net benefit uptake by farmers following land drainage improvement has been to compare 'before' and 'after' scheme situations, and assess the extent and timing of extra revenues and extra costs which are attributable to the drainage improvement. This financial definition of uptake is more comprehensive, yet more difficult to ascertain than the indicative measures of land use change and field drainage installation.

In the course of the farmer interview farmers were asked to recall the pre-scheme drainage situation and land use, and describe how this had changed over time since scheme completion. The restrictions imposed by the single visit interview method (which was justified in terms of the need to obtain a sample large enough for statistical inference), and the lack of reliable field and farm specific financial data, meant that obtaining estimates of changes over time in physical conditions (drainage status), practices (land use, fertiliser rate), and performance (yields, grazing season), was more feasible than requiring farmers to recall financial benefits and costs. Information on physical inputs and outputs was translated into financial values using standard 1982 prices, and expressed in terms of gross margins and fixed costs. Net returns were measured in terms of the increment in gross margin, the value of extended grazing, less any additional fixed costs including field drainage investments. This measure of net return was used as a basis for estimating both the nature and rate of benefit uptake, and also the overall return on capital invested for each STWA scheme.

These 'uptake' and 'investment appraisal' estimates are distinguishable but related. The financial measure of 'uptake' for each year of scheme life, was the extra gross margins less extra fixed costs, plus other non-automatic benefits, derived by farmers from the scheme. Farmer investment

in field drainage was excluded from this definition of uptake. With respect to investment appraisal, for each year of scheme life, the previously defined 'uptake' benefits were combined with automatic benefits such as the reductions in flood damage costs attributable to the scheme. From this was deducted the cost of field drainage and the 'without-project' returns that would have been obtained in the benefit area in the absence of any improvement. The resultant stream of net benefit, termed the net agricultural cash flow, was set against the stream of scheme level capital and recurrent costs, and discounted over scheme life at the relevant rate to derive a measure of net present value for the scheme as a whole (see Section 3 below).

In accordance with MAFF guidelines, the method adopts a quasi-financial viewpoint using prevailing farm gate prices (to the base September 1982), except for drainage investments which were taken before grant.

2.4.5 Particular Problems in Benefit Assessment

Two particular problems in the assessment of financial net benefit are worthy of comment; first, the difficulty of assessing the effect on farm fixed costs of changes in farming system; second, the difficulty of assessing the benefits of improved drainage for grassland.

(i) Gross Margins and Fixed Costs:

The conventional definitions of farm gross margins and fixed costs reduce their validity for assessing marginal enterprise changes. The main criticism is that the definition of variable costs in the calculation of the gross margin is not sufficiently comprehensive and excludes such items as extra plant and machinery operating costs, and direct labour expenses, which are likely to be reasonably constant per unit of activity, and thus likely to increase with the level of activity.

To overcome these problems a distinction was made in the STWA study between gross margins, semi-fixed costs, and total fixed costs, and this method has been retained for the Regional study. The gross margin is taken to be the conventional farm management definition. Semi-fixed costs per unit of activity are items of recurrent expenditure associated with the use of existing fixed resources (eg. machinery operating costs). Total fixed costs

per unit of activity combine the latter with a charge for capital investment (eg. machinery depreciation). If farmers reported an increase in regular labour, machinery and buildings, and/or the use of contractors, total fixed costs were charged. Otherwise semi-fixed costs were considered appropriate. The rates for estimated semi- and fixed costs are based on farm management survey and enterprise study reports (see Morris et al, 1984, Annexe V).

The distinction between semi- and fixed cost is most problematic in the case of labour. Because theoretical standard man day requirements exceeded regular family and hired workers by a factor of 1.7 and because intensification is likely to increase labour peaks, labour was charged as a semi-fixed cost (see Morris et al, 1984, Annexe V.2.5).

(ii) Grassland Productivity:

A large proportion of both pre-scheme and post-scheme land use involved grass. Assessing the productivity of a given area of grassland requires detailed records of the kind not usually kept on most farms, namely, turnout dates and liveweights, liveweight gains or milk yields at grass, livestock unit grazing days, diet supplementation, conservation dry matter yields and energy values. The efforts of researchers, however, have shown that for given environmental conditions, grass production is largely a function of nitrogen application. Given that farmers are better able to estimate fertiliser input than physical livestock output, nitrogen can be used as a proxy for grass productivity.

For this purpose a physical model, described in Morris et al (1984), Annexe IV, was developed which, drawing on the results of research at the Grassland Research Institute, estimates the physical productivity of grassland in terms of utilised metabolisable energy (UME) on the basis of site class (soil type, rainfall), drainage status (flooding, waterlogging), poaching risk, N fertiliser use, and conservation (hay, silage, number of cuts). Estimates for UME production so derived were compared with figures from the most reliable national surveys and the results confirm the validity of the model.

For a given site class, an improvement in drainage status, combined with an increase in nitrogen application encouraged by earlier access, results

in increased energy from grass. This extra energy has been converted into an increase in stocking rate for given types of livestock assuming standardised grass energy requirements per head. The increase in stocking rate has then been converted into increased livestock gross margins and fixed costs as previously described. The additional costs of forage production and conservation, and the benefits of extra grazing days have also been incorporated in the measure of net return.

2.4.6 Explaining the Nature and Rate of Uptake

The data collected during the farm survey, relating to physical field and farm level factors were combined with the data derived from the benefit assessment procedures and stored on a computer based data logging and retrieval system using the Statistical Package for Social Scientists (SPSS).

The statistical analysis of uptake was carried out on the aggregated data set for blocks of land and farmers.

Financial net return was taken as the main definition of uptake and statistical analysis proceeded to identify field, farm, and farmer factors which explained variation in the nature of uptake (the size of net returns), and the rate of uptake (the timing of net returns). The statistical methods used and the results obtained are summarised in Chapter 4.

2.4.7 Critique and Sensitivity

Critiques of the methodology used for benefit assessment and scheme evaluation are contained in Morris et al (1984), Annexe V and Annexe IX respectively. The implications of critical assumptions was tested by way of sensitivity analysis in Annexe V of that report.

CHAPTER 3

THE STUDY AREAS

3.1 INTRODUCTION

This Chapter comments briefly on the agricultural policy issues and sectoral changes over the relevant period and summarises the main features of the schemes selected for evaluation and resultant changes in drainage conditions and agricultural practice.

3.2 AGRICULTURAL POLICY AND CHANGE

Agricultural productivity and output increased continually during the 3 decades to the 1980's in response to Government pricing and subsidy incentives justified in terms of increased self-sufficiency in indigenous foods. During this period, the farming sector experienced major structural adjustment involving more specialisation, fewer but larger farms, and a much reduced work force. Yields consistently increased by 2 to 3% per year, whilst labour productivity often rose by between 4 and 6% annually. In spite of Government support, the long term trend since the mid 1960's has been one of falling average farm incomes, with the dairy and fatstock sector hardest hit. In the mid-1980's, the imposition of production quotas, and reductions in subsidy and support measures, has reversed what was hitherto an expansionist agricultural policy.

For the most part, the agricultural environment relevant to the present study was one of expansionism and market optimism, although more recently drainage improvements by farmers have decreased in response to reduced support grants and market uncertainties. Additionally, it was a period of rapid technological change, where improved drainage was seen by policy makers and farmers alike as a technology which enabled the adoption of other improved farming practices, such as new cropping systems and varieties, chemical treatments, and larger and more sophisticated equipment, and a means of enhancing or protecting farm incomes. In the analysis of drainage benefits and farmer uptake, benefits directly or indirectly attributable to improved drainage provide the basis for evaluation, and changes not related to drainage have been excluded.

3.3 SELECTION OF SCHEMES FOR STUDY

Six land drainage improvement schemes were selected for study and their locations are given in Figure 3.1.

In broad terms, the 6 schemes were selected to complement the STWA sample. The criteria for selection were:

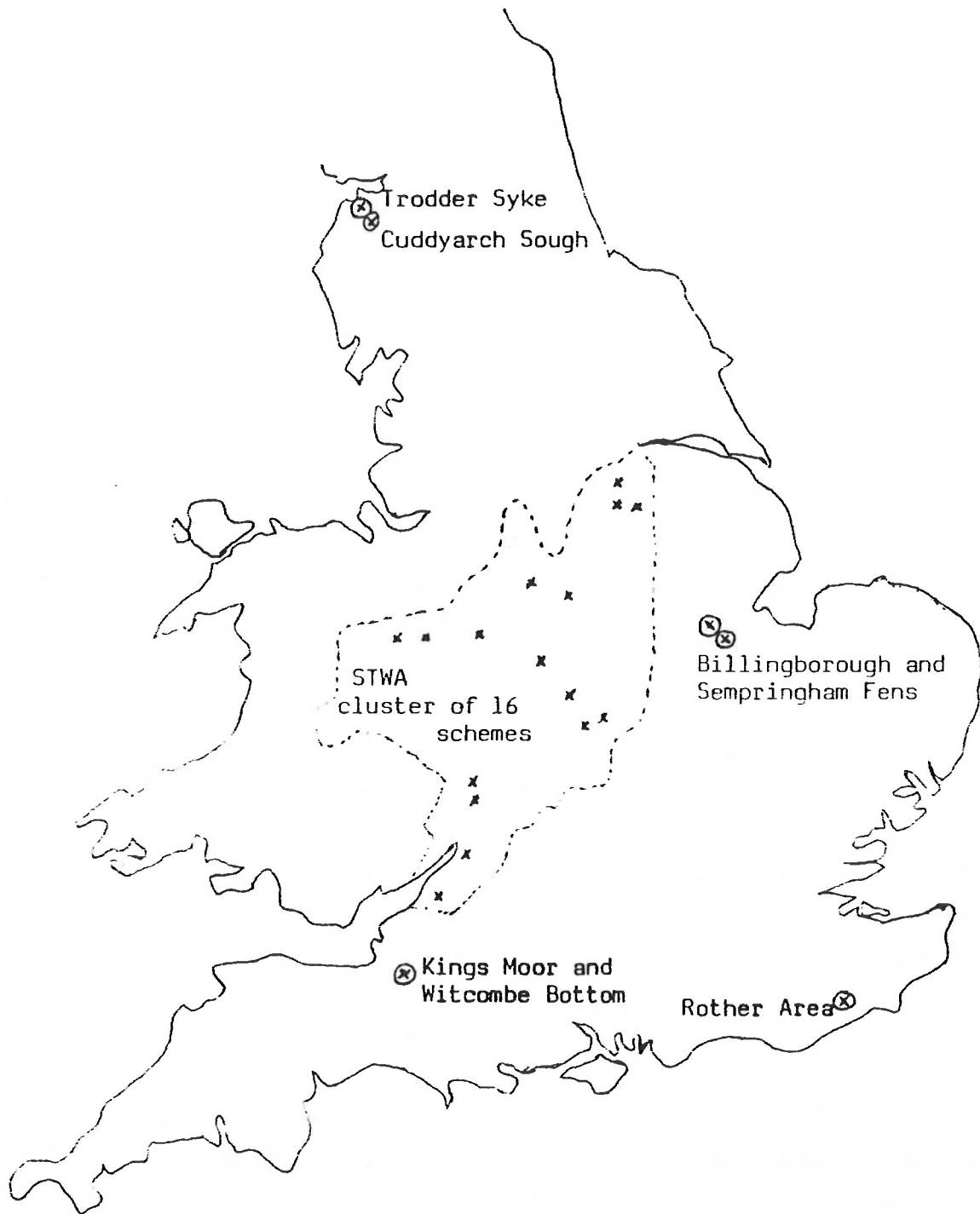
- (i) The areas benefitting from the schemes should be primarily agricultural and the schemes justified in terms of agricultural benefits.
- (ii) The schemes should have presented a definable 'improvement opportunity' for which 'uptake' could be observed. (Schemes carried out to maintain the status quo by preventing further deterioration of drainage conditions arising say from urban development upstream were not considered.)
- (iii) The schemes should be at least 10 to 20 years old to provide sufficient maturity to allow for benefit uptake, yet not too old to invalidate an evaluation based on farmer recall and records.
- (iv) The schemes should be regionally diverse, and cover different types of drainage/farming circumstances than those contained within the STWA sample.

Discussions on scheme selection were held with Regional Water Authorities, selected Internal Drainage Boards, and MAFF Land and Water Services and 6 schemes in 4 regional locations were chosen.

There was an important element of bias in scheme selection. Drainage organisations were keen to identify schemes with regional characteristics where measurable uptake had occurred. However, compared to the larger STWA sample which covered a broader and possibly more representative cross-section of scheme types found within a given region, the present study is biased towards the 'better, larger and more successful' schemes. This bias does not detract from the purpose of the present study

Figure 3.1

Location of schemes covered in the Regional and STWA studies



with its emphasis on uptake evaluation, but it does mean that their financial performance is better on average than for the STWA sample.

The selected schemes are listed below with their reference names underlined.

<u>Scheme</u>	<u>Location</u>	<u>Drainage Authority</u>
South Forty Foot Drain:		
<u>Billingborough Fen</u>	Lincolnshire	Black Sluice IDB
South Forty Food Drain:		
<u>Sempringham Fen</u>	Lincolnshire	Black Sluice IDB
River Yeo:		
<u>King's Moor and Witcombe Bottom</u>	Somerset	Wessex Water Authority
<u>Cuddyarch Sough</u>	Cumbria	North West Water Authority
<u>Trodder Syke</u>	Cumbria	North West Water Authority
<u>Rother Area</u>	Sussex	Southern Water Authority

3.4 CHARACTERISTICS OF SCHEMES

3.4.1 Scheme Design Features

The characteristics of the selected schemes in terms of age, type of works, benefit area, and capital cost per hectare are given in Table 3.1.

3.4.2 Farm Characteristics

Table 3.2 summarises farm type, farm size, field tenure and the percentage of the farm that was within the scheme benefit area. The overall average size of farm was 128 ha (compared to a national average of 118 ha), although this figure concealed a range from 88 ha on the mainly dairying Cuddyarch Sough scheme to 194 ha in the mainly arable Rother Area. An average of 59% of the farm (or 76 ha) was within the benefit area with the Lincolnshire Billingborough and Sempringham Fens having greater than 70% - reflecting how the individual fens form distinct physiographic units.

Forty-three percent of all the total benefit areas was under a mainly dairy farming system largely reflecting the predominance of grassland on the Somerset King's Moor and Witcombe Bottom, and the Cumbrian Trodder Syke and Cuddyarch Sough schemes. For these schemes, 68%, 94% and 83% of the benefit area was in dairying respectively. The Lincolnshire fenland schemes

Table 3.1
Summary of scheme characteristics

Water Authority	Internal Drainage Board	Watercourse	Reach/Fen	Length (km)	Date of commencement	Nature of major works	Area of benefit (ha)	Capital cost per hectare of benefit (ha)
Wessex	Langport	R. Yeo	Ilchester to Long Load Bridge	4.8	1971 ³	Construction of pumping station; construction of one main drain, extension of another with connecting tunnel under R. Yeo; strengthening of river floodbanks; resectioning and regrading of tributary ditches.	1,419	925
Anglian	Black Sluice	South Forty Foot Drain	Sempringham Fen	-	1966	Construction of pumping station; raising of highland carriers; floodbank improvement of main and tributary drains.	825	235
Anglian	Black Sluice	South Forty Foot Drain	Billingborough Fen	-	1966	Construction of pumping station; raising of highland carriers; floodbank improvement of main and tributary drains.	668	389
North West	-	Cuddychurch Sough	Full length	2.5	1974	Regrading and enlargement of 4 watercourses; outfall and culvert replacement; revetement of drains.	268	368
North West	-	Trodder Syke	Full length	1.0	1972	Regrading and enlargement of 2 watercourses; replacement of access bridges and culverts; revetement of drains.	246	222
Southern	Rother, Walland, Pett	R. Rother	Scots Float Sluice to Bodiam (selected pumping station catchments)	-	1968 ⁴	Raising of Rother floodbanks; watercourse embankment; raising tidal embankments; construction of 24 pumping stations; dredging river; reorganisation of drainage network.	1,453	486

Notes:

1. As defined following farm survey.
2. Brought to common 1982 price base using PWN Index; Cost after contributions but including capital expenditure by non-farmer third parties (eg. IDB) and, where appropriate, a proportion of costs of 'regional' works.
3. Benefits commenced in 1976.
4. Benefits came on stream in a series of stages.

Table 3.2
Sampled farms by scheme, farm type, size and tenure

Scheme	Area surveyed (ha)	Number of farmers interviewed	Mean farm size (ha)	Mean SMD requirement	Type of farm : % of benefit area				Mean % of farm in benefit area	Field tenure : % of area		
					Dairy	Livestock	Cropping	Mixed		Owned	Tenanted	Other
Billingborough Fen	668	6	177	1,523	0	0	53	47	77	6	94	0
Sempringham Fen	825	11	89	979	7	0	79	14	73	23	77	0
King's Moor and Witcombe Bottom	1,260	20	125	1,347	68	4	6	11	61	68	29	3
Trodder Syke	246	8	96	1,239	94	0	0	6	55	100	0	0
Cuddyarch Sough	268	9	88	1,210	83	17	0	0	43	100	0	0
Rother Area	1,543	15	194	2,312	4	10	25	50	45	79	21	0
Total or Average	4,810	67	121	1,435	43	5	28	23	59	63	37	0
STWA results	5,417	170	105	926	46	18	22	6	42	56	34	10

and the Rother were predominantly cropping. The distribution of farm types reflects regional farming systems, modified by local physical conditions.

Field tenure arrangements varied between schemes. Land on the Lincolnshire schemes was mainly held on Crown Estate tenancies. The Cumbrian schemes were wholly owner-occupied, whilst the Somerset and Sussex schemes were mainly owner-occupied.

In comparison with the STWA sample, the Regional Sample has a larger average farm size, a greater proportion of cropping and mixed farms, a larger share of farm size in the benefit area, and a bigger incidence of owner-occupancy.

3.5 DRAINAGE AND LAND USE CHANGE AT SCHEME LEVEL

3.5.1 Drainage Status

Table 3.3 summarises the pre- and post-scheme situation on the 6 selected schemes with respect to flood risk, drainage status, and installation of field drains. Before improvement, an average 80% of the benefit areas were flood-prone, and 47% experienced at least one event per year. Flood risk was highest in the King's Moor and Witcombe Bottom area, where the whole benefit area was previously subject to flooding (with 89% of the area experiencing more than one flood per year). Flood risk was lowest for the Trodder Syke, where the main problem was one of waterlogging caused by a high watertable. Post-scheme flooding has not occurred on average on 70% of the area, and has been reduced on a further 28%. Trodder Syke and Billinghamborough have not experienced flooding since improvement, whereas on King's Moor and Witcombe Bottom and on Cuddyarch Sough only 3% and 26% respectively are 'flood-free'.

Pre-scheme flood risk shows a high positive correlation with poor drainage status. An average of 79% of the benefit areas was classified as either 'commonly' or 'usually' wet. The Cuddyarch Sough was perceived by farmers to have particularly severe drainage constraints, with 68% described as usually wet.

Overall, 1,622 ha of the benefit areas (or 32%) had new underdrainage installed post-scheme, and a further 16% have been redrained.

Table 3.3
Drainage status and change

Scheme	Pre-scheme flood risk (% of benefit area)					Pre-scheme drainage status (% of benefit area)				Underdrainage (% of benefit area)				Change in flood frequency (% of benefit area)			
	Did not flood	1 in 5	1 in 2 to 1 in 5	One per year	1 per year	Rarely wet	Occasionally wet	Commonly wet	Usually wet	Un- drained	Drained pre-scheme	Drained post-scheme	Re- drained	No floods	Reduced	Same	Increased
Billingborough	39	17	45	1	0	0	30	34	36	16	20	54	10	100	0	0	0
Sempringham	5	45	38	9	3	9	30	57	4	15	12	65	8	95	5	0	0
King's Moor & Witcombe Bottom	0	0	0	11	89	0	12	82	6	66	9	17	8	3	97	0	0
Trodder Syke	49	2	15	34	0	0	4	54	42	43	5	27	25	100	0	0	0
Cuddyarch Sough	27	0	3	20	50	10	2	20	68	47	21	13	19	26	61	13	0
Rother Area	0	29	1	47	23	0	30	57	13	45	15	16	24	95	5	0	0
Average	20	16	17	20	27	3	18	51	28	38	14	32	16	70	28	2	0
STWA Average	39	17	1	7	36	13	31	33	22	42	26	19	13	68	9	21	2

Thirty-eight percent remains undrained. Twenty-six percent has underdrainage which pre-dates the scheme. The Lincolnshire fenland schemes have shown the most post-scheme field drainage. The Somerset King's Moor and Witcombe Bottom scheme has the least post-scheme field drainage, with two-thirds of the whole benefit area without underdrainage.

3.5.2 Land Use Change

Table 3.4 summarises the pre- and post-scheme land use for individual schemes. Overall, the pre-scheme situation was 55% down to grass, 45% accounted for by permanent pasture. The overall post-scheme situation is characterised by a decline in grassland to 42% of total area with permanent pasture reduced to 28%, and an increase in temporary leys. Arable/ley rotations reduced markedly, and continuous cropping showed a threefold increase to 46% of the post-scheme benefit area. Compared to the STWA sample, the Regional sample showed a greater predominance of arable/ley and all arable farming in both the pre- and post-scheme situations.

If rough grazing is arbitrarily ascribed the lowest land use rating, with permanent pasture, temporary grass, arable/leys, and continuous cropping representing an increasing order of land use intensity, then land moved to a higher category on 44% of the total benefit areas, and declined on 7% of the area (largely associated with a move on the Trodder Syke from arable/ley to improved temporary grass leys). This exceeded the degree of land use change found in the STWA sample.

The major differences between schemes in terms of land use is apparent from Table 3.4. In many respects, improved drainage allowed the schemes to more fully exploit their comparative advantages. The predominantly arable areas of the Lincolnshire Fen and the Rother Valley schemes increased their arable specialisation post-scheme. Similarly, the mainly grassland farming in the Somerset and Cumbrian schemes was retained in the form of improved permanent pastures or new temporary leys. The Somerset scheme showed the least evidence of land use change.

3.6 SCHEME FINANCIAL EVALUATION

Each of the 6 land drainage schemes were considered as separately identifiable investment projects to which benefits and costs can be ascertained over a 30 year project life and discounted at the Treasury's test discount rate for public sector investments.

Table 3.4
Land use change

Scheme	Pre-scheme land use (% of area)				Post-scheme land use (% of area)				Shift in land use (% of area)				
	Rough grass	Permanent pasture	Temporary grass	Arable /ley	Crops	Rough grass	Permanent pasture	Temporary grass	Arable /ley	Crops	Decline	No change	Improved
Billingborough Fen	0	20	0	57	23	0	0.5	0	0	99.5	0	24	76
Sempringham Fen	0	18	0	44	38	0	6	0	0	93.4	0	52	48
King's Moor and Witcombe Bottom	0	84	11	5	0	0	67	22	6	5	0	82	18
Trodder Syke	2	54	0	44	0	0	52	37	11	0	43*	50	7
Cuddyarch Sough	44	56	0	0	0	0	41	27	28	4	0	34	66
Rother Area	0	39	0	32	29	0	3	0	22	75	0	51	49
Average	8	45	2	30	15	0	28	14	12	46	7	49	44
STWA average	2	75	4	5	11	1	47	7	12	31	2	64	32

* mainly a switch from spring barley/long grass leys to improved permanent grass.

