UNIVERSITY OF STIRLING

Department of Management Science and Technology Studies

LAND USE MODELLING IN THE SEDBERGH DISTRICT OF CUMBRIA

Thesis submitted for the degree of

Doctor of Philosophy in Technological Economics

by

ROSEMARY E BUDD BSc, MSc

February 1981

LAND USE MODELLING IN THE SEDBERGH DISTRICT OF CUMBRIA

ABSTRACT

This study investigates a potential planning method that may be useful to rural planning, which looks at the use of land for agriculture and forestry by means of a simple modelling approach. A land use model based on linear programming is defined for the Sedbergh district of Cumbria. The model looks at the optimal allocation of land use activities to different land types which are classified on a grid square basis. It provides valuable information on suggested land allocations in the district and the associated levels of production, production value and labour requirements. The model is capable of exploring a wide range of conditions looking at the effect of policy proposals or a certain course of action. The ability of the model is illustrated by exploring land use allocation under different restrictions and by looking at the suggested use of common land in the Sedbergh district.

The model suggests that it would be advantageous in terms of the economic value of production, to use the upper and middle slopes for forestry and sheep rearing and to devote the lowland areas to dairying and cattle rearing activities. Common land is suggested as being used for both forestry and sheep rearing. The limitations and uncertainties of the model are considered and the potential value and likely use of the model in planning is discussed. The model offers an aid to part of the rural planning process which could improve communications between the planners concerned and provide a basis for stimulating planning discussions.

ACKNOWLEDGEMENTS

Throughout this work many people have given generously in terms of time, interest and effort. I would like to thank particularly my supervisors, M Makower (University of Stirling) and O W Heal (Institute of Terrestrial Ecology) who have been helpful in offering suggestions, criticisms and other assistance. Many organisations and individuals have assisted in the preparation of this thesis and the contributions of all these people are gratefully acknowledged. I would like to thank D