The method for evaluation followed that of the STWA study apart from a more detailed assessment of flood damage costs used in the Regional study. The analysis used constant 1982 financial prices. The main benefit and cost parameters were as follows.

3.6.1 Net Agricultural Cash Flow

Comprising:

- Net agricultural benefits attributable to the drainage improvement scheme are the sum of the estimated financial value of benefit uptake at field and farm level within the scheme's boundary of influence. Estimates of uptake were assumed constant for any remaining part of project life beyond 1986 and no attempt was made to predict future uptake.
- Flood damage reduction benefits due to consequent savings, if any, in damages to standing crops and livestock, and additional costs such as stock housing or remedial works. The extent of these savings depends on changes in flood risk and the cost of flood events when they do occur. The SCADE model (Hess and Morris, 1986) was used to estimate average annual flood costs before and after scheme completion.
- Without-project benefits, it is assumed, would have accrued to project farmers even without drainage improvement. These have been charged at 1% compound per year of the average pre-scheme net returns for those farmers who took up benefits.
- Field drainage costs before grant derived from MAFF records have been charged for the year in which they occur, together with any private pumping, secondary drainage treatments or irrigation where relevant.

3.6.2 Scheme Costs

Comprising:

- Capital costs recorded at out-turn prices and converted to 1982 prices. These costs include the initial cost of works including supervision, compensation payments, third party (IDB) investments and costs associated with environmental protection. Contributions from Local Authorities were deducted. Where joint costs are apparent, as for example where schemes share the services of a large regional pumped main drain, costs have been apportioned according to share of likely benefits.
- Recurrent costs; expenditure on extra operating and maintenance items have been charged, including reported running costs of lowland pumping stations where relevant.

3.6.3 Scheme Performance

(i) Net present value (NPV) and internal rates of return (IRR):

Table 3.5 summarises the financial performance of the 6 schemes. On the basis of observed performance to date and the assumption that benefits continue at their 1985 levels over the remainder of a 30 year project life, 5 of the 6 schemes recover costs and appear profitable at the 5% discount rate. The sixth scheme (King's Moor and Witcombe Bottom) has an internal rate of return of 4%, and a switching value which suggests that the scheme would break even if benefits were 16% greater than those estimated. This requirement could be met during the remaining 15 years of project life.

(ii) Capital costs per hectare:

Average capital costs per hectare of benefit were £438 in 1982 prices on an average scheme size of 813 ha, ranging from £222 in the Trodder Syke to £925 in the King's Moor and Witcombe Bottom scheme. In 3 schemes, there were significant increases in actual over estimated costs, but this did not prejudice feasibility.

For the STWA sample average capital costs per hectare were £882, on an average scheme size of 350 ha. The Regional sample included a greater

Table 3.5
Summary of scheme performance

(1982 constant prices)

Scheme	Capital cost £ per ha of benefit area ¹		Field drainage investment £ per ha of benefit area	Performance to date ²			Present value of costs at 5%	Present value of benefits at 5%	Benefit cost ratio
	Estimated	Actual		NPV at 5% £'000s	IRR %	Switch value			
Billingborough Fen	368 ³	389	270	1,234,530	+24.7	0.346	305,474	1,540,004	5.00
Sempringham Fen	123 ³	235	250	1,352,370	+28.8	0.346	278,872	1,631,242	5.80
King's Moor and Witcombe Bottom	986	925	91	-152,435	+3.98	1.160	1,297,642	1,145,207	0.90
Trodder Syke	165	222	313	+191,269	+23.5	0.455	51,395	242,664	4.70
Cuddyarch Sough	360	368	213	+443,183	+39.0	0.20	93,749	536,932	5.70
Rother Area	392	486	202	+4,733,760	+24.57	0.21	1,922,488	6,656,249	3.46

Notes:

1. Capital costs adjusted to 1982 prices using PWR index.
2. Observed performance to date with benefits continuing at their 1986 level for remainder of project life.
3. Excluding apportioned costs of full Black Sluice scheme.

proportion of large pumped schemes which were part of larger integrated regional drainage developments, most notably on the Lincolnshire Fens, and in the Rother Valley.

(iii) Field drainage investments:

Field drainage investments by farmers averaged £223/ha of benefit area, ranging from £91 on the Somerset scheme to £313 in the Cumbrian Trodder Syke. The STWA sample average was £141/ha of benefit area.

(iv) Increased gross margins and net returns:

A summary of benefits by scheme is given in Table 3.6. Overall, net returns increased by an average £210/ha in 1982 prices, being highest on the large scale pumped schemes of the Black Sluice IDB and the Rother Valley, and lowest on the Somerset scheme. The relatively high returns on the Cumbrian Cuddyarch Sough (£147/ha) reflect the virtual reclamation of over 40% of the area from rough grazing.

Billingborough Fen shows the lowest increase in gross margin mainly because a large proportion of the area was in arable cropping prior to the scheme. On this scheme, however, net returns are highest partly reflecting a switch from root crops to winter cereals and concomitant savings in average fixed costs.

Overall net returns increased by an average £93/ha on the STWA sample.

(v) Flood damage reduction:

Flood damage reduction shows the difference between average annual flood costs before and after the schemes, which depend on a combination of flood frequency, duration, seasonality and land use. Flood damage reduction is highest on schemes where flood alleviation was a major objective. Flood damage reductions are largely automatic benefits which do not require action on the farmer's part. Flooding has been virtually eliminated on the Rother and much reduced on the Somerset King's Moor and Witcombe Bottom.

Table 3.6
Summary of benefits by scheme

Scheme	Date of commencement of works	Number of farmers in benefit area surveyed	Number of farmers taking up benefits	Benefit area (ha)	Extra net returns (£/ha)	Flood damage reduction (£/ha/year)	Increase in gross margin (%)	Increase in net returns (%)	Ranking (based on extra net returns/ha)
Billingborough Fen	1964	6	6	668	268	9.50	39	179	3
Sempringham Fen	1964	11	11	825	277	9.50	55	136	2
King's Moor and Witcombe Bottom	1971	20	15	1,419	70	31.54	43	38	6
Trodder Syke	1972	8	8	246	106	7.37	55	53	5
Cuddyarch Sough	1973	9	8	268	147	23.49	79	94	4
Rother Area	1966	15	12	1,453	390	38.50	69	133	1

(vi) Take-up of benefits:

Of the 69 farmers who were identified as potential beneficiaries of the schemes, 60 (87%) reported deriving benefits which could be expressed in financial terms. In Billingborough Fen, Sempringham Fen and Trodder Syke, 100% of farmers took up benefits, in King's Moor and Witcombe Bottom, 75% reported some degree of benefit uptake.

This compares with an average 66% of farmers reporting some degree of benefit in the STWA sample.

3.7 FACTORS INFLUENCING INDIVIDUAL SCHEME PERFORMANCE

The factors which influence the nature and rate of uptake of agricultural benefits at field, farm and scheme level are discussed in detail in Chapter 4. The discussions in each of the scheme evaluation reports (Annexe 1) identifies locally relevant factors in the determination of scheme performance.

In the sensitivity analyses of individual scheme performance, it is the size and timing of the net agricultural returns which critically affect the benefit stream. In the case of the King's Moor and Witcombe Bottom scheme, the value of reduced flood damage costs was also important.

The King's Moor and Witcombe Bottom scheme was the only one of the 6 examined which did not break even at the 5% test discount rate. This was due to both the relatively high capital costs of the scheme per hectare of benefit (£925/ha), and the fact that post-scheme flood frequency was too high to encourage grassland re-seeding and intensification or the adoption of arable/ley rotations. Furthermore, the uptake of improved drainage potential was constrained by the fragmented field distribution and prevailing traditional farming methods.

In contrast, Sempringham and Billingborough Fens had a greater proportion of farms with a high percentage of their area held as contiguous blocks within the benefit area. Drainage conditions had been improved over a long period, and the Black Sluice scheme removed the remaining drainage constraints to allow farmers to exploit the arable potential of these fenlands. The 2 fens were also part of the Billingborough Crown Estate. The

landlords provided funds for field drainage installations, as well as for other farm improvements. This was recovered in the form of higher rents which required farmers to exploit improved drainage opportunities in order to maintain or enhance farm incomes.

The scheme with the highest IRR is the Cuddyarch Sough, a relatively small, low cost scheme justified in terms of flood alleviation to which a large part of the benefits accrued automatically.

In common with the findings of the STWA study, a critical factor determining scheme success was the presence of formal or informal drainage organisations. All 6 schemes had or still contain Internal Drainage Board's acting as a vehicle for farmer pressure to achieve land drainage improvement, and taking over responsibility for subsequent follow-up work and maintenance.



CHAPTER 4

NATURE AND RATE OF UPTAKE

4.1 INTRODUCTION

Physical parameters describing land use change and underdrainage have been examined in conjunction with estimates of financial benefits. Farm survey data together with physical data on soils and land classification were stored on computer with the estimates of gross margins and net returns on a field by field basis. These data sets were then examined in association using the Statistical Package for Social Scientists (SPSS-X).

The discussion of the results follows a similar methodology to that in the previous Severn-Trent report (Reference 1):

- (i) the observed variation in the nature of uptake is examined and the factors encouraging uptake identified;
- (ii) the rate of uptake is studied;
- (iii) curves of uptake are presented which may enable benefits identified in a pre-scheme evaluation to be phased over time;
- (iv) the factors associated with the uptake of benefits are examined at the scheme level;
- (v) the attitude of farmers towards field drainage is discussed.

At each stage, the findings from the present study (referred to as the Regional study) are compared with the results from the earlier Severn-Trent study of farmer uptake (referred to as the STWA study).

4.2 VARIATION IN THE NATURE OF UPTAKE OF BENEFITS

4.2.1 Observed Variation in the Nature of Uptake of Benefits

When considering uptake, four important factors were investigated:

- (i) change of land use class,
- (ii) installation of field drainage,
- (iii) change in grassland nitrogen application rate, and
- (iv) change in grassland conservation system.

The distribution of benefits from each of these factors is shown in Tables 4.1 to 4.4.

Table 4.1 shows that 57.5% of the benefits observed (measured in terms of a change in gross margin¹) occurred on sites which had changed land use (42% of the area), and compare favourably with the STWA findings of 60% of the benefits on 33% of the area. Also, as in the STWA findings, the greater the change in land use after the scheme, the greater the degree of benefit. No shifts in land use greater than 4 were recorded.

Table 4.2 shows that 63% of the benefits were found to have occurred on sites which had been drained following the scheme (54% of the area). This is almost the same as with the STWA study (61%) although in the Regional sample the percentage area drained is higher, at 54% compared to 32%. The average benefit on drained sites was 1.6 times greater than that on undrained sites. This figure had been over 3 times greater for the STWA study.

Table 4.3 shows that for fields which have remained in grass, 98% of the benefits occurred on sites which have increased nitrogen application rates (85% of the area). For the STWA study the figure had been similar (90%) but these benefits had occurred on only 50% of the area. The average benefit to grassland sites which had not increased 'N' was low at £17/ha.

Table 4.4 shows that 59% of the benefits accrue to sites where there has been a change in grass conservation method (53.5% of the area); in the STWA results, these values were 44% and 24% respectively. The greatest benefits relate to those sites which have gone from grazing to silage conservation, but these only account for a tiny percentage of the sites surveyed. The most common and beneficial change is from hay to silage conservation. In general, the present average benefits in the Regional study (all expressed in 1982 prices) are much greater than those observed in the STWA analysis. In the STWA results, large benefits had been associated with a move from hay to zero conservation, but this trend was not in evidence in the Regional sample.

1. Change in gross margin is a better indicator of uptake than change in net return in most cases as it does not generally include automatic benefits (which are reflected in reduced costs). In some cases, however, an increase in net return can be accompanied by a decrease in gross margin. Change in gross margin does not, therefore, provide a perfect measure of uptake.

Table 4.1
Distribution of benefits from land use change - ALL SITES

Shift ¹	% of benefit		Average benefit (£/ha)		% of area
	△ gross margin	△ net return	△ gross margin	△ net return	
- 1	2.14	1.40	230.44	127.80	2.20
0	40.39	38.04	154.64	129.61	55.43
1	22.23	28.17	225.92	212.48	24.04
2	5.76	5.03	310.26	234.58	3.54
3	29.06	26.98	380.03	322.84	14.53
4	0.42	0.38	349.20	294.40	0.26
Total ²	100.00	100.00	218.52	185.36	100.00

1. The shift in land use class is calculated as the numerical value of the post-scheme class minus the pre-scheme class. Classes were coded as follows:

0 - not used,	1 - rough pasture,
2 - permanent grass,	3 - temporary grass,
4 - crop/ley rotation,	5 - crops,
6 - horticulture.	
2. Columns 3 and 4 have been weighted by % area.

Table 4.2
Distribution of benefits from drainage - ALL SITES

Post-scheme drainage	% of benefit		Average benefit (£/ha)		% of area
	△ gross margin	△ net return	△ gross margin	△ net return	
None	37.33	33.26	162.47	126.22	45.71
Drained	62.67	66.74	265.72	235.16	54.29
Total	100.00	100.00	218.52	185.36	100.00

Table 4.3

Distribution of benefits from increased nitrogen - grassland

Change in "N" rate	% of benefit		Average benefit (£/ha)		% of area
	△ gross margin	△ net return	△ gross margin	△ net return	
-ive	0.07	0.16	32.50	37.5	0.28
None	2.07	3.74	20.27	17.29	14.89
up to 50 kg	2.43	1.93	121.43	48.00	2.74
50-100 kg	49.08	41.17	100.85	47.19	49.64
101-150 kg	18.91	20.42	153.21	74.87	16.66
151-200 kg	14.60	17.84	259.05	173.32	7.14
over 200 kg	12.84	14.74	205.74	120.06	8.65
Total	100.00	100.00	118.31	62.65	100.00

Table 4.4

Distribution of benefits from change in grass conservation - grassland

Change in conservation	% of benefit		Average benefit (£/ha)		% of Area
	△ gross margin	△ net return	△ gross margin	△ net return	
No change	40.82	48.98	93.55	56.23	53.45
Hay to silage	42.26	32.93	183.02	96.47	27.68
Grazing-silage	0.94	0.64	244.50	93.50	0.44
Conservation-grazing	15.98	17.45	104.29	56.95	18.43
Total	100.00	100.00	120.95	67.67	100.00

The schemes chosen for the Regional analysis, whilst regionally representative of their regions, were biased towards the more successful schemes (see Chapter 3 above). In the light of this, it is not surprising that higher average benefits were experienced over much higher percentages of the benefit areas in the Regional study than in the STWA study.

It is possible to observe that sites with the most benefit are those which have one or a combination of the following attributes:

- (i) a post-scheme shift to a higher order land use,
- (ii) post-scheme underdrainage,
- (iii) grassland sites with increased rates of nitrogen application, and
- (iv) grassland sites with a post-scheme move from hay making to silage conservation.

These attributes are virtually the same as for the Severn-Trent results.

4.2.2 Factors Explaining the Variation in Nature of Uptake

(i) Change of Land Use

The farms surveyed were classified according to the percentage of the benefit area that had changed land use since the scheme into 4 groups:

- (i) 'None',
- (ii) 'Less than Half',
- (iii) 'More than Half, and
- (iv) 'All'.

Chi-squared statistics or, where appropriate, Pearson's ' r^1 ' were calculated to identify the farm level variables which have a significant influence upon the observed variations in the area of land use change. The results are summarised in Table 4.5.

1. This type of calculation may only be used on continuous variables. Discrete variables are tested with the Chi-square analysis.

Table 4.5
Farm and farmer factors associated with land use change

Significant variables (Signif. < 0.05)	Significance
Percentage of farm underdrained since the scheme (Pearson's $r = 0.42$)	0.0000
Membership of local farmers' group	0.0418
Insignificant variables (Signif. > 0.05)	
Farm size (ha) (Pearson's $r = 0.19$)	0.0590
Standard Man Day Requirement (Pearson's $r = 0.9$)	0.2290
Change of ownership	0.1900
Farm type	0.5394
Change of management	0.1874
Management status	0.2840
Farm tenure	0.3872
Farmer's age group	0.2416
Agricultural qualifications	0.2056
View of farming as a business	0.5120
Expected family lineage	0.6457
Representation on committees	0.4858
Percentage of farm in the benefit area (Pearson's $r = 0.92$)	0.2240
Whether brought up on the present farm or not	0.1842

Fields were then divided into 3 groups:

- (i) those which have not changed land use,
- (ii) those which have 'improved' (a positive shift), and
- (iii) those which have 'declined' (a negative shift).

Field level variables were then cross-tabulated against these 3 classes and Chi-squared statistics calculated. The results are summarised in Table 4.6.

Table 4.6
Field factors associated with land use change

Significant variables (Signif. < 0.05)	Significance
Pre-scheme gross margin (Pearson's $r = -0.1528$)	0.0000
Pre-scheme drainage status	0.0000
Whether the land was underdrained pre-scheme	0.0378
Field distance from buildings	0.0010
Contiguity of field with farm	0.0027
Pre-scheme flood frequency	0.0000
Pre-scheme flood duration	0.0000
Post-scheme flood frequency	0.0000
Post-scheme flood duration	0.0000
Pre-scheme land use	0.0000
Change of field occupant since scheme	0.0000

All the farm and field level variables with a significance of less than 0.05 were entered into a stepwise Discriminant Analysis to attempt to differentiate between sites which have changed land use and those which have not.

A discriminant function with 10 variables was obtained which correctly classified 77% of the cases studied. The variables are listed in Table 4.7 along with their standardised coefficients¹.

1. The standardised coefficients are used to compute the discriminant score where the original discriminating variables are in standard form (Z-scores). The absolute value of the coefficient represents the relative contribution of its associated variable to the function. The sign denotes whether the variable is making a positive or negative contribution.

Table 4.7
Change of land use - standardised discriminant function

Variable	Standardised coefficient
Membership of farmers' group	-0.21
Pre-scheme gross margin	-0.11
Drainage status pre-scheme	+0.53
Drained pre-scheme	-0.15
Field as contiguous farm unit	+0.14
Pre-scheme flood frequency	-0.38
Pre-scheme flood duration	-0.63
Pre-scheme land use	-0.80
Change of occupant since scheme	+0.34
Not flooded since	+0.52

These variables fall evenly into one of 3 groups:

- (i) Those with a strong positive contribution -
 - Pre-scheme drainage status (+0.53)
 - Not flooded since (+0.52)
 - Change of occupancy (+0.34)
- (ii) Those with a strong negative contribution -
 - Pre-scheme flood frequency (-0.38)
 - Pre-scheme flood duration (-0.63)
 - Pre-scheme land use (-0.80)
- (iii) Those with small absolute values -
 - Membership of farm group (-0.21)
 - Pre-scheme gross margin (-0.11)
 - Pre-scheme drainage (-0.15)
 - Field contiguous to farm (+0.14)

Group 1: Not surprisingly, sites which prior to the scheme have a poor drainage status are more likely to change land use than those which already have good drainage conditions. Sites which were flood-prone before the scheme, but which have not experienced any flooding since are more likely to change land use than those where

flooding is still a risk. On the King's Moor and Witcombe Bottom scheme, for example, post-scheme flood risk discouraged grassland re-seeding and the adoption of arable/ley rotations. A new occupant taking over a site in the benefit area is also more likely to instigate land use change.

Group 2: Blocks of land which were in a high-order land use class before an improvement scheme are less likely to change use than land that was in a lower class. This agrees with the observations on pre-scheme drainage status because most poorly drained land is usually under a low order of land utilisation before the scheme. Higher order land uses will simply tend to intensify production rather than seek to change to a new land use. Sites which experienced more frequent floodings and floods of long duration are less likely to have changed land use. These figures would tend to contradict the influence of both pre-scheme land use and drainage status, but may be explained through reference to the schemes involved. The King's Moor and Witcombe Bottom scheme had experienced the worst pre-scheme flooding regime (89% of the area affected by more than one flood each year) but was characterised by the least change in post-scheme land use as a result of continued flood risk. Areas of the large Rother Area scheme which experienced annual floods were already under arable farming systems and showed little post-scheme land use change.

Group 3: Farmers who are members of a local farmers' group, sites with a high pre-scheme gross margin and land that had been drained before the scheme are all less likely to have changed land use, although their relative contributions (measured in terms of their absolute values) are small. A high pre-scheme gross margin will normally be associated with a high pre-scheme order of land use which has already been seen to have an important negative contribution. A block of land that forms a contiguous unit with the farm is more likely to change land use, and this was certainly the case in the two Black Sluice schemes where large percentages of the farms were located as regular blocks in the benefit area.

If post-scheme drainage is entered as an independent variable, a 10 variable function is obtained which correctly classifies 79% of the cases studied. Eight of the original 10 variables are maintained, all with the same direction of influence but with slightly reduced values. Pre-scheme gross margin and field fragmentation are no longer included. Post-scheme drainage enters, with a value of -0.47 meaning that sites which have installed underdrainage after the scheme are quite likely to change land use. Reduction in post-scheme flooding enters the function with a positive influence, but it is those sites where flooding has not occurred since the scheme which are even more likely to change land use (with a value of +0.7) and reflect the influence of the Black Sluice and Rother schemes, where there has been no flooding over all or most of their areas since the improvements.

In the STWA survey 5 additional farm level variables had proved to have a significant influence upon the observed variations in the area of land use change. These were, farm size, the percentage of the farm in the benefit area, farmer age group, farm type, and whether or not there had been a change of management since the scheme. These were no longer included in the Regional results. The percentage of the farm underdrained since the scheme has proved to be the only farm level variable that has remained significant for the 2 analyses.

The field level variables seen as significant in the Regional study agreed with those identified in the STWA analysis, except for the addition of pre- and post-scheme flooding variables.

The Severn-Trent discriminant function was able to correctly classify cases with the same level of accuracy (77%) as the Regional function, although the variables included in the function were somewhat different. The percentage of the farm in the benefit area, for example, had proved to be an important variable (with a strong negative influence), whilst a post-scheme change in management exerted a positive influence, but neither are included as significant in the Regional results. In addition, the 3 flood-related variables (pre-scheme flood frequency and duration and post-scheme prevention of flooding) form a very important part of the Regional function but are not included in the STWA results.

(ii) Field Drainage Installation

A similar approach was adopted to examine factors influencing post-scheme underdrainage. Firstly, the farm and farmer variables were cross-tabulated against the percentage of the farm underdrained. Secondly, all fields were divided into 2 groups - those drained post-scheme and those not. Post-scheme drainage was then cross-tabulated against a number of field level variables. The significance of the Chi-squared (or Pearson's r) statistics are summarised in Table 4.8.

Table 4.8
Farm and field factors associated with underdrainage

Significant variables (Signif. < 0.05)	Significance
<u>Farm Level</u>	
Farm tenure	0.0170
Percentage of farm to have changed land use (Pearson's $r = 0.40$)	0.0000
<u>Field Level</u>	
Field size (Pearson's $r = -0.0721$)	0.0470
Field tenure	0.0120
Field fragmentation	0.0000
Pre-scheme drainage status	0.0485
Field distance from buildings	0.0000
Pre-scheme flood frequency	0.0000
Pre-scheme flood duration	0.0000
Soil type	0.0000
Pre-scheme land use	0.0000

Finally, all variables with a significance of less than 0.05 were entered into a stepwise Discriminant Analysis to attempt to differentiate between those fields which have been drained since the scheme and those which have not. A discriminant function with 9 variables was obtained which correctly classified 72.5% of the cases entered. The variables included together with their standardised coefficients are shown in Table 4.9.

Table 4.9
Drainage installation - standardised discriminant function

Variable	Standardised coefficient
Owned land	-0.25
Field size	-0.28
Field contiguous to farm	+0.18
Pre-scheme drainage status	+0.35
Distance of field from farm buildings	-0.25
Pre-scheme flood frequency	-0.17
Percentage of farm in benefit area	+0.16
Silty clay soil	+0.18
Clay soil	-0.53

The discriminant function for the Regional data suggests that fields contiguous to the farm, with poor pre-scheme drainage, or with silty clay soils show more likelihood of field drainage installation following an improvement scheme. Where farms have a large percentage of their total area in the benefit area of a scheme, there is a greater likelihood of field drainage installation.

These findings reflect the influence of the Rother and Black Sluice schemes with large pumped areas containing large proportions of arable farms where field drainage was needed to fully exploit the potential of soils suited to arable production.

The negative standardised coefficients suggest that owned land is less likely to have drains installed. This is partly explained by the need to meet rents on tenanted land, and the fact that landlords may provide additional grants for farm improvements, whereas owner-occupiers need to produce much of the investment capital themselves. This was certainly the case in the Black Sluice scheme. Large field sizes, large distances from farm buildings, and clay soils all mitigate against drainage. These latter factors

particularly reflect the conditions on the King's Moor and Witcombe Bottom scheme.

If change of land use post-scheme is included as a discriminating variable, no increase in the percentage correctly classified is obtained.

The significant field level variables identified in the Regional analysis are the same as those found in the STWA results, but the list of significant farm level variables is quite different. Only one farm variable (the percentage of the farm that has changed land use) has proved significant. Previously significant farm variables such as farm size, farm type, farmer's age group and change of management since the scheme are no longer included.

The variables included in the Regional discriminant function were also very different from those included in the STWA function. Only 2 variables (owned land and percentage of farm in the benefit area) were common to both functions. The STWA function included a distinction between dairy and non-dairy farms, and between livestock and non-livestock farms, and highlighted those sites where there had not been continued security of tenure. The STWA function had been able to correctly classify 78% of all sites that had installed underdrainage after the improvements.

(iii) Change in Nitrogen Application on Grassland

A stepwise multiple regression was carried out on all fields that have stayed in grass since the scheme in order to identify factors that account for the observed variation in the change in nitrogen application. All field, farm and farmer variables were entered and an equation including 8 variables emerged. The variables included are shown in Table 4.10 along with their standardised regression coefficients (beta weights) which indicate the relative contribution and direction of influence of the associated variable.

Pre-scheme nitrogen application rates have the highest relative contribution (0.62), and have a negative direction of influence. This implies that sites which already had high nitrogen application rates were unlikely to increase usage after the scheme. This negative relationship between pre-scheme nitrogen levels and post-scheme levels had been found in the STWA

Table 4.10
Factors affecting the increase in nitrogen application on grassland

Variable	Beta weight
Change of field ownership since scheme	-0.457615
Pre-scheme nitrogen application rate	-0.623516
Agricultural qualifications	-0.130024
Drained pre-scheme	-0.279974
Member of NFU	-0.566299
Post-scheme grass type	-0.411260
Livestock farm	-0.215640
Pre-scheme drainage status	-0.115966

$$R^2 = 0.9306$$

analysis. Those sites where previously application rates were necessarily low because the land was so wet, are the ones that benefit most from increased nitrogen after the scheme. Two other "pre-scheme" variables influence application rates. Sites that had been drained before the scheme are associated with low increases in nitrogen application because rates were already relatively high (eg. Trodder Syke), whilst those with poor pre-scheme drainage status also recorded low increases (probably reflecting the effect of the King's Moor and Witcombe Bottom scheme). Sites with temporary grass after the scheme are associated with higher rates of nitrogen application. Livestock rearing and fattening farmers are associated with large increases in nitrogen application, but dairy farms do not influence either way.

Surprisingly, the 2 farmer characteristics 'membership of NFU' and 'possession of agricultural qualifications' are associated with low application rates, as are those fields that have changed ownership since the scheme. Each of these have assumed negative directions of influence whereas they had been positive in the STWA results.

(iv) Change in Grass Conservation System

To examine factors influencing the change in the grass conservation system, all sites which had stayed in grass were classified into one of 3 groups:

- (i) those which experienced no change,
- (ii) those which had changed from hay to zero conservation, and
- (iii) those which had changed from hay or zero conservation to silage.

A stepwise discriminant analysis was again used to differentiate between the groups. As, this time, there were 3 groups involved in the analysis, 2 discriminant functions were obtained (which between them correctly classified 92% of the cases studied). However, despite the high percentage of cases correctly classified, a total of 23 variables had to be combined to do so, and few of these have large absolute values, making interpretation difficult. The closeness of the group-means precludes individual variables from being significant in isolation or even in combination with one or 2 other variables.

It would appear that the best discrimination is between those sites that have experienced no change and those which have moved into silage-making. The 2 most important contributory factors are farm size and change of ownership. Larger farms and those which have changed ownership since the scheme seem to be more likely to move into silage.

4.2.3 Summary of Factors Influencing the Nature of Uptake

The Regional results suggest that common factors are responsible for land use change and field drainage installation. They are both more likely on fields with a poor pre-scheme drainage status and on those which form a contiguous unit with the farmstead. Land use change is also associated with change of occupant since the scheme. Post-scheme underdrainage is greatest where a large proportion of the farm lies within the boundary of an improvement scheme.

The Regional data suggests little association between factors influencing nitrogen application and change in grass conservation. Increased nitrogen use is particularly associated with livestock rearing and fattening farms, and fields undrained pre-scheme and those which had low initial levels of application. The move into temporary grass is also associated with higher nitrogen use. Changes in conservation system, however, are not influenced by any dominant variable or variable combination, although size of farm appears significant, as does land that has experienced a change in ownership since the scheme.

A degree of overlap of factors influencing land use change and underdrainage was also found in the STWA study, namely farm type (dairy), change of occupier following the scheme, and the proportion of the farm in benefit. With respect to the latter the STWA suggested more uptake occurred on farms with a lower proportion of farm size in the benefit area, the converse of the Regional findings. In the main, this reflected differences in farm types, sizes, and the configuration of the schemes between the Regional and STWA samples. In the STWA case, where farms were almost wholly in the benefit area they were generally committed to grass production and showed less tendency to change land use or install drainage. It was often those farms with small proportions in the benefit areas that changed land use and underdrained to bring such areas into the same farming pattern as the rest of the farm.

4.3 VARIATION IN THE RATE OF BENEFIT UPTAKE

4.3.1 Observed Variation in the Rate of Benefit Uptake

The field by field analysis of financial benefits revealed that it is possible to classify fields into one of 3 groups upon the basis of the rate at which financial benefits are taken up:

- (i) those with no take-up of potential benefits,
- (ii) those where the take-up is gradual, and
- (iii) those where take-up is abrupt¹.

1. Abrupt take-up of benefits is applied to a site where 50% or more of the increase in gross margin occurred in one year.

The relative importance of these 3 types is shown in Table 4.11 below.

Table 4.11
Types of benefit uptake

Type of uptake	% of area	% of benefit ²
Zero uptake	4.8	-
Abrupt uptake ¹	65.7	67.9
Gradual uptake	29.5	32.1
Total	100	100

1. Abrupt take-up of benefits is applied to a site where 50% or more of the increase in gross margin occurred in one year.

2. Excluding negative benefits. Measured as the difference in gross margin.

Zero uptake was reported on about 5% of the total surveyed areas. Two-thirds of the observed financial benefits (measured in terms of change in gross margin) occurred on sites where over 50% of the benefit arose in one year. There was little difference between gradual and abrupt uptake in the eventual average value of benefits per hectare. The timing of uptake, however, is critical where discounting methods are used for scheme appraisal.

Compared to the STWA study, the Regional results show much greater overall farmer response. In the STWA sample, zero uptake was recorded on 44% of the total benefit area, although the relative importance of abrupt and gradual uptake on areas recording benefit was similar. Undoubtedly, the main reason for the difference between the Regional and STWA findings reflects the difference in scheme selection within the 2 studies. The Regional sample understandably contains schemes considered by the respective drainage organisations to have been amongst the best performers. The STWA sample was a much broader and less biased selection of schemes within one Water Authority region.

The STWA findings highlighted the fact that in the study of the uptake of potential benefits, the dependent variable ('uptake of benefits') is

not binomial. This meant that, at any point in time, farmers could not be classified into "those who have taken up potential benefits" and "those who have not", and that therefore farmers could not easily be placed on a continuum of adopter categories from innovators to laggards. Some may have taken up benefits on one part of the farm, but not on another. It is therefore more useful to look at the benefit components, and study rates of uptake of these.

4.3.2 Factors Influencing the Rate of Uptake of Potential Benefits

Table 4.12 shows the relationship between the classes of uptake found above and drainage and land use change.

Table 4.12

Land use change and underdrainage by type of uptake (% of sites)

Land use change \ Drainage	No	No	Yes	Yes	Total (%)
	No	Yes	No	Yes	
No benefits from scheme	4.1	0.0	0.8	0.4	5.3
Abrupt uptake	26.7	9.7	11.0	24.2	71.6
Gradual uptake	6.8	6.3	4.9	5.1	23.1
Total	37.6	16.0	16.7	29.7	100

Significance of Chi-square = 0.0000

Gradual uptake is spread evenly over the 4 combinations of land use change and underdrainage. The abrupt uptake category is most likely to involve either no land use change and no drainage, or both land use change and drainage. In the former case benefits are mainly associated with intensification of grass or arable following reduced flood risk.

The STWA methodology was further followed in that stepwise multiple regression techniques were used to derive equations for predicting the timing of uptake on sites where it has been abrupt. Three variables were taken as the dependents:

- (i) the timing of financial uptake (measured as the year in which 50% or more of the change in gross margin occurred),

- (ii) the timing of drainage, and
- (iii) the timing of land use change.

Like the STWA findings, no meaningful equation could be derived for the timing of financial uptake using the farm, farmer and field variables.

(i) Timing of Land Use Change

Eleven independent variables were included in the final regression equation on the timing of land use change, and these are summarised with their relevant Beta weights in Table 4.13. Only those sites which had experienced a change in land use since the scheme were included in the analysis.

Table 4.13
Variables associated with timing of land use change

Variables	Beta Weight
<u>Farm Level</u>	
Arable farm	0.45
Farm as business	0.36
Age group of farmer	-0.12
Percentage of farm in benefit area	0.26
Farm size	-0.17
Member of NFU	-0.23
Agricultural qualifications	-0.19
Sons to take over farm	0.17
<u>Field Level</u>	
Change of occupant since scheme	0.33
Pre-scheme land use	-0.43
Pre-scheme flood duration	-0.13

$$R^2 = 0.43$$

Although 11 variables are included the regression equation explains only 43% of observed variation in the timing of land use change. Several factors have been identified as having moderate associations with the timing of land use change. Arable farms, for example, are more likely to change land use quickly, reflecting the influence of the Black Sluice and Rother farms as opposed to the non-arable sites of the Trodder Syke and King's Moor and

Witcombe Bottom. Farms which are run more as a business than a way of life are also more likely to change land use soon after improvements (certainly the case on the tenant farms of the Black Sluice) together with those that have a large percentage of the farm within the benefit area.

The STWA study produced a much higher R^2 value (0.77) and identified high pre-scheme flood frequency and poor pre-scheme drainage status as variables strongly related to more rapid land use change.

(ii) Timing of Drainage Installation

Seven independent variables were included in the final regression equation on the timing of drainage installation, and these are summarised with their relevant Beta weights in Table 4.14. Only those sites which had had field drainage installed since the scheme were included in the analysis.

Table 4.14
Variables associated with timing of drainage installation

Variables	Beta Weight
<u>Farm Level</u>	
Arable farm	0.25
Farm size	0.34
Percentage of farm in benefit area	0.23
NFU member	-0.12
<u>Field Level</u>	
Change of management since scheme	0.19
Clay soil	-0.26
Silty soil	-0.24

$$R^2 = 0.299$$

The R-squared value for the equation shows a low level of explanation, and few significant variables can be identified. Large farms, particularly arable farms, with large proportions of the whole farm in the benefit area are more likely to install field drainage in early project life, reflecting similar important variables to those associated with the timing of land use change.

In the Severn-Trent results, an R^2 value of 0.65 was obtained, and the equation showed that early drainage installation tended to be associated with sites where the change in flood frequency had been highest and which had not been drained pre-scheme.

4.4 UPTAKE CURVES

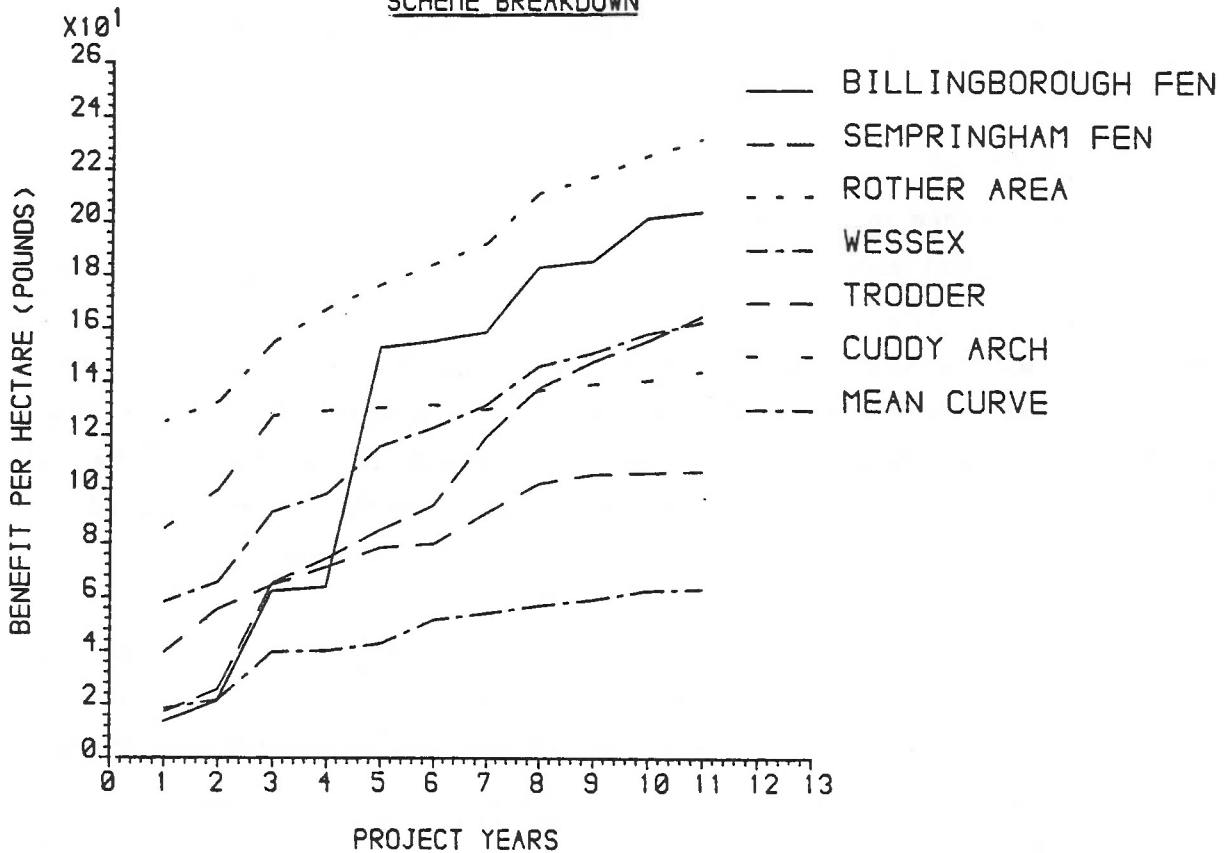
4.4.1 Uptake of Financial Benefit

The observed values for net returns for each year of project life were converted to a value of extra benefit per hectare by subtracting the pre-scheme net return, and expressed by year of project life. The first year of project life was deemed to be that containing the completion of major (but not necessarily all) project works such that potential benefit uptake is feasible. On some larger schemes, the completion of works often occurred in stages over a period of years, and this complicates the analysis.

The curves in Figure 4.1 show the mean uptake of financial benefits for the 6 schemes examined in the Regional study. There are considerable differences between schemes in terms of the degree of benefit uptake. Benefits are greatest on the large, mainly arable, pumped schemes of the Rother and Black Sluice, more moderate yet considerable on the mainly grassland schemes of Cuddy Arch and Trodder Syke, and least on the King's Moor and Witcombe Bottom. In the majority of cases it is possible to identify an 'S'-shape in the individual curves; a slow start, a period of rapid uptake, followed by a levelling off. This is generally consistent with the theory of innovation adoption and diffusion. The predominantly arable schemes show a continuing increase in benefit uptake over time, whereas benefit uptake on mainly grassland schemes shows a tendency to level off.

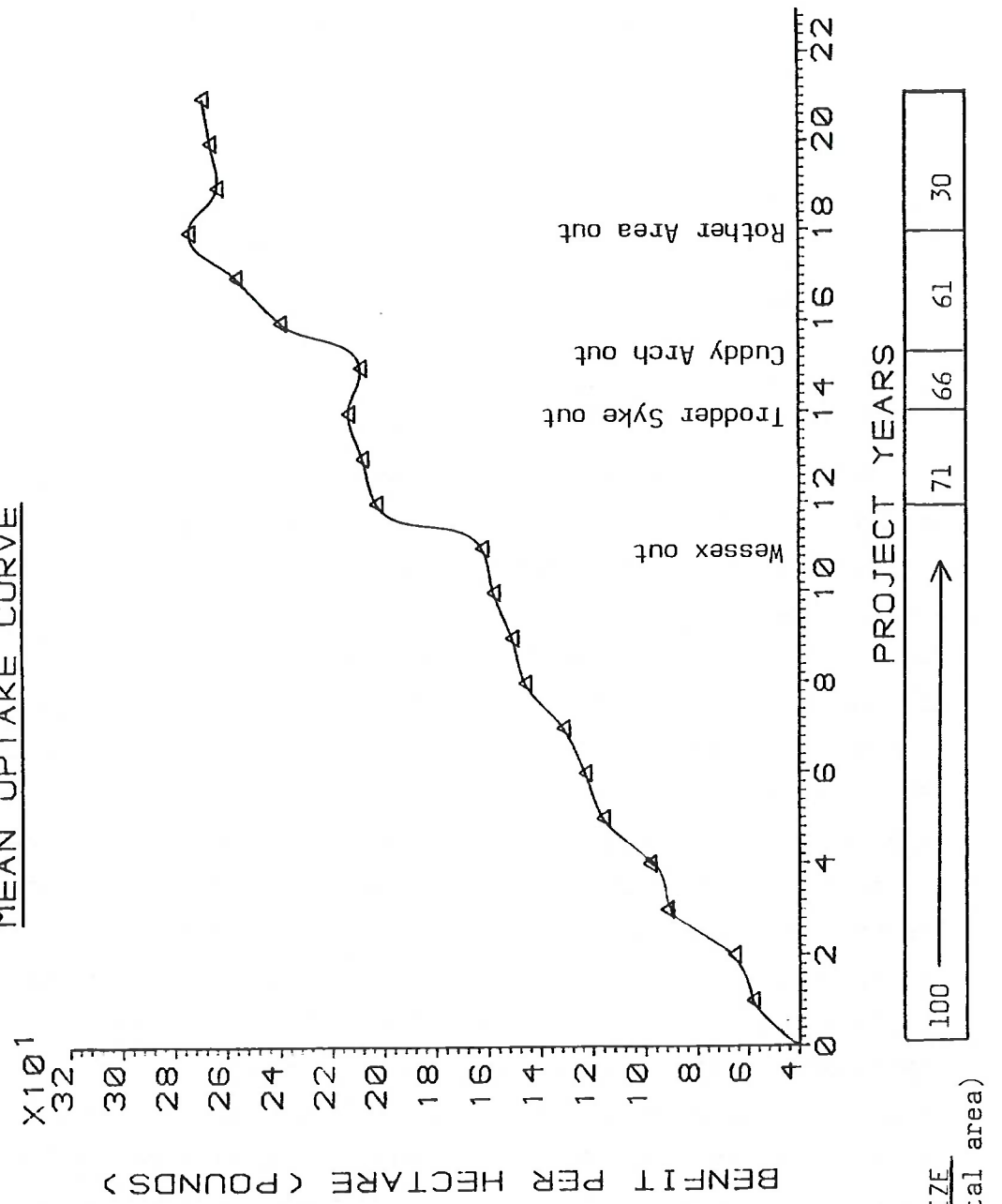
Figure 4.2 aggregates the individual scheme curves into a mean uptake curve for the entire sample over a 21 year period. The number of years observed for schemes varies from 11 in the case of the King's Moor and Witcombe Bottom scheme to 21 years for the Black Sluice IDB. Consequently the sample size varies from 4,969 ha (100% of the total areas surveyed) in year 1 to 2,912 ha (58%) in years 19 to 21. The distribution of points about the curve, however, is wide (with a mean standard deviation of £115).

FIGURE 4.1 UPTAKE OF BENEFITS
SCHEME BREAKDOWN



The 'S'-shape observed for individual schemes is obscured in the aggregate curve. The curve has a step in the first year reflecting automatic benefits largely associated with extended grazing and savings in flood damage costs. The large variation in average benefits per hectare between the schemes and the variation in their ages means that the aggregate curve is difficult to interpret. Upto year 11, with all schemes in the sample, an 'S'-shape is discernable. After year 11 the steps in the curve largely reflect the change in sample size. For example, the first step in the curve is a reflection of the impact of the King's Moor and Witcombe Bottom scheme. This is a scheme characterised by much lower levels of benefit uptake than the other 5 schemes, and does in fact depress the average benefit per hectare. Once it is removed, net benefits increase by over £40/ha. The older schemes in the sample are also those with the highest benefits (a reflection of scheme characteristics rather than maturity). Thus, when the younger, mainly grassland schemes leave the sample, those remaining generate a higher average

FIGURE 4.2 : UPTAKE OF BENEFITS
MEAN UPTAKE CURVE



benefit per hectare. Figure 4.3 shows the average incremental benefit per hectare. It demonstrates high benefit uptake in the first year followed by great annual variations such that a 'normal' distribution associated with an S-shaped curve is not apparent.

Figure 4.4 compares the Regional and STWA mean aggregate uptake curves. By comparison, the STWA curve conforms more closely to the 'S'-shaped adoption curve. However, the rate of adoption and the degree of uptake was much greater in the Regional sample compared to the STWA cases. Uptake showed a tendency to stagnate in the third and fourth years in the STWA sample, whereas in the Regional study this was a period of rapid adoption. From Year 5 onwards average annual benefit uptake per hectare is higher by £80 (1982 prices) in the Regional study. This difference largely reflects the relatively greater average potential for improvement offered by the schemes in the Regional study.

4.4.2 Standardised Uptake Curves

The mean uptake curve (Figure 4.2) is difficult to interpret because of the great variation amongst schemes in terms of benefit levels and age of scheme. Attempts were made to remove the influence of these variations by producing standardised uptake curves. This was done in 2 ways. First, a mean standardised potential uptake curve (Figure 4.5) was obtained by taking for each scheme the observed annual uptake (in terms of gross margin) and expressing this as a percentage of the potential increase in gross margin for the scheme concerned, and finding the average annual value for the 6 schemes. The individual potential for each scheme are described in the relevant scheme appraisal reports (Annexe 1) and have been based on a reasonably achievable target for post-scheme land use, depending upon land capability and local farming practice. As explained in the STWA Report (Morris et al, Annexe IX, 4.4), however, this estimate of potential, because it is made in terms of gross margins, does not consider the extent of extra capital investments required on individual farms, and also does not make an adjustment for the fact that pre-scheme benefit levels may have been below pre-scheme potential. As a result of this, the mean potential uptake curve in Figure 4.5 should be interpreted with caution, yet the shape is important. Rapid uptake is observed in the first 5 years of project life after which the rate of uptake continues almost linearly albeit at a lower rate. Overall, the curves

Figure 4.3

Mean financial uptake curve: incremental benefit
(with Wessex and STWA comparison)

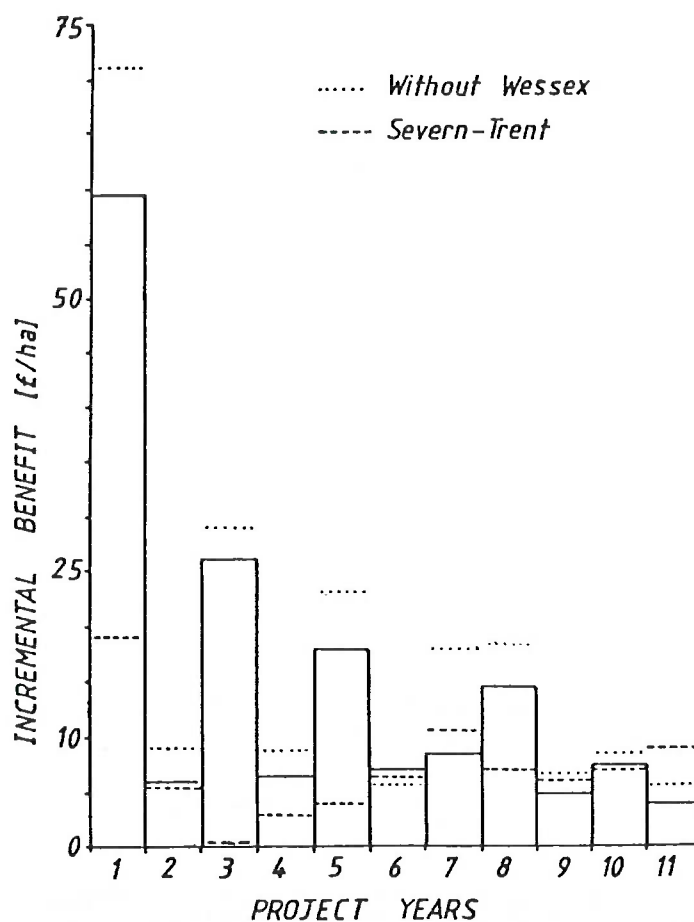


FIGURE 4.4

COMPARISON OF MEAN FINANCIAL UPTAKE CURVES

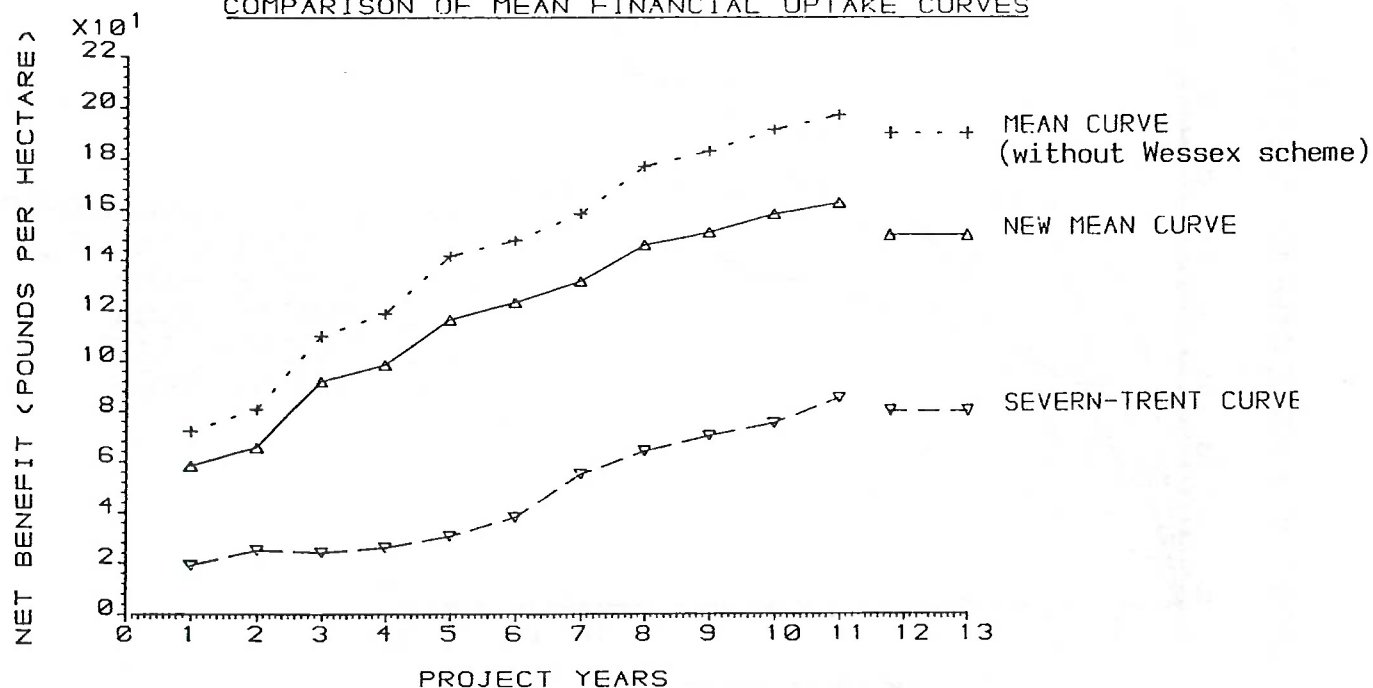
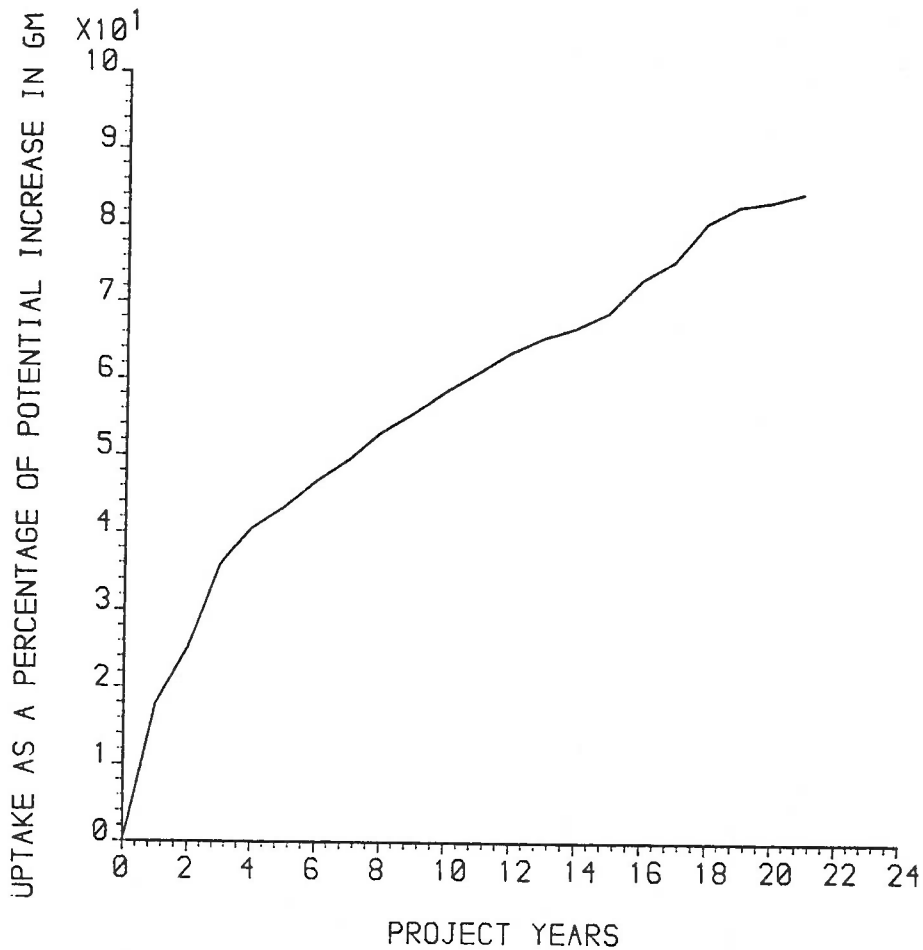
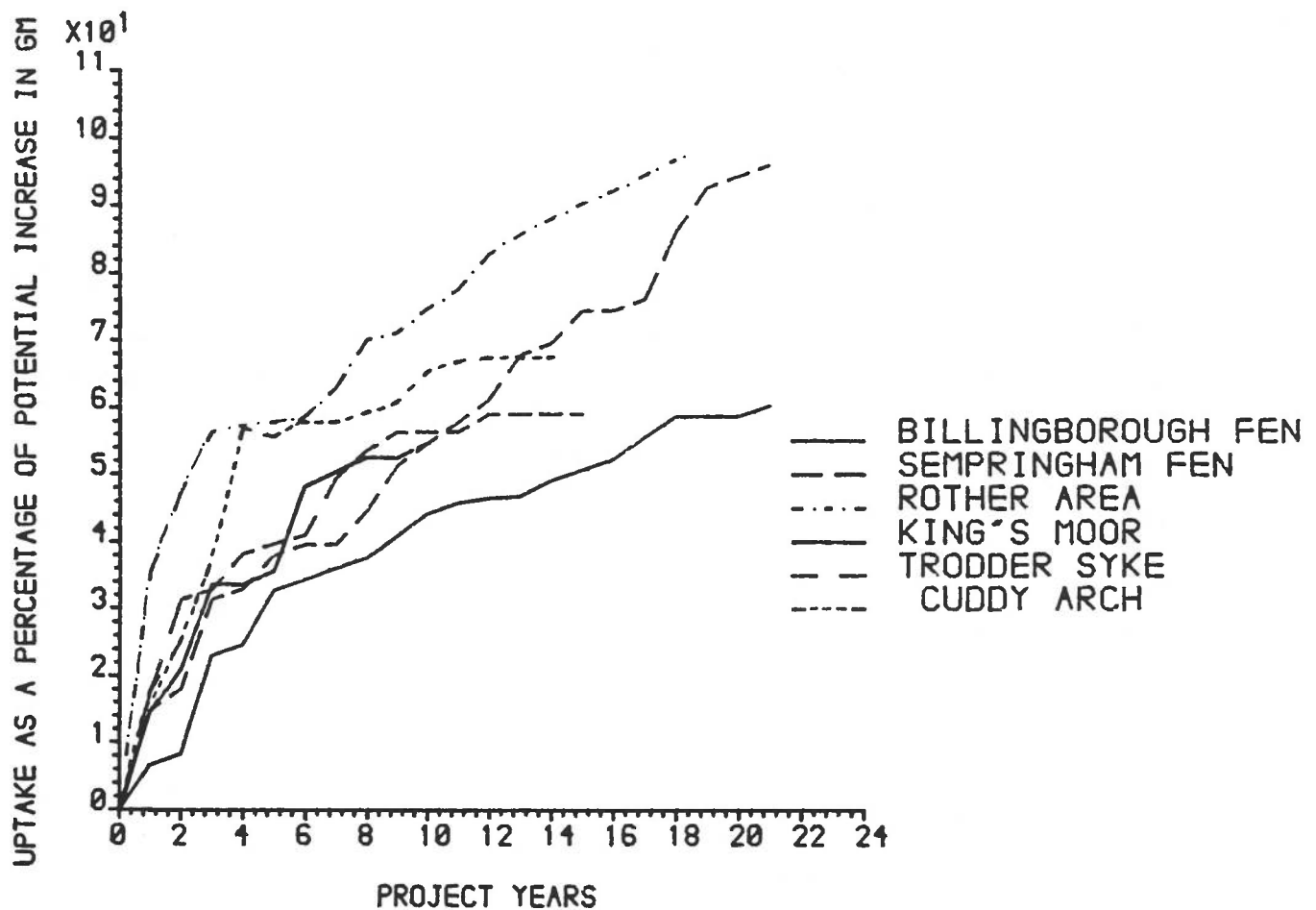


Figure 4.5 : MEAN STANDARDISED POTENTIAL UPTAKE CURVEFigure 4.6 : COMPARISON OF STANDARDISED POTENTIAL UPTAKE CURVES

demonstrate a diminishing marginal rate of uptake, with a tendency to flatten at about 20 years. Final average uptake as a percentage of potential is high at 84%. Figure 4.6 shows the individual scheme potential curves on which Figure 4.5 is based.

A second standardising approach produced mean benefit uptake curves for each scheme, as well as the average of the 6, by expressing annual benefit uptake (in terms of net benefit) as a percentage of the final observed uptake. This was the approach used to obtain the 'S'-shaped aggregate uptake curve for the STWA study (Morris et al, Main Report, Figure 7.1). The curves produced are shown in Figures 4.7 and 4.8. Once again, the shape is important, and is much more convex than 'S'-shaped. The first 3 years are noted for a very rapid phase of benefit uptake, with 50% of total benefits already taken up by the end of that period. Years 4 to 8 exhibit a reduction in the rate of uptake, by the end of which period 78% of final benefits have been taken up. Thereafter, benefits begin to level off. Overall, the curve demonstrates a diminishing marginal rate of uptake.

4.4.3 Classification of Uptake by Selected Variables

A number of classifications were examined in an attempt to derive a suite of uptake curves for individual variables which may give a better description of uptake than the aggregate curve. As in the STWA study, the variables chosen for this purpose were simple and easily measurable (in order to avoid complex multivariate interactions that would be inappropriate for simple prediction).

The curves are shown in Figures 4.9 to 4.22, together with the mean uptake curve for comparison. To further compare the advantage of each classification over the simple mean curve, the mean standard deviation was used as a simple indicator of fit and the values of the various curves are shown in Table 4.15. The curves have been drawn to reveal any differences in shape between classes within a suite rather than differences in height. The height of the curve measured on the y-axis represents the value of benefit, whereas shape reflects the rate or timing of uptake; highlighting differences in shape are more useful for predictive purposes.

Figure 4.7 : MEAN BENEFIT UPTAKE CURVE
(FOR ALL SIX SCHEMES)

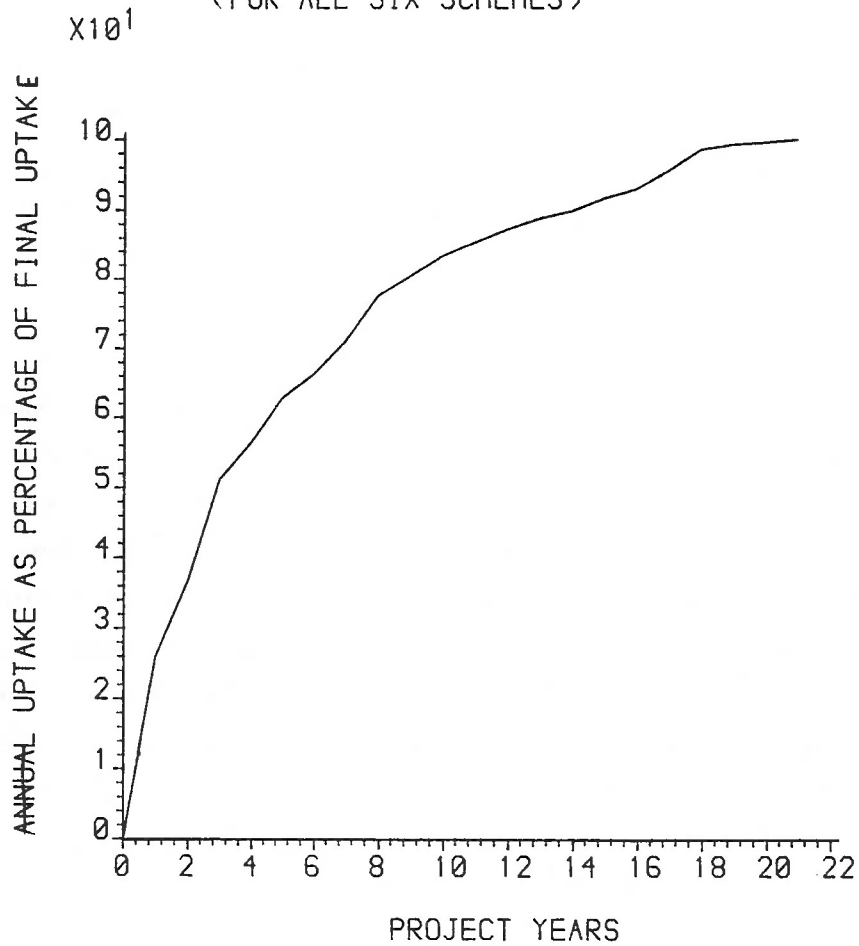


Figure 4.8 : COMPARISON OF MEAN BENEFIT UPTAKE CURVES

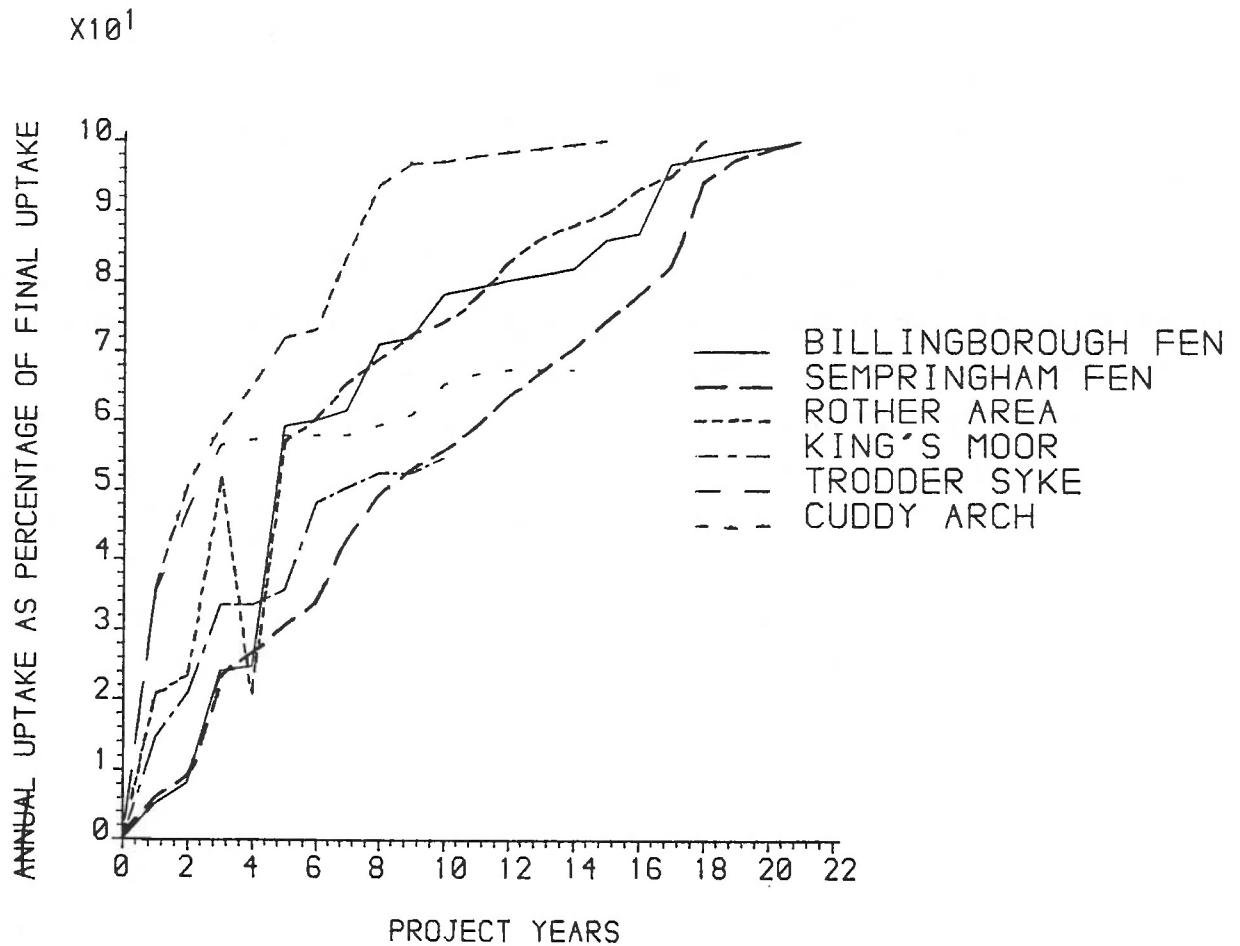


FIGURE 4.9 UPTAKE OF BENEFITS
FIELD TENURE STATUS

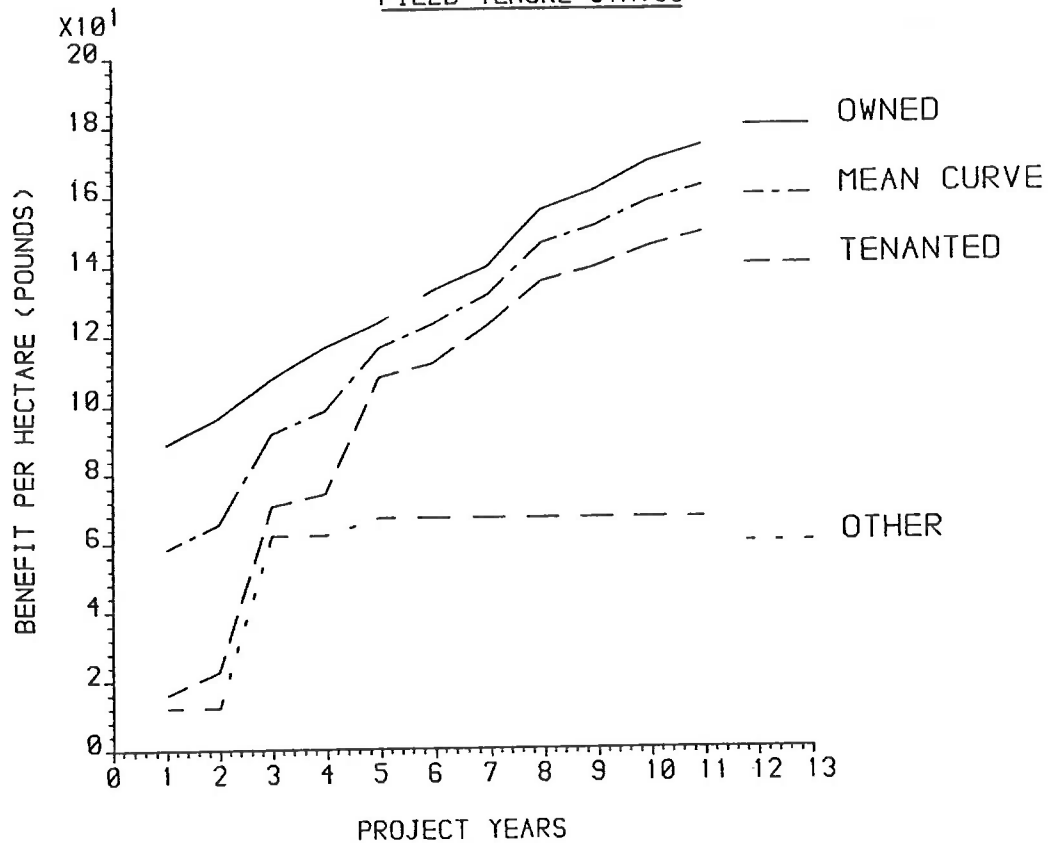


FIGURE 4.10 UPTAKE OF BENEFITS
LENGTH OF FIELD OCCUPANCY

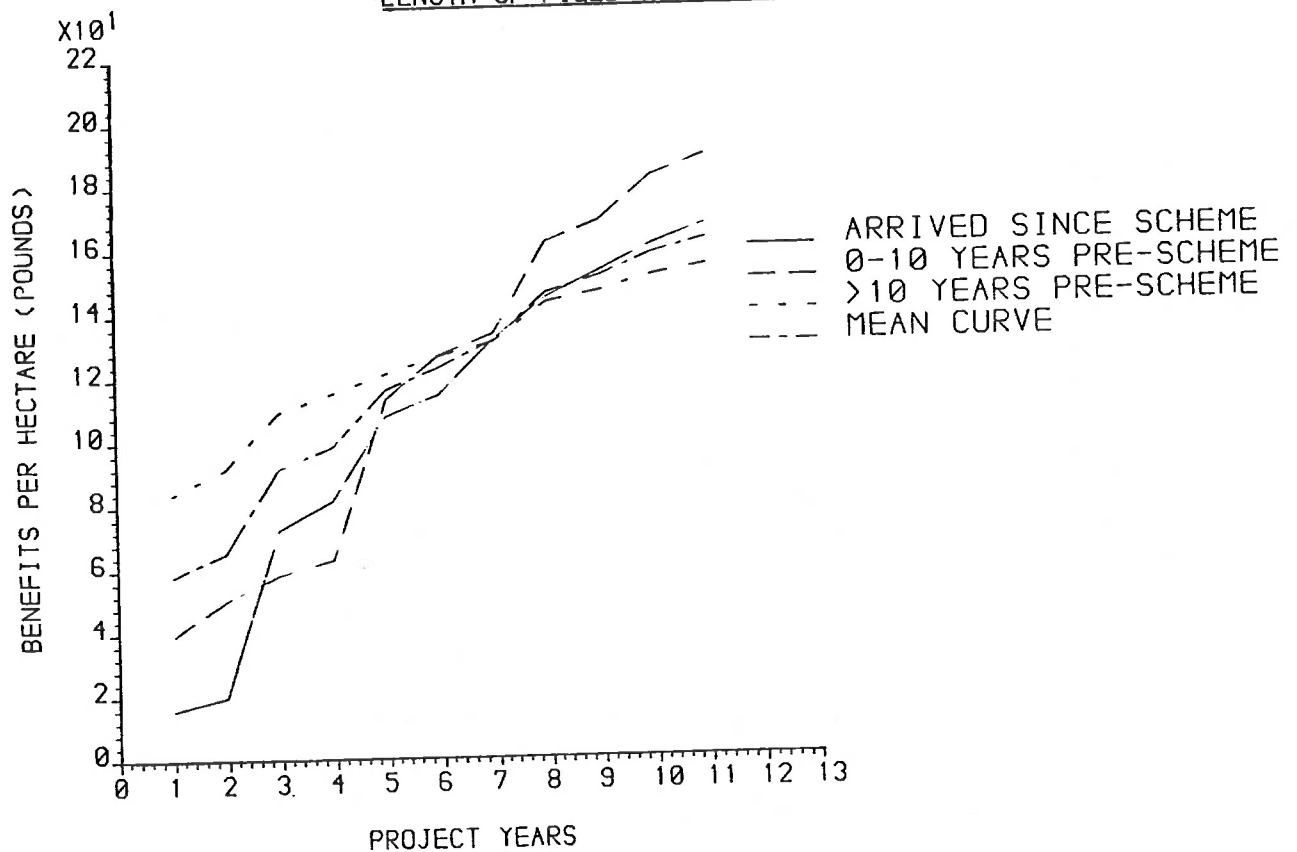


FIGURE 4.11 UPTAKE OF BENEFITS
LAND USE CHANGE

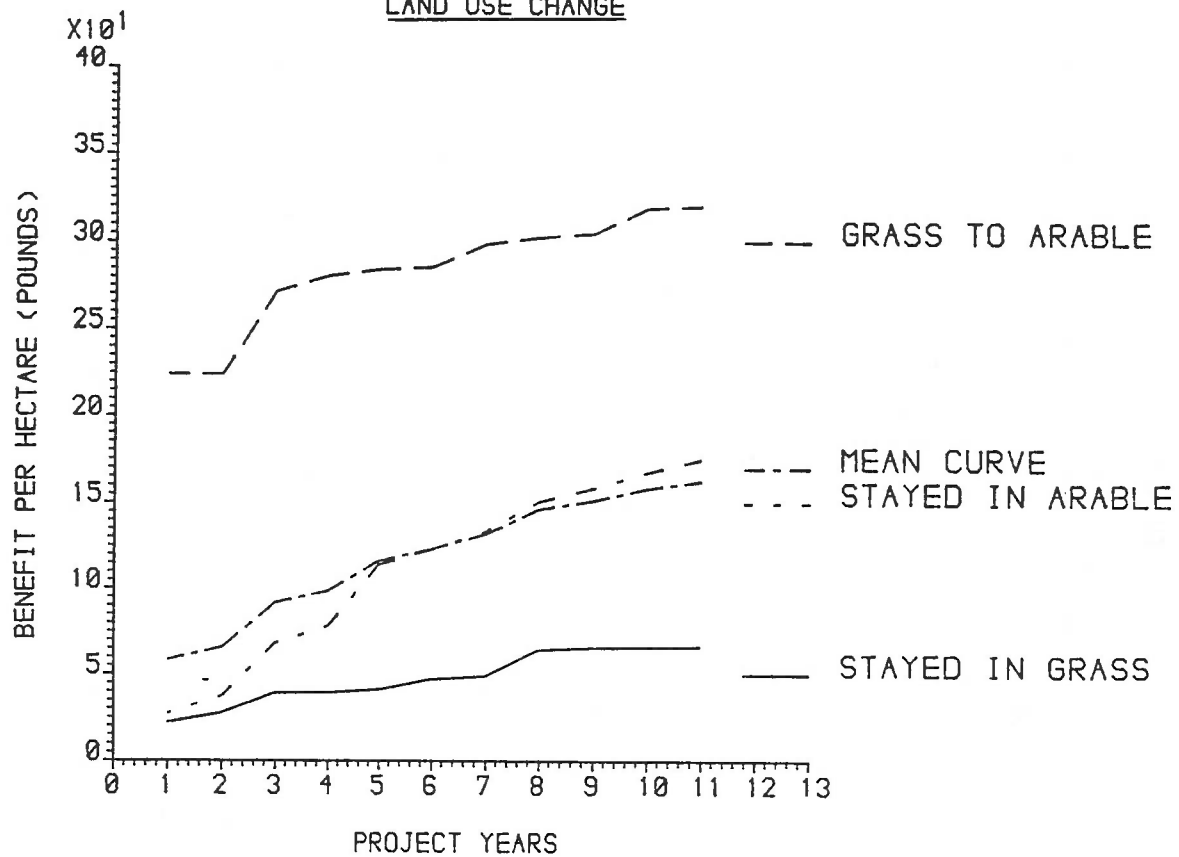


FIGURE 4.12 UPTAKE OF BENEFITS
AGRICULTURAL QUALIFICATIONS

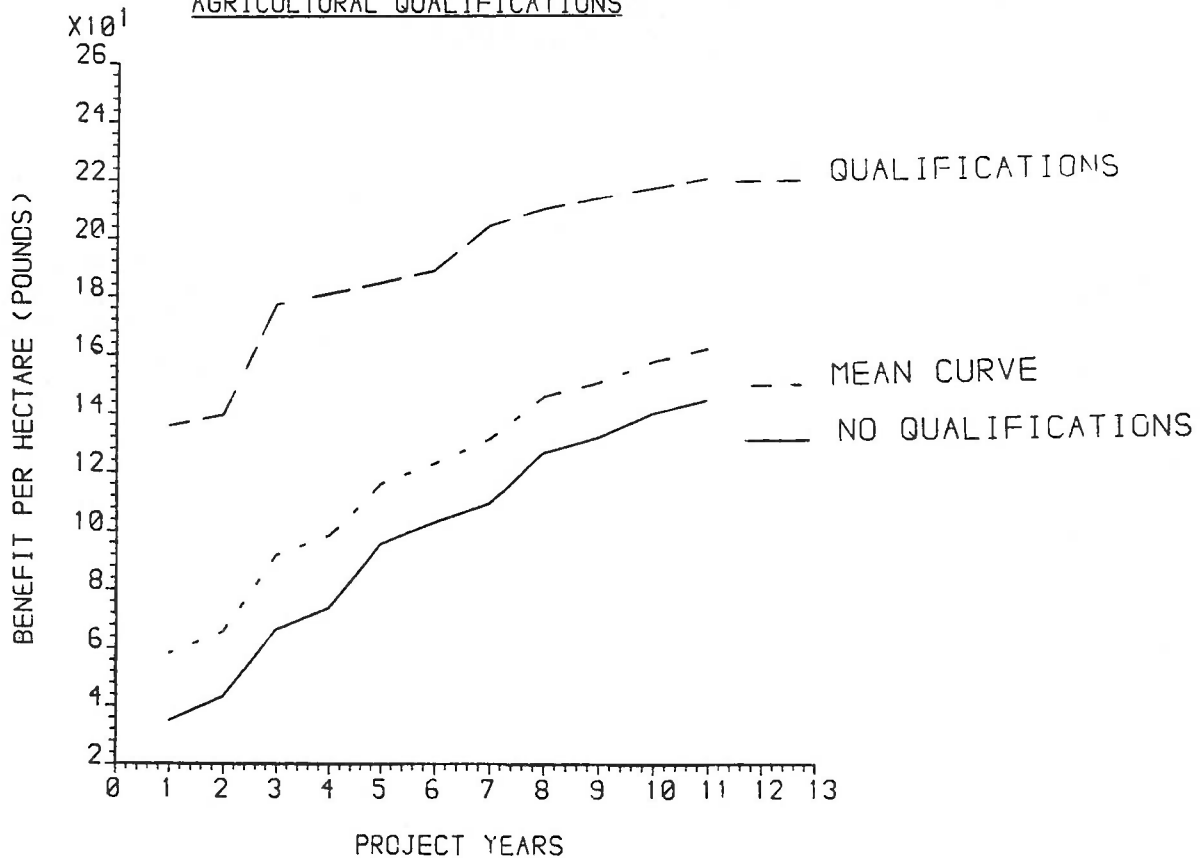


FIGURE 4.13 UPTAKE OF BENEFITS
NUMBER OF HOLDINGS

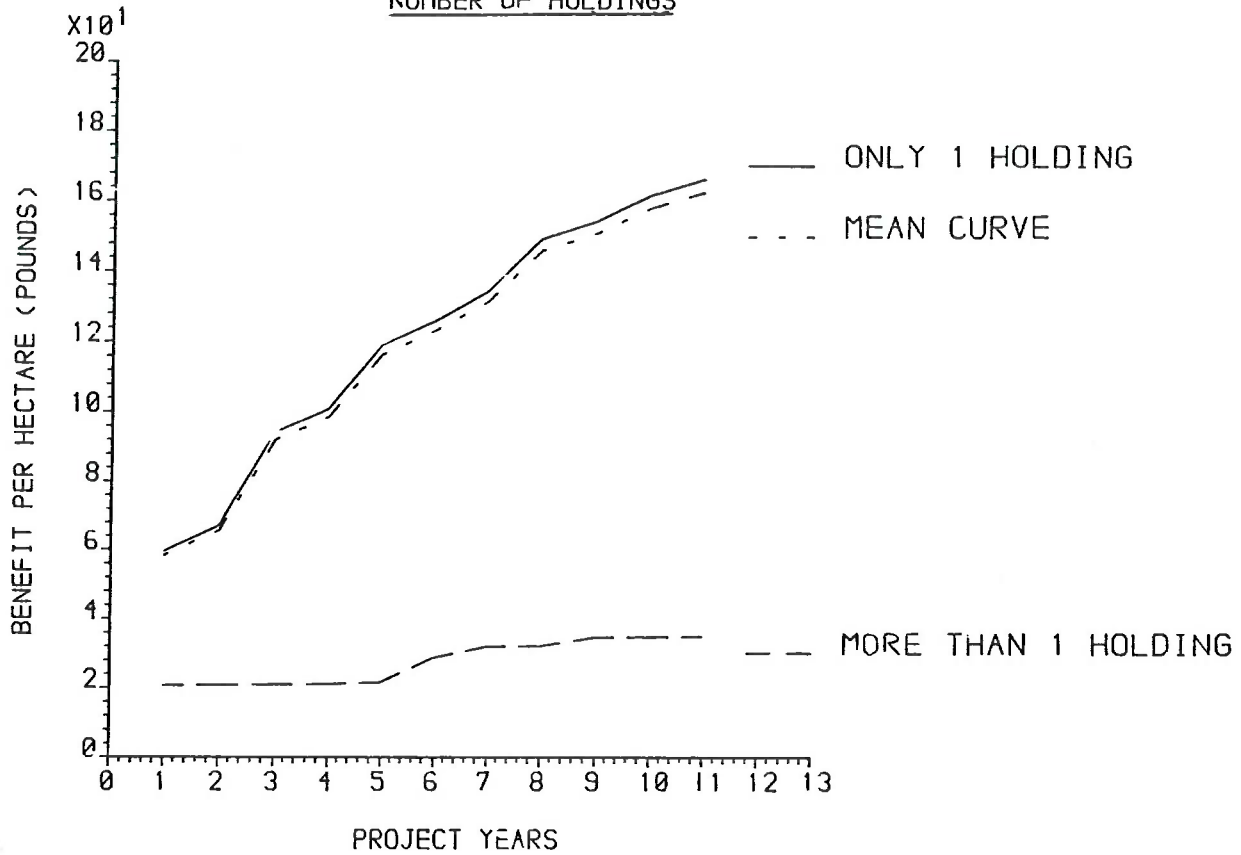


FIGURE 4.14 UPTAKE OF BENEFITS
DISTANCE OF FIELD FROM FARM

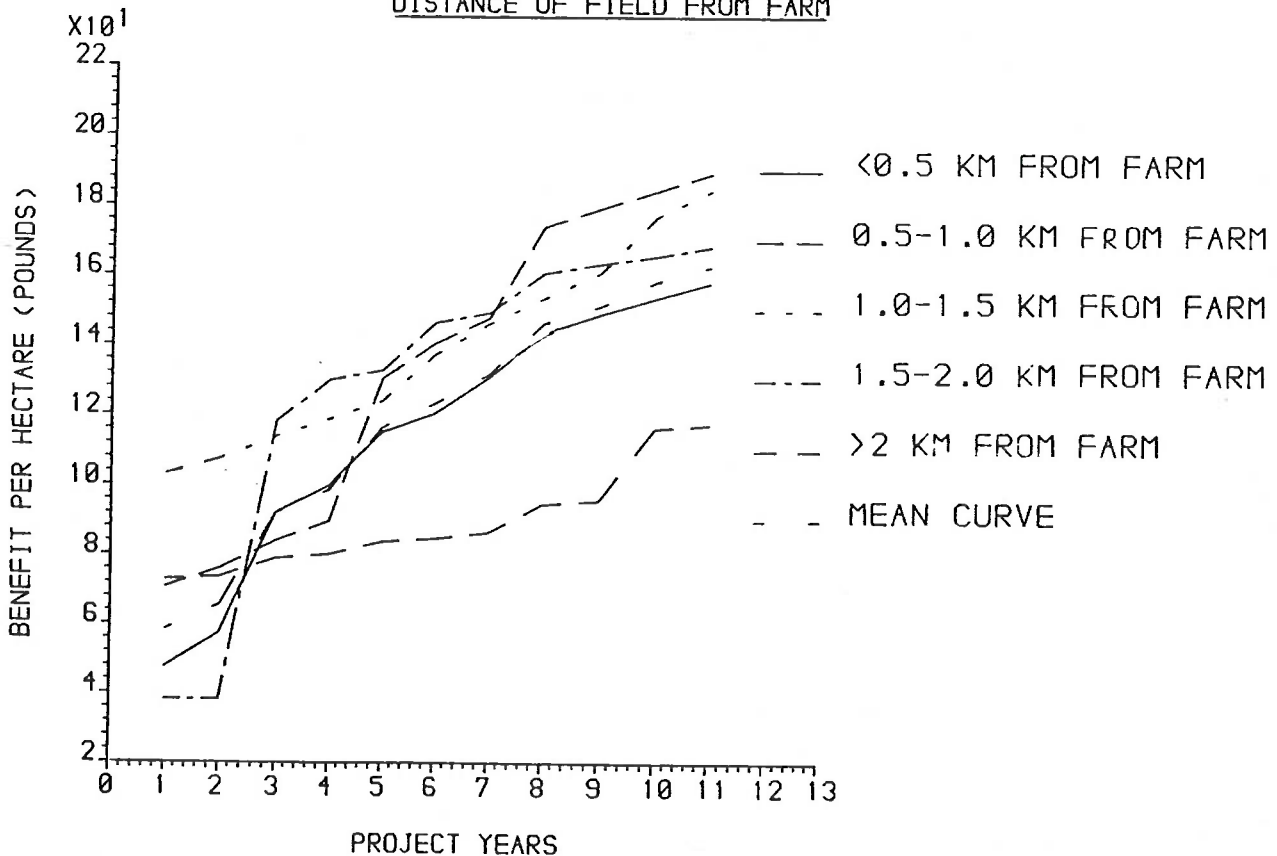


FIGURE 4.15 UPTAKE OF BENEFITS
PRE-SCHEME UNDER-DRAINAGE

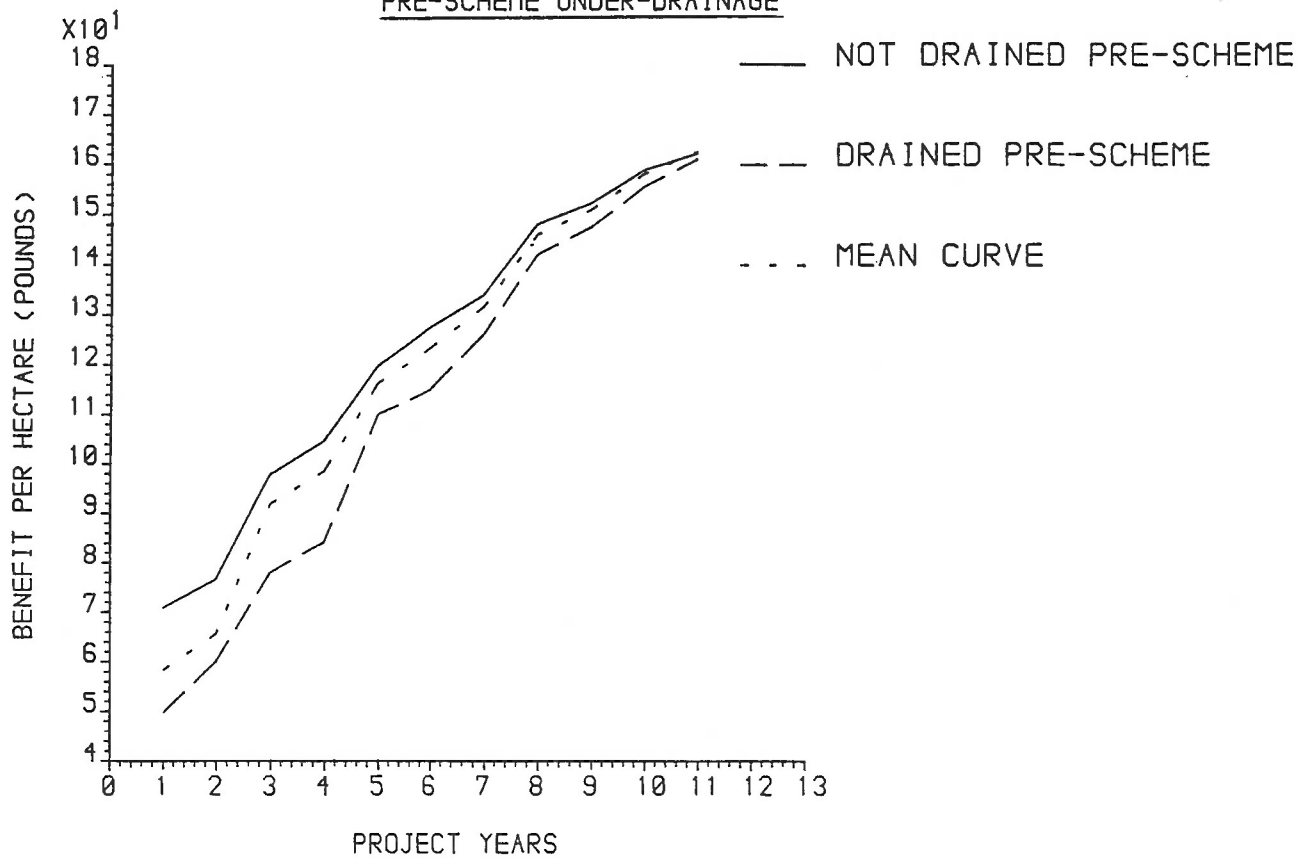


FIGURE 4.16 UPTAKE OF BENEFITS
POST-SCHEME UNDER-DRAINAGE

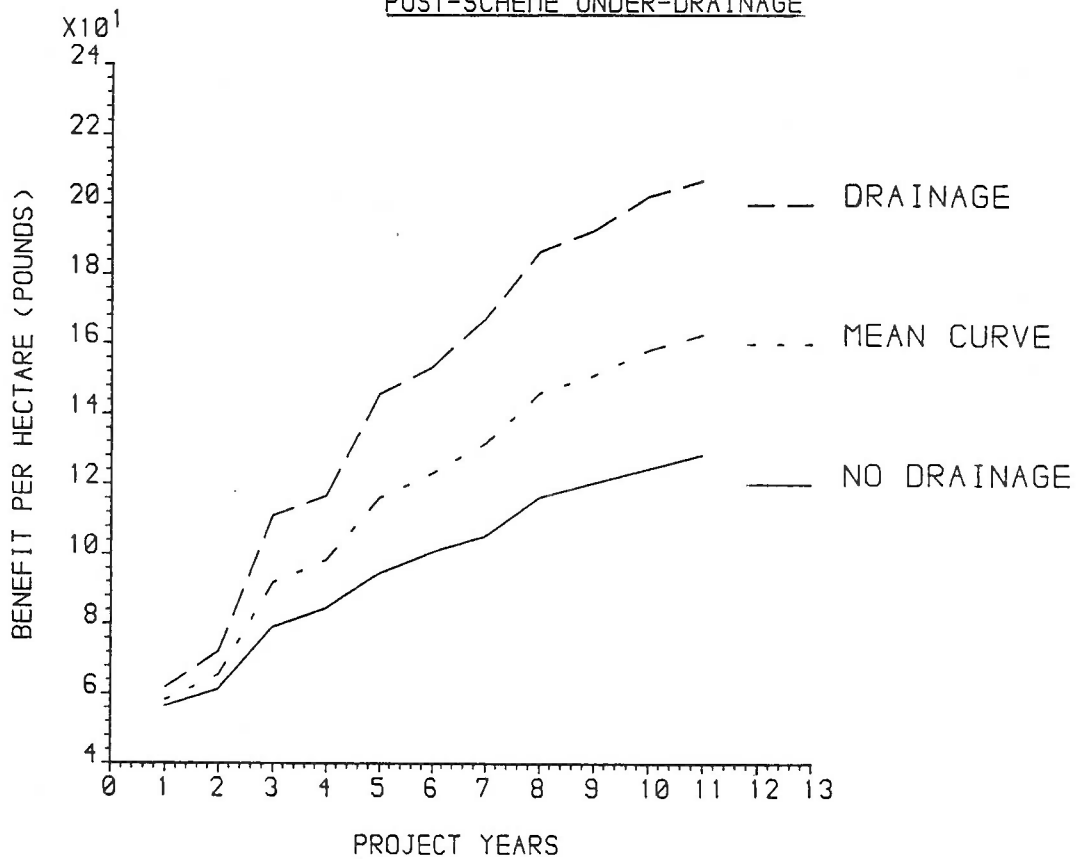


FIGURE 4.17 UPTAKE OF BENEFITS
FARMER AGE GROUP

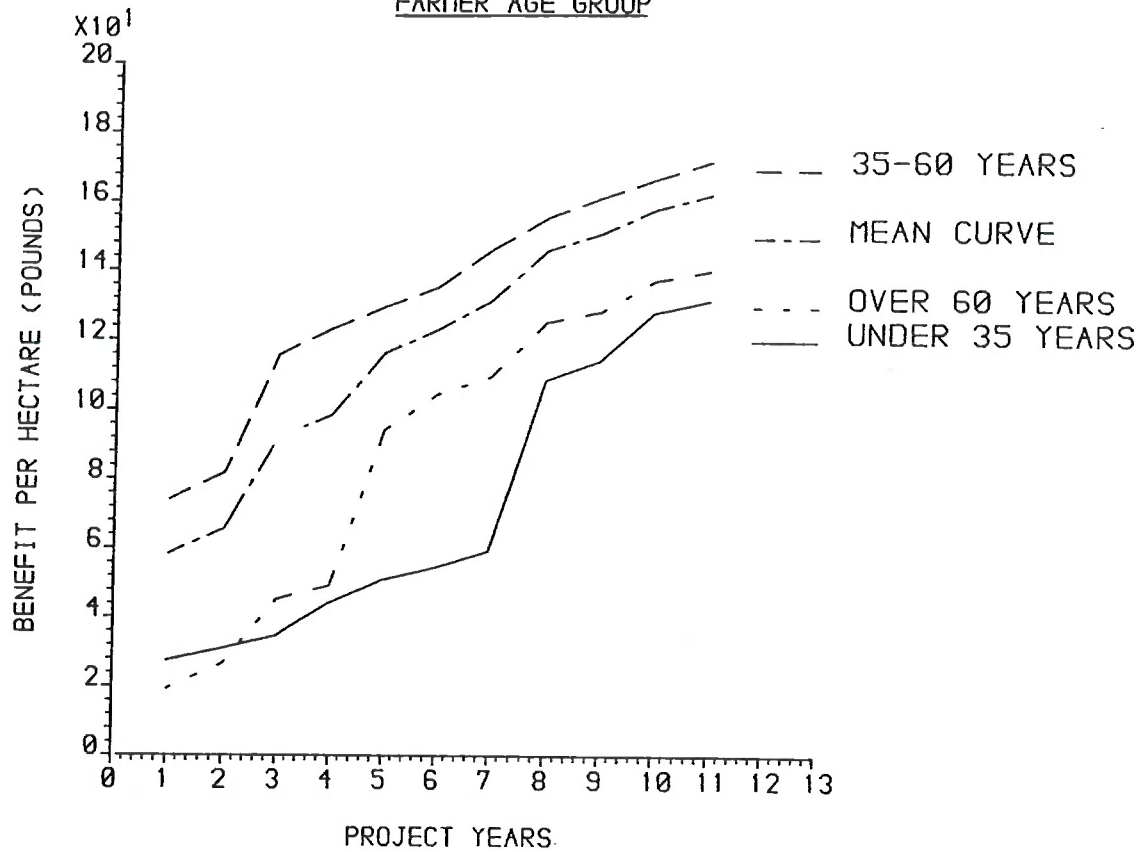


FIGURE 4.18 UPTAKE OF BENEFITS
CONTINUITY IN MANAGEMENT

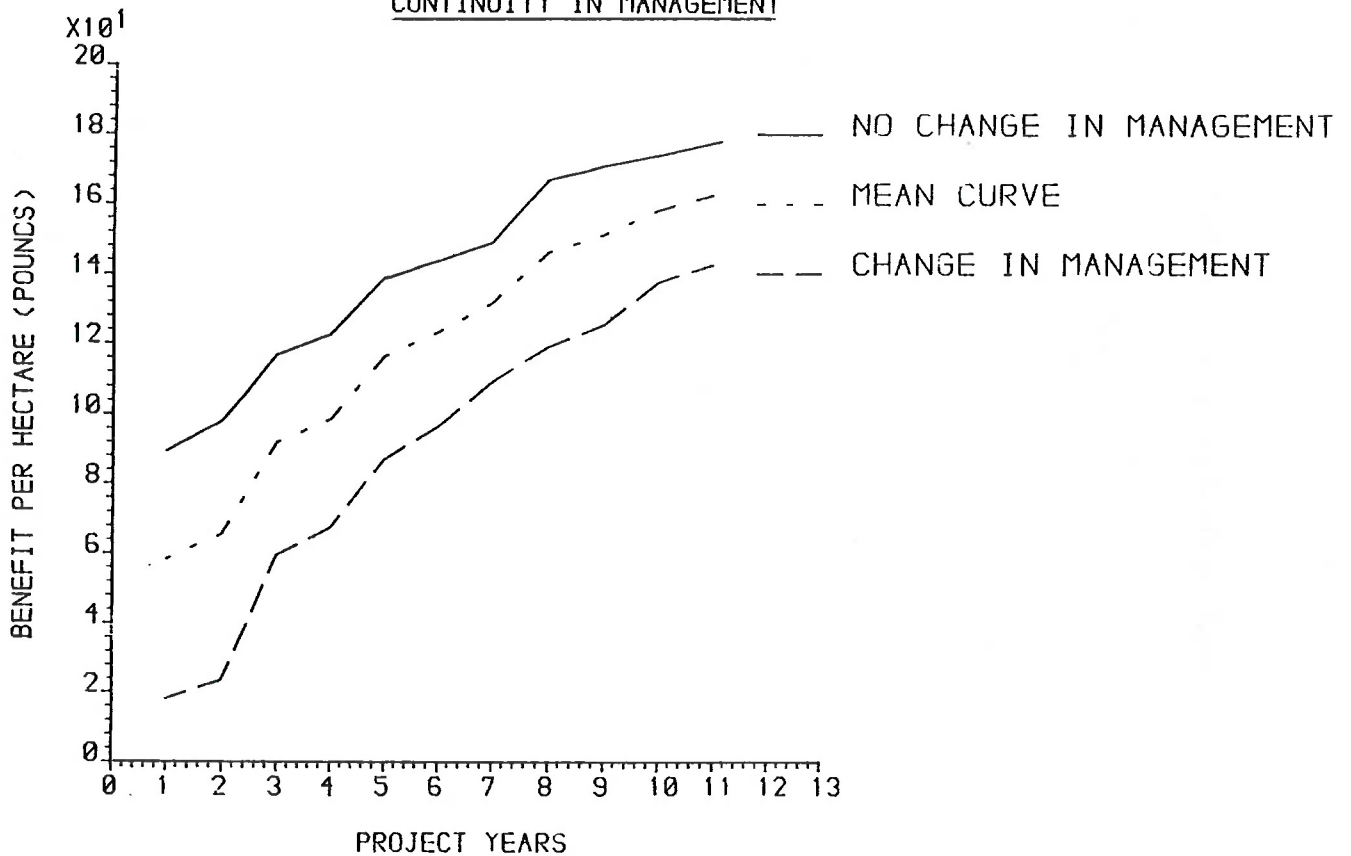


FIGURE 4.19 UPTAKE OF BENEFITS
FARMTYPE

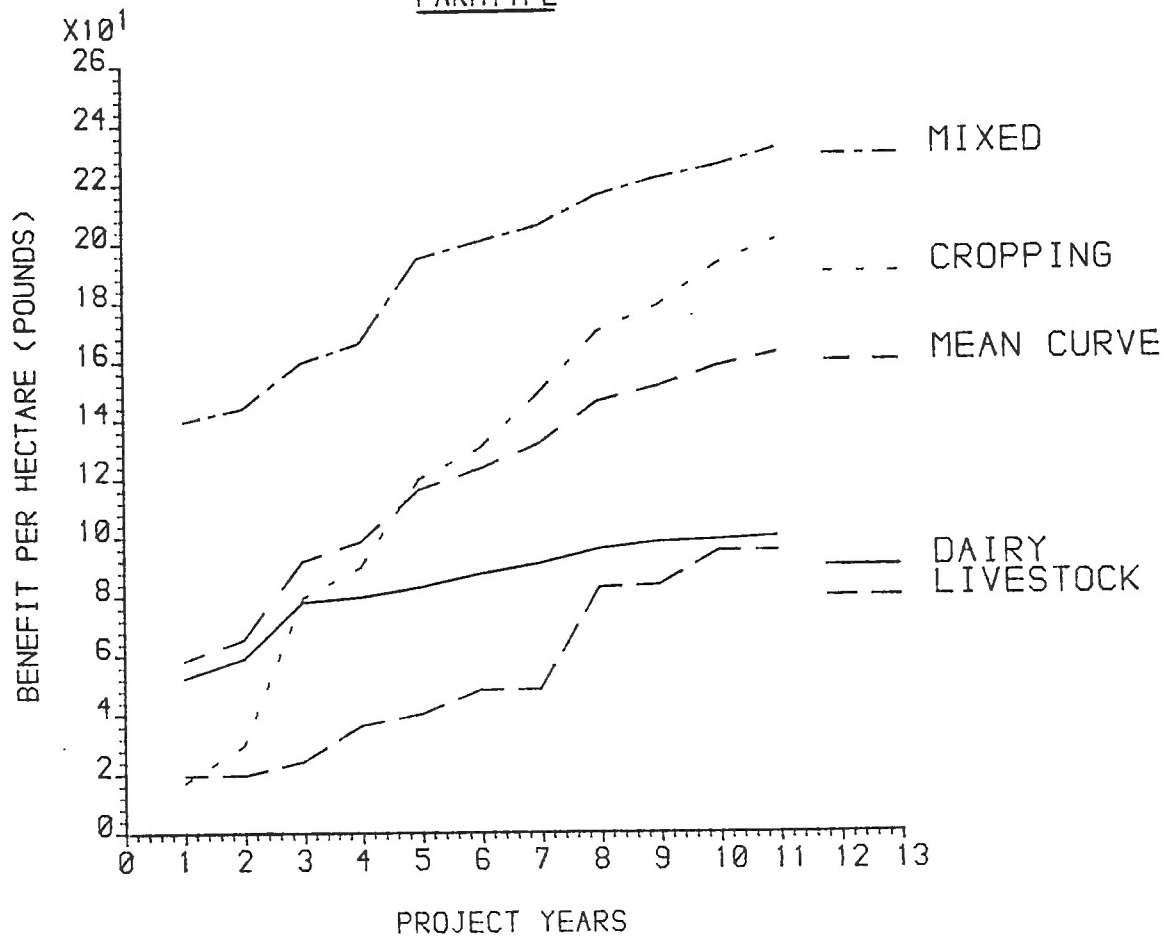


FIGURE 4.20 UPTAKE OF BENEFITS
POST-SCHEME FLOODING

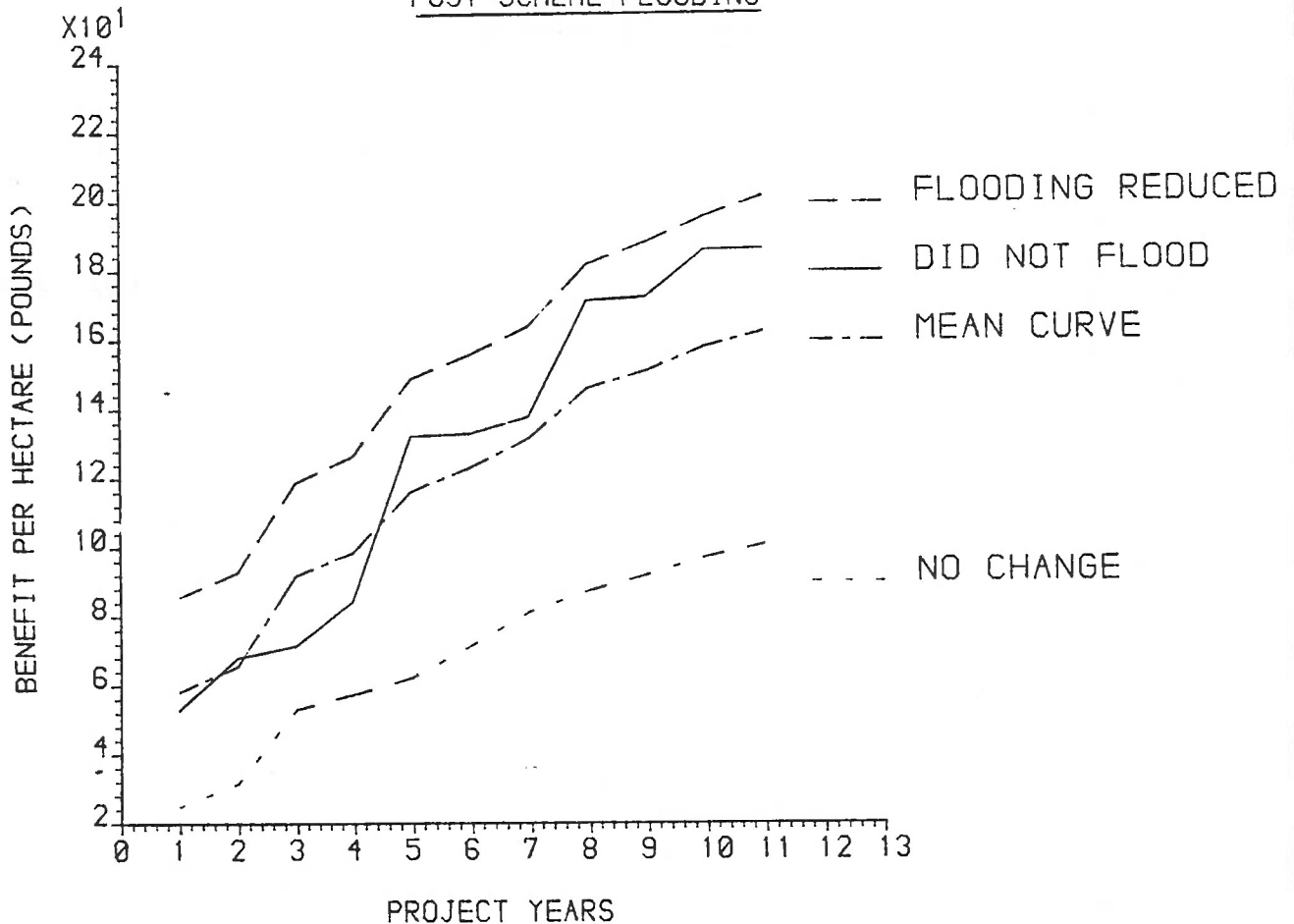


FIGURE 4.21 UPTAKE OF BENEFITS
CONTINUITY IN OWNERSHIP

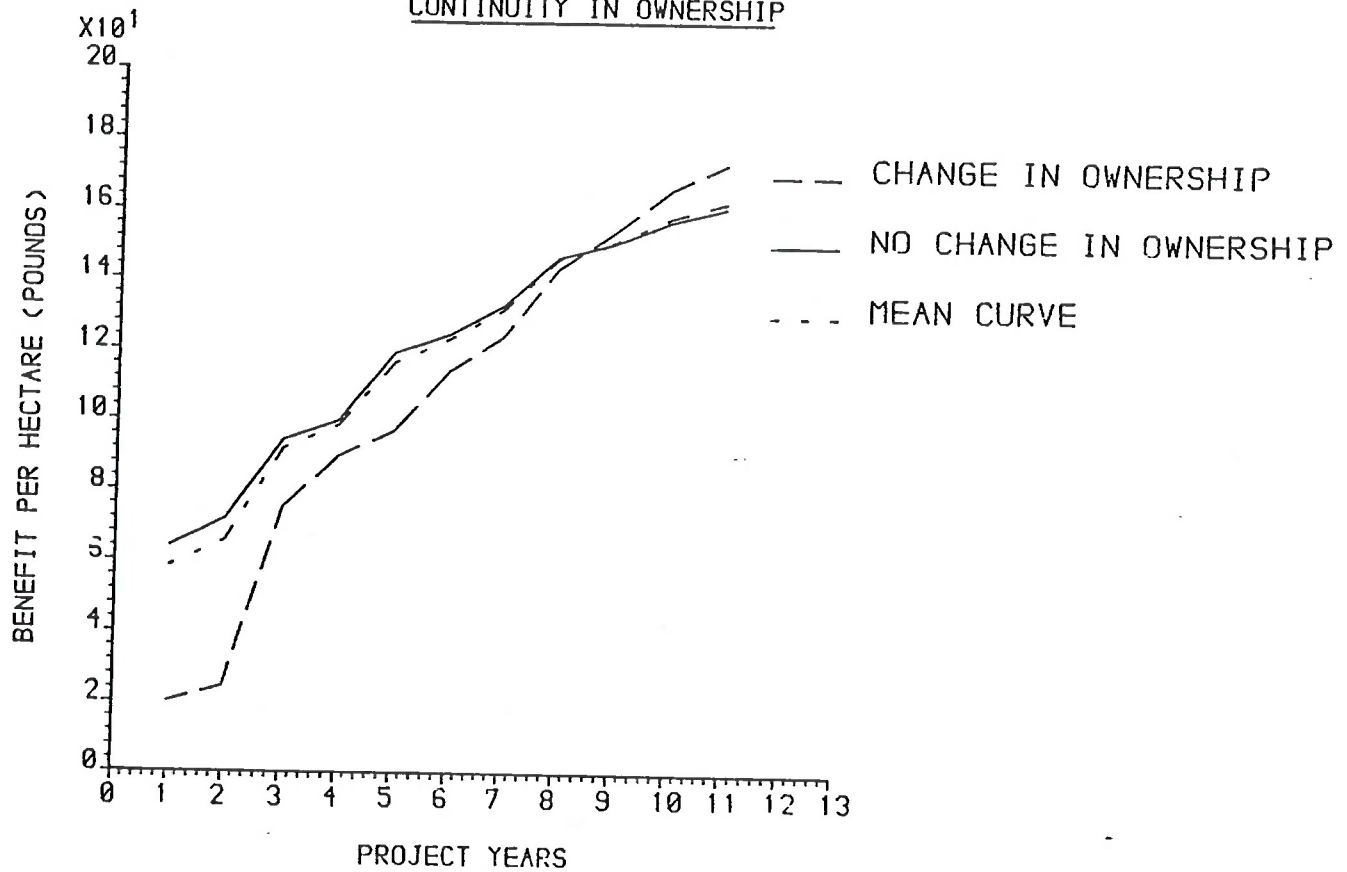


FIGURE 4.22 UPTAKE OF BENEFITS
PRE-SCHEME DRAINAGE STATUS

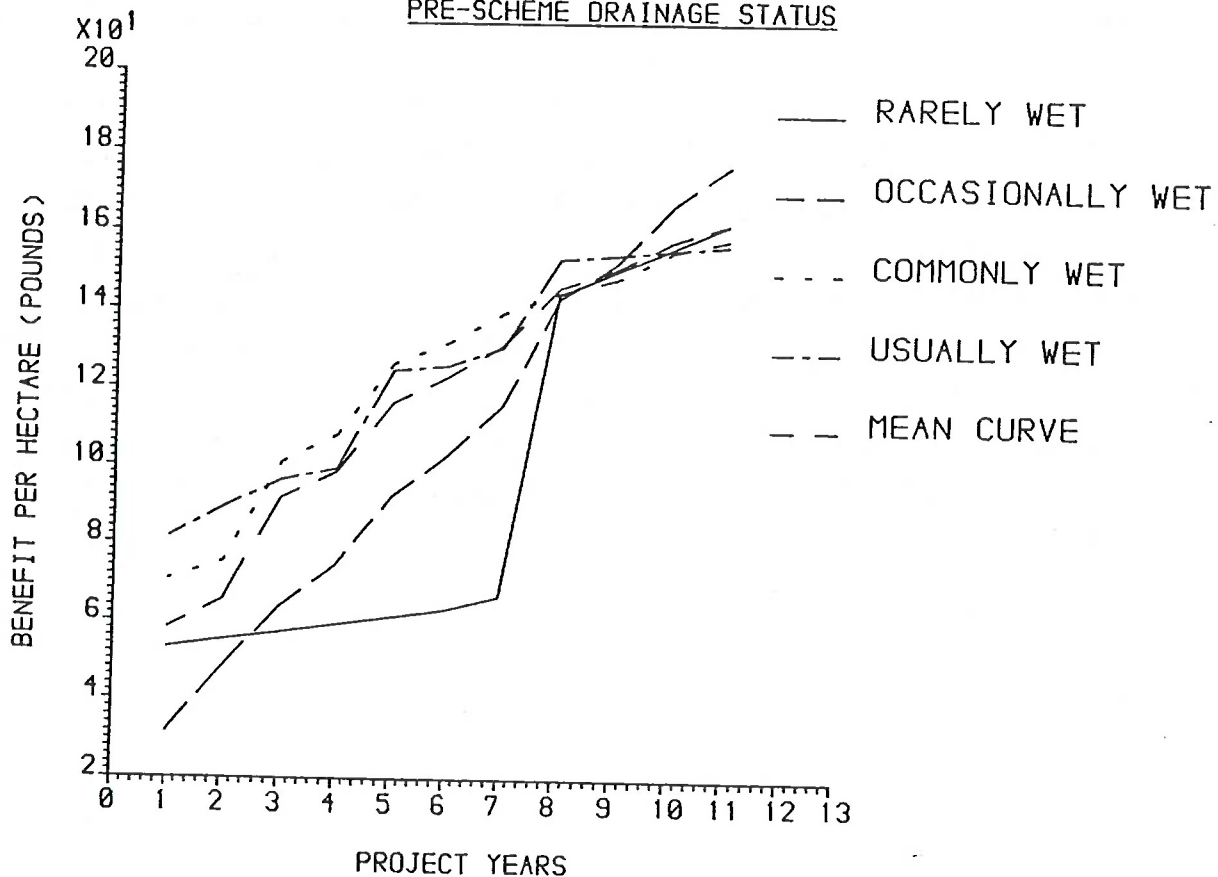


Table 4.15
Mean standard deviation for the curves presented in
Figures 4.9 to 4.22

Classification	Mean standard deviation
<u>Total</u>	115.60
<u>Field Variables</u>	
Pre-scheme underdrainage	110.51
Post-scheme underdrainage	109.93
Pre-scheme drainage status	97.78
Change of land use	90.36
Distance from farm buildings	112.54
Change in flood frequency	102.88
Field tenure status	113.52
Length of occupation	99.26
Management change	108.86
Ownership change	109.97
<u>Farm/Farmer Variables</u>	
Farm type	92.11
Number of holdings	90.72
Education/qualification	116.44
Age group	104.55

The Regional analysis shows that for the schemes surveyed, the spread of points about the mean uptake curve is given by a mean standard deviation of £115.60. The 3 best classifications are based on change of land use, the number of farm holdings run by the farmer, and farm type. Their mean standard deviations are £90.36, £90.72 and £92.11 respectively. However, the number of farm holdings recorded exceeded one only in a small number of cases, whilst change of land use is of little help when one is concerned with prediction. Length of occupancy and pre-scheme drainage status also offer classifications which provide a significantly better estimate than the aggregate curve.

By comparison, the Severn-Trent mean uptake curve was shown to have a mean standard deviation of £81.20, and the 3 best classification suites were field tenure status, farmer age group and farm type (with respective mean standard deviations of £70.99, £71.88 and £74.40).

It is evident therefore, that few of the curves offer any better explanation than the overall curve as the scatter of points is wide, but they are still useful in that they provide a visual representation of the relationships explained earlier and highlight differences within classifications. The more distinct curves are described below:

(i) Field tenure status:

(Figure 4.9) There exists a constant difference between the 'owned' curve and the 'tenanted' curve, with the former always at a higher benefit level. Little difference, however, exists in their relative shapes except in the first 5 years of project life. Whilst the 'owned' curve follows a linear pattern of benefit uptake, the 'tenanted' curve experiences rapid uptake in Years 3 and 5, to bring it up to a level just below the mean curve which it mirrors from Year 6 onwards.

(ii) Length of field occupancy:

(Figure 4.10) Little height differences are exhibited within this suite except in the early and later years. Those farmers arriving after the scheme initiate an early phase of rapid uptake, but after Year 7 it is those farmers who had been resident for up to 10 years before the scheme who show belated uptake.

(iii) Pre-scheme drainage status and flooding:

(Figures 4.20 and 4.22) Where the pre-scheme drainage status was worst benefits commence at a higher level, though their rates of uptake are very similar to the mean curve. In this suite it is the 'rarely wet' curve which is most distinct. For the first 7 years of project life these sites exhibit a low linear rate of uptake. Thereafter Year 8 sees a rapid uptake, bringing this group up to a benefit level equal to the other sites. Where flooding has been reduced, the initial benefits are high as a result of automatic benefits on grassland. On sites that did not flood, take-up is rapid after Year 4.

(iv) Land use change:

(Figure 4.11) Those sites that have transferred from grass to an all-arable land use obviously stand out from the remainder, although their relative shape of uptake is not very different. Year 3 marks the point at which uptake takes place most rapidly. Sites that have stayed in arable mirror the mean curve and show benefit levels similar to the mean curve.

(v) Schemes:

(Figure 4.8) The most rapid early uptake is shown by Trodder Syke and Billingborough Fen. The Rother area exhibits the highest benefits and follows a diminishing marginal uptake trend. Billingborough shows abrupt uptake in Year 5 following a move out of root crops into intensive cereals and field vegetables, which was often linked to drainage installation. The King's Moor and Witcombe Bottom scheme (Wessex) shows the lowest and most linear level of uptake.

(vi) Pre- and post-scheme drainage:

(Figures 4.15 and 4.16) There is not much difference between sites which had pre-scheme field drains and those that did not. However, those fields in which drains were installed post-scheme give greater benefits than those which had none installed.

(vii) Changes in ownership or management:

(Figure 4.18) Those fields on which there was a continuity of either ownership or management have the same shape as, but is consistently higher than, the mean uptake curve. Those that have experienced changes show more rapid uptake in Year 3, albeit at a lower level.

4.4.4 Land Use Change and Drainage Installation

Variables previously shown to have a significant influence upon the timing of farmers' responses were used as the criterion variables to produce suites of curves for land use change and post-scheme drainage installation, but these suites provided little extra information on the rate of benefit uptake over that given by the aggregate curves shown in Figures 4.23 and 4.24.

FIGURE 4.23

MEAN UPTAKE CURVE : POST-SCHEME FIELD DRAINAGE

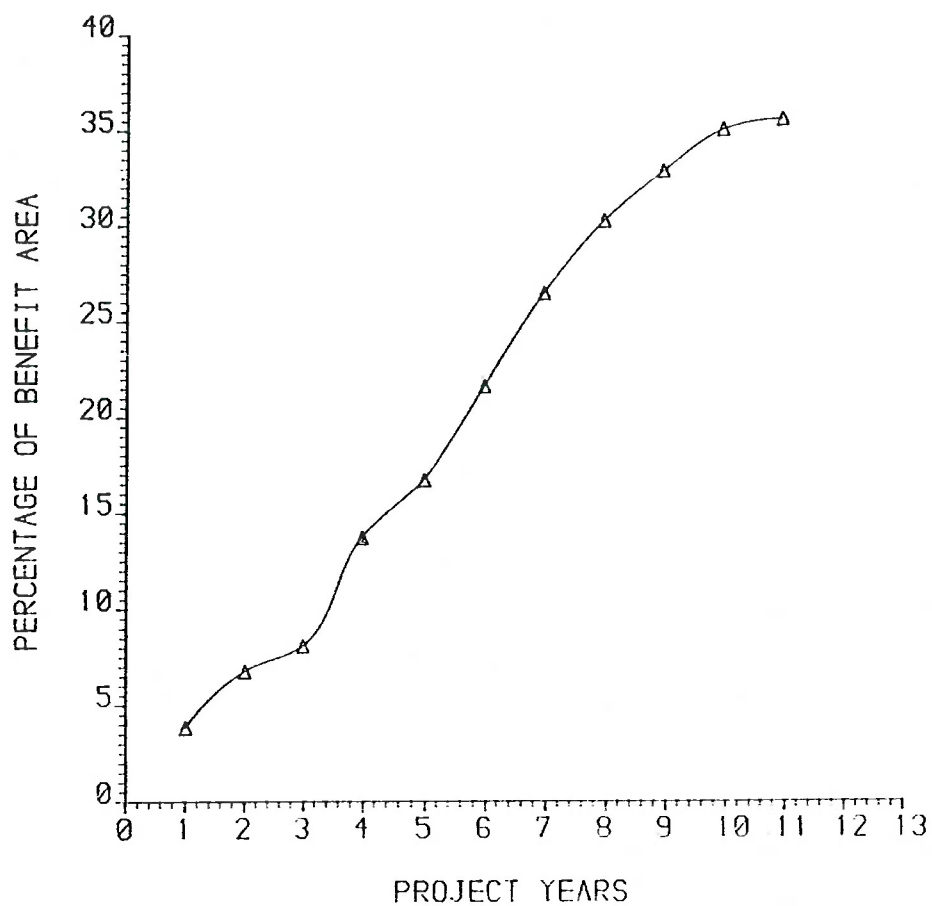
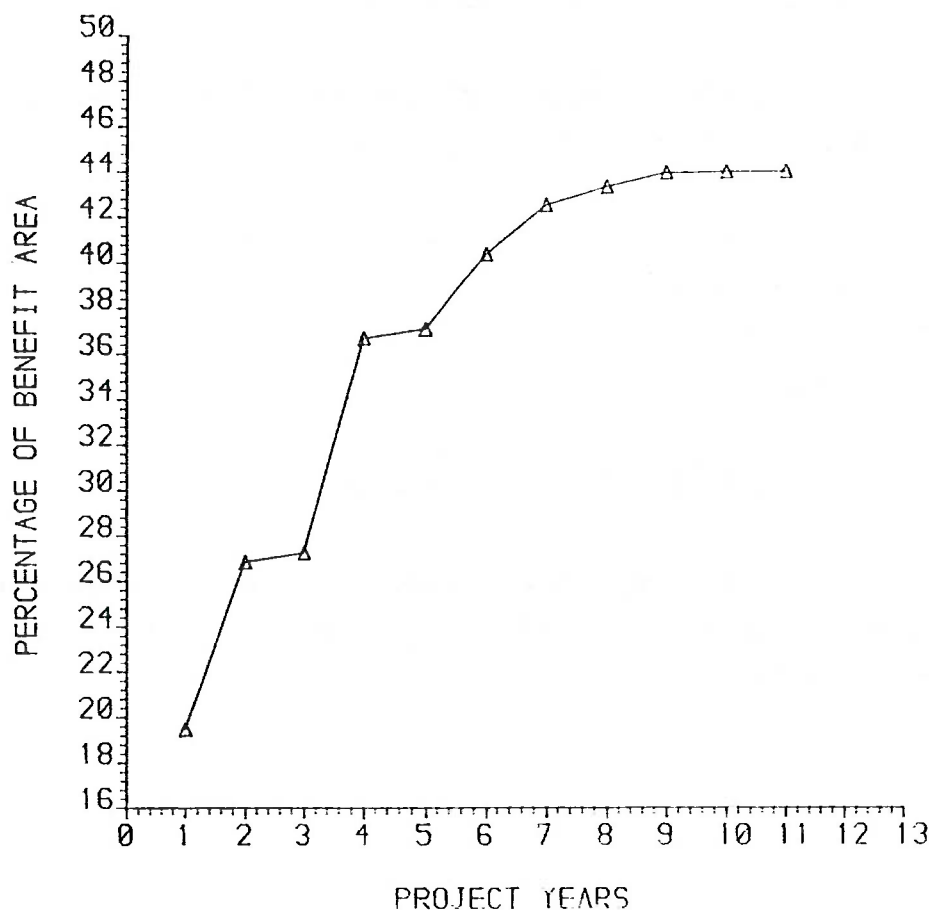


FIGURE 4.24

MEAN UPTAKE CURVE : POST-SCHEME LANDUSE CHANGE



Thirty-six percent and 44% of the total benefit area installed underdrainage and changed land use respectively in the first 11 year period. The land use change curve exhibits a much earlier rate of uptake than the drainage curve, levelling off after Year 4, whereas drainage installations increased linearly until about Year 10.

Both curves are quite similar to those produced from the STWA data. A similar percentage of the total benefit area has changed land use, though there has been slightly less drainage installed in the Regional sample (35% compared to 45%). The shapes of the curves are also broadly similar.

4.5 SCHEME SUMMARIES OF FACTORS INFLUENCING UPTAKE

The scheme appraisals in Annexe 1 consider the worthwhileness of the 6 schemes studied. The schemes can be ranked in order according to the change in net returns per hectare over the first 11 years of the scheme as follows:

- (1) Rother Area
- (2) Billingborough Fen
- (3) Sempringham Fen
- (4) Trodder Syke
- (5) Cuddy Arch Sough
- (6) King's Moor and Witcombe Bottom

If the schemes are ranked according to the change in net returns per hectare over the whole observed life of the scheme, the order then becomes:

- (1) Rother Area
- (2) Sempringham Fen
- (3) Billingborough Fen
- (4) Trodder Syke
- (5) Cuddy Arch Sough
- (6) King's Moor and Witcombe Bottom

Tables 4.16 to 4.17 show mean values for those variables shown to be associated with the uptake of benefits. A number of points can be made concerning these figures:

Table 4.16
Summary of field variables

Scheme	% of area		% of area		% of area drained pre-scheme	Mean shift in land use class	Mean pre-scheme gross margin per ha (£)	Pre-scheme %		Pre-scheme 'N' rate on grassland kg/ha*
	Free from flooding pre-scheme	Flooding reduced	1 km from farm	1-2 km from farm				usually wet	rarely wet	
King's Moor and Witcombe Bottom	5	70	62	14	15	0.39	335	10	0	92
Billingborough Fen	30	100	88	-	16	0.81	399	30	0	85
Senpringham Fen	33	100	82	9	18	0.88	406	10	6	63
Cuddy Arch Sough	26	61	81	15	47	1.30	257	68	10	80
Trodder Syke	50	100	93	2	26	-0.10	337	42	0	96
Rother Area	5	90	85	13	40	1.17	362	14	0	93
Total Average	25	87	83	9	25	0.74	349	28	3	85
STWA Average	38	36	65	17	38	0.79	345	22	13	110

* Weighted by field size

Table 4.17
Summary of farm and farmer variables by scheme

Scheme	(% area) farm changed management since scheme	Mean no. years occupied pre-scheme	% of area farmers aged		% of farmers been to agricultural college* (full-time)	% of farmers* qualified in agriculture	% of farmers belonging to a farming group	% of farmers representing on committees ¹	% of farmers with 1 holding	Mean view of farming ²	% of benefit area under livestock farms	Mean % of farm in benefit area
			35	60								
Kings Moor & Witcombe Bottom	67	27	20	42	10	25	75	15	10	2.85	89	61
Billingborough Fen	54	25	6	67	-	10	70	13	-	1.96	-	77
Sempringham Fen	75	13	15	0	-	25	80	25	20	2.86	14	73
Cuddy Arch Sough	14	32	0	16	-	-	90	-	-	3.83	100	43
Trodder Syke	5	37	0	7	-	30	50	10	5	3.25	92	56
Rother Area	22	32	10	19	-	30	85	40	20	2.00	19	45
Total Average	40	28	9	25	2	20	63	17	10	2.79	52	59
STWA Average	35	15	21	12	20	29	50	37	49	2.70	14	42

* Weighted by area in Benefit Area

(1) Includes IDB or Drainage Group

(2) On scale 1-6: 1 = profits most important
2 = way of life most important

The best performing schemes, the Rother Area and the 2 Lincolnshire Fen Schemes, are large, regional pumped drainage schemes offering considerable economies of scale in both capital and running costs. They have virtually eliminated flooding problems and by improving arterial systems have removed the drainage constraint and allowed full exploitation of arable potential. These schemes contained many large arable and mixed farms with a large part of their individual areas lying in contiguous blocks within the scheme boundary.

In the case of the Fenland schemes, improved drainage allowed the switch to more winter sown crops and vegetables. On the Rother, better drainage allowed the affected areas to be assimilated into the rest of the farms' mainly arable cropping systems. On the Fen schemes, a number of tenancy changes occurred shortly after (and partly influenced by) the scheme completion. New management, encouraged by an institutional landlord providing funds for field drainage in return for higher rents, were relatively quick to exploit improved drainage potential.

Net returns are more modest on the mainly grassland schemes of the Cumbrian Trodder Syke and Cuddyarch, and the Somerset King's Moor and Witcombe Bottom. The Cumbrian schemes were concerned with reducing flooding and lowering outfalls for field drains for improved grassland. After the scheme, farmers brought the affected areas into an already relatively intensive dairy system. On the Cuddyarch, a large part of the area was reclaimed from rough grazing following the scheme.

The lowest net returns were observed on the Somerset scheme. Here, farmers perceived that whilst the scheme significantly reduced the incidence and duration of flooding, this was insufficient to warrant changes in farming practice. Problems of land fragmentation, limited access to fields, and preferences for traditional farming methods, further discouraged any major changes in farming activities.

Compared to the STWA sample of schemes, the Regional sample demonstrates much more favourable returns on investment. This confirms the opinion that the Regional schemes were biased towards the better performers. However, the Regional sample conforms with the better STWA schemes in a number of ways. They were largely conceived and designed specifically to meet

agricultural and farmers' needs. Informal or formal (IDB) organisations were active during scheme identification, design, implementation, and subsequent operation. They were, for the most part, relatively large schemes, offering some economies of scale. They occurred where drainage was the biggest remaining constraint which once removed allowed potential to be fully exploited (the Somerset scheme is an exception to this), involving both the intensifying of existing land use, or bringing the affected area into the same system as that of the rest of the farm.

4.6 FARMER ATTITUDES TO FIELD DRAINAGE

The farmers interviewed during the farm surveys were asked to rank the 3 most important areas of future investment on their farm, from a list of 6 possibilities. As in the Severn-Trent analysis, farm buildings and storage ranks first (on a first choice basis) followed by farm machinery with field drainage in the benefit area third (Table 4.18). Under present circumstances field drainage is not seen as the major constraint.

Table 4.18
Areas of future investment on the farm

Area of investment	1st choice (%)	2nd choice (%)	3rd choice (%)
Farm buildings and storage	28.4	16.3	7.2
Farm machinery and equipment	28.4	33.2	5.6
Land purchase	8.0	3.2	31.2
Field drainage (in benefit area)	14.7	16.9	13.4
Field drainage (outside benefit area)	12.8	9.5	12.8
Working capital	7.7	20.9	29.8

Those farmers who had drained within the benefit area were asked to rank the benefits of field drainage for arable and grassland use (see Tables 4.19 and 4.20). The factors are obviously interdependent, though the farmers appear very consistent in their views with the farmers interviewed in the Severn-Trent fieldwork. Higher yields per hectare and increased stock carrying capacity are perceived to be the most important drainage benefits to

arable and grassland respectively, with the ability to sow winter crops and reduced poaching second.

Table 4.19
Ranking of drainage benefits for arable use

Type of benefit	1st choice (%)	2nd choice (%)	3rd choice (%)
Higher yields	57.2	33.7	7.4
More winter crops	12.0	5.6	10.4
Less risk of failure	10.0	7.4	21.3
Less variation	8.7	10.4	10.9
Increased trafficability	7.8	32.9	26.4
Increased land value	4.3	0.0	3.5
Earlier drilling	0.0	10.0	19.1
Less plant disease	0.0	0.0	1.3

Table 4.20
Ranking of drainage benefits for grassland use

Type of benefit	1st choice (%)	2nd choice (%)	3rd choice (%)
Higher stocking rate	59.8	4.8	8.8
Improved trafficability	18.0	8.4	4.8
Reduced poaching	8.6	18.2	18.5
Improved species composition	4.5	26.4	26.9
Earlier top dressing	3.6	11.9	15.0
Extended grazing season	3.2	27.7	10.1
Increased grass cuts	2.3	2.6	9.7
Reduced disease risk	0.0	0.0	6.2

Of the area that remains undrained, the reasons for not draining are given in Table 4.21.

Table 4.21
Reasons for not draining

Reason	% of undrained area ⁽¹⁾
Insufficient outfall for drains	1.0
Farmers could not afford drainage	35.0
Expected benefits insufficient to cover costs	20.6
Flood frequency too great	19.5
Requires cooperation with neighbours	1.5
Present land use does not necessitate drainage	4.0
Land is of conservation value	1.0
Better return on other investments	7.1
Other reasons	10.3

Note: (1) Excluding naturally freely drained land.

On the schemes studied over one-third of the undrained area will remain undrained for the next few years because of financial constraints. When this is compared with the figures in Table 4.18 on investment priorities it would appear that these areas may not be drained for some time because, even if the finances were to become available, other more pressing areas of investment exist on the farm.

Twenty percent of this undrained land was perceived by the farmers as not having adequate agricultural potential to justify drainage investment. These areas were mostly on grassland sites. This was a frequent response recorded in the King's Moor and Witcombe Bottom benefit area where the sites were often small, irregular fields, distant from the farm buildings, with problems of access. A further 20% of the undrained area remained so because flooding frequency was still too high. These sites were confined to the Cuddy Arch Sough and the King's Moor schemes.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

The objectives of the Regional study were to evaluate farmer uptake of agricultural benefits and overall project performance on selected non-STWA land drainage improvement schemes which reflect the diversity of regional situations with respect to agricultural systems and drainage characteristics. Simultaneously, the purpose was to compare the Regional results with those of the STWA study, and consider the implications for future benefit assessment and scheme appraisals.

The methods in the Regional study followed exactly those used in the STWA study to ensure consistency of approach and results. These involved a single visit farm survey covering 67 farmers and 4,810 ha which recorded pre-scheme drainage conditions, land use and farming practice, and how these had changed over time. Uptake was assessed in terms of incremental financial benefit, land use change and the installation of field drainage. Investment appraisals of individual projects were also undertaken.

With respect to factors influencing the nature of uptake, the Regional study suggests that common factors are responsible for land use change and field drainage installation. They were both more likely on fields with a poor pre-scheme drainage status, whose drainage condition, especially flood risk, was substantially improved, and where the field formed a contiguous unit with the farmstead. Land use change was also associated with change of occupant since the scheme, and field drainage was greatest where a large proportion of the farm lay within the boundary of a scheme. Benefit uptake on grassland was mainly associated with increased nitrogen use and changes in grass conservation system. Higher nitrogen use was associated with low application rates and undrained fields in the pre-scheme situation and with the move from permanent to temporary grass.

With respect to the timing of benefit uptake, the rate of land use change was more rapid on arable farms, those with large proportions of their

area within the scheme boundary, and those experiencing change of occupancy since the scheme. The timing of field drainage installation was similarly influenced by the latter factors, and was also greatest on the larger farms.

Statistical analysis was carried out to derive mathematical expressions to explain, and possibly predict the nature and rate of uptake. Whilst the expressions for the nature of uptake explain almost 80% of observed variation they contain about 10 variables, none of which are particularly dominant in their influence. The expressions for the rate of uptake have a similar number of variables but explain less than 50% of the observed variation in the timing of uptake.

In many respects the Regional study confirms the findings of the STWA study that land use change and underdrainage are strongly associated with financial benefit uptake, and that the greatest benefits are usually taken up early in project life. Furthermore, the Regional study confirms that a broad complex of field, farm, and farmer variables influences benefit uptake; it is difficult to explain or predict benefit uptake in terms of a small number of dominant factors.

The Regional study derived an aggregate benefit uptake curve with rapid uptake in early years but marginally diminishing throughout its length to a peak at about 20 years. This contrasts with the S-shaped curve of the STWA study which appeared to peak at 13 years. On average for the Regional study, 55% of recorded financial benefits, 80% of land use change, and 50% of field drainage had occurred in the first 5 years of scheme life.

Attempts were made to derive uptake curves for individual independent variables (eg. uptake for farmers below 35 years of age) to determine whether such classifications would give a better description than the aggregate curve. It was concluded that statistically the aggregate uptake curve was as good as any sub-classification.

Compared to the STWA study, the Regional schemes demonstrate better average net benefits per hectare, and higher returns on investment. This is partly because the Regional sample is biased towards the better performers. However, the Regional sample compares well with the better STWA schemes. They

were largely conceived and designed specifically to meet agricultural and farmers' needs. They occurred where for the most part drainage was the biggest remaining constraint. They were mainly large scale pumped schemes offering economies of scale, and perhaps most important contained drainage organisations (IDB's) instrumental in scheme identification, design, and follow-up. Because of these favourable conditions it is not surprising uptake has been greater and more rapid within a sample of (6) regional best performers compared to the broad range of (16) schemes covered within the single STWA region.

5.2 CONCLUSIONS AND RECOMMENDATIONS

The conclusions of the Regional study are consistent with those of the preceeding STWA study. The conclusions have implications for planning and evaluating investments in agricultural land drainage.

5.2.1 Pre-investment Appraisal

The Regional study confirms the need for a survey of the benefit area of a proposed scheme at the pre-investment stage to assess field, farm, and farmer characteristics identified as important determinants of benefit uptake. The level of detail required will depend on the stage of the appraisal. At scheme identification and preliminary appraisal stage, information gleaned by walking the benefit area, by speaking to a few farmers, and from secondary published sources combined with standardised evaluation methods could be sufficient. For detailed project preparation an in-depth survey along the lines of those adopted in this study would be justified, paying particular attention to pre-scheme drainage conditions, existing land use, and other factors relevant to subsequent uptake of benefits. The fact that the most successful schemes from an uptake viewpoint have been where pre-scheme drainage conditions were poor and a major constraint on farming, where the scheme has provided a significant drainage improvement, and where there has been organised pressure from farmers to resolve drainage problems, suggests a context for pre-investment field work, design and appraisal.

The Regional study confirms that the most suitable approach to predicting the nature of benefit uptake is the development of 'benefit scenarios' or standardised budgets reflecting given field, farm, and farmer circumstances, eg. the likely increase in net returns associated with a given

drainage improvement and related changes on a grassland site. Having identified the aggregate degree of benefits at scheme level, the phasing of benefits can be based on the observed uptake curve. The uptake curve derived from the Regional sample suggests rapid uptake over the first 5 years, after which uptake rate declines and levels off over the 15 to 20 year period. This shape of curve was common to the more successful STWA schemes which also demonstrated the scheme characteristics previously referred to. Schemes which offer greater potential benefits appear to demonstrate earlier, more rapid, and greater benefit uptake. It is possible that a curve with a diminishing marginal rate of uptake with about 90% of final uptake achieved by year 15 is applicable to the higher potential schemes, whereas schemes with lower potential benefits show a traditional S-shaped curve with uptake peaking at a more modest level after 13 years. The statistical basis for this distinction still remains to be tested (see 5.3 below).

Since the completion of the STWA study, the suggestion that a preferred approach to scheme appraisal based on benefit scenarios and phased uptake based on observations, has been developed in the form of the Silsoe College Agricultural Drainage Evaluation Model (Hess and Morris, 1985). The model has been used to assist in the appraisal of a number of proposed capital improvement schemes.

The Regional study further confirms one important finding of the STWA study, that is, the necessity of bringing together at the planning stage the representatives of all the parties responsible for scheme design, implementation, and successful conclusion, namely, the Water Authority, ADAS, Local Authorities, IDB's and farmers. The strong presence of IDB's and/or active extension support from the agricultural advisory service, were key determinants of scheme success.

5.2.2 Influencing Uptake

Once a scheme has been justified on the basis of an objective benefit assessment, consideration should be given to encouraging farmers to take up potential benefit. This may mean creating farmer awareness of drainage benefits, or improving access to technical advice and services. These are best pursued through existing organisations such as ADAS, IDB's, NFU, TFA, CLA, drainage contractors, and farmer discussion groups. Whilst it

is inappropriate that Water Authorities should themselves generate demand for land drainage beyond that already expressed by farmers, it is important that for schemes which are well conceived, actual improvements are to design standards, environmental qualities are protected or enhanced, follow-up by third parties are carried out, and farmers are made aware (through existing support organisations) of the potential benefits afforded.

5.2.3 The Need for Monitoring and Evaluation

Many of the criticisms of methods used in the Regional and STWA study relate to the assumptions required by reliance on a single visit interview in which farmers were asked to recall past conditions and events. Many of these problems would be avoided if a system of frequent visit farm surveys was set up to provide on-going monitoring and ex-post evaluation of selected schemes. The data needs of the present study provides the checklist of field, farm, farmer and scheme level factors and units of measurement which would be incorporated initially in an inventory of the base-line, pre-scheme situation, and subsequently in the on-going monitoring of change. Given the completion of the statistically-based STWA and Regional studies, it is considered that on-going monitoring and evaluation should adopt a more in-depth, case study enquiry into selected 'benefit scenario' situations.

Repeated annual visits to selected farms on selected schemes is probably the most cost effective basis for monitoring, supported by interim telephone reporting. Such monitoring would allow the timely recording of physical data, and allow more accurate calculations of financial implications, particularly regarding fixed costs. In some instances, paying for farmer subscription to an enterprise recording scheme (such as MLC beef costing services) may provide measures of performance not easily available by other means, particularly for grassland. Special attention would be needed to devising easily recordable measures of drainage condition which indicate changes in drainage status in relation to river and arterial improvements, and standards of maintenance, and field drainage practices. The evaluation procedure would not only allow an assessment of the extent to which a particular scheme was meeting its objectives in terms of design standards, follow-up work, farmer response, and levels of maintenance, but would generate a catalogue of detailed case histories for use in predicting uptake under similar circumstances elsewhere. To be useful, ex-post evaluation must feed

back into the planning process, and preferably those with a hand in the latter should have experience or at least be exposed to the former.

In addition to the in-depth monitoring of selected farms it is considered that a simple monitoring and evaluation procedure be devised for each scheme at the planning stage. This procedure would require at least one visit to each farmer beneficiary in the first year of scheme life to record farmers' perceptions of the impact of the scheme on drainage status, and outstanding drainage problems, particularly with respect to follow-up work. Subsequent monitoring could be conducted through selected farmers and/or land drainage committees. It was apparent from both the Regional and STWA surveys that very few farmers had seen or corresponded with River Engineers after scheme completion, and where they had it was usually to exchange ideas on litigation and claims for compensation. A very simple ex-post monitoring procedure would pay dividends in terms of ensuring that schemes meet original design standards, including follow-up work, creating farmer awareness of potential benefits, identifying the need for and timing of maintenance work, protecting environmental standards, and improving the data base for future scheme planning.

5.3 FURTHER WORK

In accordance with the terms of reference, the preceeding analysis compared the results of the Regional and STWA samples and there appear to be differences between the two in terms of the nature and rate of uptake and the factors influencing. In the main, this is thought to reflect the biased nature of the Regional sample towards the larger, more successful schemes rather than regional characteristics per se. It is recommended that the Regional and STWA data sets are merged and the combined samples examined as one set. Because of recent changes in computer systems, this has not been possible within the present study period.

For reasons discussed in 5.2.3 above, further work on ex-post evaluation should concentrate on an in-depth, case study monitoring of selected farms representing important benefit situations.

The study has pointed to the need for consistent guidelines and operating procedures for data collection, analysis, planning and evaluation

methods for the appraisal of agricultural land drainage capital and maintenance works. Such methods are being developed at Silsoe College involving computer-based expert systems supported by technical manuals which explain the principles and techniques involved. It is hoped to continue research and development along these lines.

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APPENDIX II

GLOSSARY OF TERMS

A. Farm Management and Miscellaneous Terms

AVAILABLE WATER CAPACITY (AWC) The amount of water a soil may hold per unit of depth which is available for extraction by crops.

CONSERVATION SYSTEM (OF GRASS) The method by which grass (or other forage crop) cut in summer is stored for winter feed. Generally as hay or silage.

DRAINAGE STATUS A classification based upon the likely, or usual, wetness of the soil which may be expressed in qualitative (eg. 'good') or quantitative (eg. watertable within top 70 cm of the soil for less than 30 days in any one year) terms.

DRY MATTER YIELD The yield of a crop expressed as a weight of dry matter. This provides a more realistic method of describing yield, particularly of grass, where total (ie. wet matter) weights are highly sensitive to variations in moisture content.

FIELD CAPACITY The amount of moisture that a soil will hold after natural (gravity) drainage. Further moisture may only be removed by evaporation and transpiration.

FIELD DRAINAGE Techniques employed to assist the rapid conveyance of water from the soil into arterial watercourses. This generally includes the laying of tile or plastic pipes within the soil and/or secondary treatments such as MOLING or SUBSOILING.

FIXED COST Costs which in the short run do not vary with output. These costs are borne even if there is no output.

FREEBOARD (OF FIELD DRAINS) The distance between drain outfall and mean water level in the field ditch.

GRASSLAND SITE CLASS A system of classification of sites developed by the Grassland Research Institute based upon summer rainfall and soil AVAILABLE WATER CAPACITY. Sites may range from 'Poor' to 'Very Good' reflecting the volume of water available to the plant during the growing season.

GRASS UTILISATION Not all the grass grown in the field is available for use by the animal as there may be losses in the field or during CONSERVATION. Utilisation is generally expressed as a percentage of total METABOLIZABLE ENERGY.

GRAZING LIVESTOCK UNIT (GLU) A system of defining LIVESTOCK UNITS based upon the energy requirement from grass in a representative diet for a given stock type and management system as a proportion of the energy requirement from grass of a 550 kg liveweight Friesian cow yielding 5,000 litres per year (ie. 33,350 MJ/year). This excludes energy from supplementary feeds and allows changes in grass production to be related directly to STOCKING RATES.

GROSS MARGIN (GM) GROSS OUTPUT less the variable costs directly associated with that level of output. The gross margin is a measure of extra revenues and extra costs per unit of enterprise activity, and is usually expressed per unit of a fixed resource, eg. £/ha.

GROSS OUTPUT The monetary value of the physical output of a farm enterprise, including production retained for on-farm use, usually expressed per unit of activity, eg. £/ha.

HYDRAULIC CONDUCTIVITY (K) The rate (in m/day) at which water may move through a soil profile. This may be either laterally, or, more usually in a drainage context, vertically.

INNOVATOR One who is early to make changes (to his farming system) in response to new opportunities.

LAGGARD One who is late to make changes (to his farming system) in response to new opportunities.

LAND CAPABILITY CLASSIFICATION The assessment of the productive capacity of land based upon limitations to use imposed by the soil, climate or topography.

LAND USE SHIFT A measure of the magnitude of change in land use based upon a nominal system of ordering from 1 (rough grazing) to 6 (horticulture).

LAND USE SUBSTITUTION A situation where improvements in the productivity of land in a benefit area can release other land for other uses, eg. improved drainage in lowland pasture allows earlier access and higher stocking, enables the maintenance of herd size on a reduced area, and increased arable cropping on land outside the benefit area previously required for grass production.

LIVESTOCK UNIT A method of expressing livestock numbers upon the basis of their energy requirements. Different classes of animals are related to a standard livestock unit which, for convenience, is usually taken as the type of dairy cow, most numerous in the UK. The standard used by MAFF is 'the energy allowance for the maintenance of a 600 kg Friesian cow and the production of a 40 kg calf, and 4,500 litres of milk at 3.6% of butterfat and 8.6% solids-non-fat'. This equates to 48,000 Megajoules (MJ) of METABOLISABLE ENERGY (ME) per year. 24-month grass beef animal, requiring 21,600 MJ of ME per year is therefore 45% of a Livestock Unit; an average ewe, 10% and so on.

LYSIMETER a piece of laboratory equipment consisting of a tank enclosing a monolith of soil and a growing crop. Water inputs and outputs are monitored and controlled to examine the effects of artificially high or low watertables on the crop.

MEDWAY LETTER LINE The boundary of the benefit area of a land drainage improvement scheme defined upon the basis of The 'Medway' Letter as a line 2.44 m (8 feet) above the level of the highest known flood (for non-tidal areas). In practice it is generally extended to the field boundary above the Medway Letter Line to include the whole field. The 'Medway' Letter (MAFF, June 1933) originally referred to the definition of the boundary of the Upper and Lower Medway Internal Drainage Districts.

METABOLIZABLE ENERGY The processes of digestion and metabolism whereby an animal obtains its energy are not achieved with complete efficiency and energy is lost in the process in a variety of forms. The energy value of the food less the energy value of the faeces, urine and the combustible gas that is produced from it is termed the Metabolizable Energy.

MOLING A secondary FIELD DRAINAGE treatment used in certain clay soils. Unlined channels are formed by pulling a 'bullet' through the soil. These mole channels generally interconnect with a system of pipe drains by means of a PERMEABLE FILL. In suitable soils, moling provides a cheap means of achieving a very close drain spacing. Mole channels need to be redrawn every 5 years or so.

NET RETURN (NR) OR NET MARGIN The GROSS MARGIN minus FIXED COSTS.

NITROGEN (N), UNITS OF Artificial N is applied either as a 'compound' of Nitrogen (N), Phosphorous (P) and Potassium (K) or as 'straight' N. The 'number' of a compound fertiliser refers to the percentages of N, P and K by weight, eg. an 8-20-16 fertiliser = 8% N, 20% P and 16% K. Straights vary in their N content but 'Nitram' (a common straight fertiliser) contains 35% N. A unit of nitrogen is an imperial measure of weight and equal to 0.01 cwt. Therefore one bag (1 cwt) of 8-20-16 contains 8 units of N. In the metric system units are replaced by kilograms.

NITROGEN APPLICATION RATE The application of NITROGEN is measured in UNITS per acre or Kilograms per Hectare. 100 units/acre = 126 kg/ha.

OPPORTUNITY COST OF GRAZING DAYS The value of grazing days may be measured in terms of net savings in bought feeds and/or savings in conservation costs and/or savings in yarding costs.

PARISH RETURNS Agricultural Censuses have been carried out annually by MAFF since 1866. All occupiers are required by law to provide information on land use, livestock numbers and workers on their farm. Individual census returns are confidential but summaries may be obtained at parish level from MAFF or the Public Records Office.

PERMEABLE FILL In soils with a slowly permeable subsoil it is often necessary to lay a band of permeable material (usually gravel) over the drain pipes to within 30-35 cm of the surface. This will assist movement of water to the drains and connect with channels and fissures produced by MOLING or SUBSOILING. The use of permeable fill adds considerably to the cost of a FIELD DRAINAGE scheme.

POACHING Excessive treading of wet soil by animals leading to destructuring of the soil and damage to the sward.

POACHING STATUS The susceptibility of a soil to POACHING dependant upon its bearing capacity.

SEMI FIXED COSTS Costs usually classified as FIXED COSTS yet, in the medium term vary with output. These are items of recurrent expenditure associated with the use of existing fixed resources (eg. machinery fuel and repairs).

SPRING FLUSH Grass grows all year round in England, merely slowing in winter, however the bulk of production occurs between April and September. As temperatures rise in spring and there is generally plenty of water available there is a rapid acceleration in grass growth during April and May. This is the spring flush. As summer rainfall rarely matches the crop's demand for water, production then falls away during the summer. The wetter (western) parts of Britain also experience an autumn flush.

STANDARD MAN DAY (SMD) A Standard Man Day consists of 8 hours of adult male labour. Standard Man Day requirements per hectare or head are published by MAFF. The Standard Man Day requirement of a farm is used as a measure of size and the distribution of that requirement amongst enterprises as a measure of farm type.

STOCKING RATE The intensity of grassland productivity can be measured by the number of animals on the farm per area of grass and forage crops. Stocking rates are expressed in terms of LIVESTOCK UNITS per hectare of grass (grassland stocking rate) or of forage plus grass.

SUBSOILING A secondary FIELD DRAINAGE treatment used to increase the HYDRAULIC CONDUCTIVITY of the subsoil by creating cracks and fissures with deep tines.

TIMELINESS Certain agricultural activities are extremely sensitive to the time at which they are carried out. The date of sowing of cereals, for instance, can influence final crop yield. Carrying out these tasks at the optimal time is referred to as timeliness.

TRAFFICABILITY The capacity of a soil to withstand loads applied by machinery or animals. The trafficability of a soil is therefore a function of both the shear strength of the soil and the nature of the machinery, or type of animal. Poor trafficability can lead to POACHING by livestock and poor TIMELINESS of operations.

UPTAKE The realisation of potential benefits of land drainage improvement schemes, requiring some investment of resources by the farmer.

UTILIZED METABOLIZABLE ENERGY (UME) Grass yields are measurable in terms of METABOLIZABLE ENERGY (ME) given in megajoules per hectare (MJ/ha). The grass ME production which is not lost, but becomes part of animal production is termed Utilized Metabolizable Energy.

UTILIZATION EFFICIENCY See GRASS UTILISATION.

VARIABLE COST A cost which varies directly with the rate of output, eg. fertiliser and chemical sprays.

WATERLOGGING The presence of a watertable at or near the soil surface as opposed to flooding where the water level is above the surface.

B. Project Appraisal Terms

AUTOMATIC BENEFITS Those benefits that do not require any investment by the farmer to be realised, eg. reduced flood damage, extended grazing seasons.

BENEFIT SCENARIO Estimates of the type and value of net benefits associated with typical combinations of pre- and post-improvement drainage status and farming activity, eg. the typical value of a move from extensive grass to arable/ley for given environmental and farming conditions.

DISCOUNTED CASH FLOW (DCF) A method of investment appraisal based on the idea that the value of a sum of money (a cost or benefit) depends upon when it is to be received. It is better to receive money earlier, therefore the later a benefit accrues, or cost is incurred, the lower the value. In Discounted Cash Flow all costs and benefits are brought to PRESENT VALUES using a specific DISCOUNT RATE.

DISCOUNT RATE The rate used in DISCOUNTED CASH FLOW to value future flows of costs and benefits in terms of PRESENT VALUES. For public investments the Discount Rate should reflect the opportunity cost of capital to the economy, and in practice is set by the Treasury.

ECONOMIC APPRAISAL A method of investment appraisal where all costs and benefits are valued in terms of their opportunity cost to the economy.

GUARANTEE SECTOR That part of the European Common Agricultural Policy responsible for farm commodity price support and stabilisation, eg. intervention prices, import levies.

GUIDANCE SECTOR That part of the European Common Agricultural Policy responsible for structural adjustment, eg. improvement grants, retirement incentives.

EX-ANTE PROJECT EVALUATION A project appraisal carried out before the start of the project to assess its expected worthwhileness.

EX-POST PROJECT EVALUATION A project appraisal carried out after the completion of the project to assess its actual worthwhileness.

INTANGIBLE COSTS AND BENEFITS Costs and benefits which do not have a MARKET VALUE, eg. reduced anxiety due to flood alleviation or loss of wildlife habitats.

INTERNAL RATE OF RETURN (IRR) The DISCOUNT RATE which when used to discount the cash flows associated with a project produces a zero NET PRESENT VALUE. An IRR greater than the test DISCOUNT RATE would suggest that the project is worthwhile.

MARKET PRICE The monetary value per unit of a good or service paid by a buyer or received by a seller.

NET AGRICULTURAL CASH FLOW In a project evaluation, the sum of the agricultural benefits minus the on-farm costs of achieving those benefits (such as field drainage costs), for each year of the project life.

NET PRESENT VALUE (NPV) The sum of the PRESENT VALUES of benefits minus the sum of the present value of costs.

PAYBACK PERIOD The period over which the cumulative net revenue from an investment project equals the original investment. This takes no account of the time profile of the cash flow.

POTENTIAL BENEFITS Benefits which require an investment of resources by the farmer in order to be realised, eg. a change of land use. These may or may not be taken up during the life of the project.

PRESENT VALUE In DISCOUNTED CASH FLOW, the value of a sum of money arising in the future taking account of its time value. The Present Value is equal to

$$\frac{V}{(1 + r)^n}$$

where: V = actual value of the cost or benefit,
r = DISCOUNT RATE,
n = number of years after the project commencement.

PRICE RELATIVE EFFECT A consideration of the extent to which, having removed the effect of inflation, some commodities have become cheaper or more expensive in real terms than other commodities over time.

QUASI-FINANCIAL APPRAISAL An assessment of project worthwhileness using market or financial prices for inputs and outputs except for selected inputs, eg. land and field drainage capital costs where grants are easily identifiable and the costs of these items are charged before grant aid.

SENSITIVITY ANALYSIS A procedure for examining the extent to which the value of an important dependent variable is influenced by the value of an independent variable, eg. the % change in the GROSS MARGIN of dairy cows due to a 1% change in the price of milk.

SHADOW PRICE The real value to the community of the consumption of one more unit of a good or service, or the commitment of one more unit of a resource. Shadow prices are the unit prices used to assess the value of inputs and outputs to the economy as a whole of an investment project. They allow for the fact that because of market conditions, or government subsidies or taxes, market prices may not be a good indicator of real economic value.

SINKING FUND METHOD A method which determines the annual charge which will accumulate with interest over time to generate an investment or replacement fund, ie. the opposite of paying off a loan, expressed as a decimal of the first estimate.

SWITCHING VALUE The required change expressed as a decimal of the first estimate in the value of an important cost/benefit parameter (eg. net agricultural benefit) which will make the investment project break even at the recommended discount rate.

UTILITY ANALYSIS A theoretically based procedure for evaluating the degree of satisfaction or happiness for an individual associated with a given activity or outcome. In traditional economic theory maximising income also maximises utility, and market prices provide good estimates of utility. More recent theory and evidence shows this is not always so.

WITHOUT-PROJECT BENEFITS It is assumed that without the project farming would not remain static and there would be some benefits due to general improvements in agricultural efficiency; eg. improved varieties, machinery or techniques. In the present study, Without-Project Benefits have been taken at 1% compound per year, reflecting general trends in recent years.

C. Statistical Terms

ANALYSIS OF VARIANCE A technique to test whether there are STATISTICALLY SIGNIFICANT differences in the mean value of a variable (measured on an interval scale) between different groups.

BETA-WEIGHT The standardised REGRESSION COEFFICIENT, which provides a measure of the relative contribution of independent variables in a MULTIPLE REGRESSION equation, by removing the effect of different scales of measurement and degrees of scatter.

CHI-SQUARED TEST A technique to test whether the distribution of cases, classified upon the basis of 2 or more nominal scales, is random or whether there is some relationship between the classifications.

DISCRIMINANT ANALYSIS A technique which attempts to explain the variation in a nominal dependent variable upon the basis of a number of interval scale independent variables, ie. an attempt to discriminate between classes. Examination of the STANDARDISED DISCRIMINANT FUNCTION can reveal which of the independent variables account for most of the variation in the dependent and the EXPLANATION OF VARIANCE (R^2) shows how much of the variation in the dependent variable is explained by the discriminant function.

EXPLANATION OF VARIANCE (R^2) A statistic that describes what proportion of the variation in the dependent variable is explained by the independent variables in ANALYSIS OF VARIANCE, MULTIPLE REGRESSION and DISCRIMINANT ANALYSIS.

MULTIPLE CLASSIFICATION ANALYSIS A technique applied to multiple ANALYSIS OF VARIANCE that predicts mean values for each class of one independent variable having accounted for variations in each of the others.

MULTIPLE REGRESSION A technique that attempts to explain variations in a dependent variable upon the basis of a number of independent variables. All variables must be measured on an interval scale. Examination of the BETA-WEIGHTS provides information on the relative contribution of each independent and the EXPLANATION OF VARIANCE (R^2) indicates what proportion of the total variation is explained by the regression equation.

PEARSON'S CORRELATION COEFFICIENT A simple statistic describing the strength of a linear relationship between 2 ordinal variables. 0 = no linear correlation; ± 1 = perfect correlation.

REGRESSION COEFFICIENT A MULTIPLE REGRESSION equation takes the form

$$Y = b_1 x_1 + b_2 x_2 + b_3 x_3 \dots + b_n x_n + C$$

where: Y is the dependent variable,
 x_1 to x_n are the independent variables,
 b_1 to b_n are the regression coefficients,
 C is a constant.

Thus the regression coefficients are the weightings applied to each independent variable in the regression equation. Unlike the BETA WEIGHTS, these provide no information on the relative contribution of each independent as scales may vary.

STANDARD DEVIATION A simple parameter describing the variation of a variable about the mean score. In a normal distribution 95% of the values will lie within 2 Standard Deviations of the mean.

STANDARD ERROR OF THE ESTIMATE An expression for the STANDARD DEVIATION of the distance of observed values about a regression line.

STANDARDISED DISCRIMINANT FUNCTION The discriminant function (similar in form to the MULTIPLE REGRESSION equation) where the coefficients are expressed in standardised form thus removing the effect of different scales of measurement and degrees of scatter.

STATISTICAL SIGNIFICANCE An effect is said to be significant if the value of the statistic used to test the relationship is unlikely to occur by chance; ie. if the probability of it occurring by chance is less than the chosen SIGNIFICANCE LEVEL.

SIGNIFICANCE LEVEL The probability chosen to describe the limits for significance tests. Levels of 5, 1 or 0.1 % are commonly chosen but are entirely arbitrary. If a relationship is said to be significant at the 1% level there is only a 1 in 100 chance that the observed distribution of relationship occurred at random.

STEPWISE MULTIPLE REGRESSION A technique of MULTIPLE REGRESSION where independent variables are added into the regression equation one by one, beginning with the variable shown, by ANALYSIS OF VARIANCE, to have the most significant effect upon the dependent variable. Further variables are included and at each stage the overall SIGNIFICANCE is tested. Some variables already entered may then be removed. The process is continued until either all variables have been entered or the entry of further variables does not significantly improve the overall EXPLANATION OF VARIANCE.



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Farmer uptake of drainage benefits a regional study

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<https://dspace.lib.cranfield.ac.uk/handle/1826/21269>

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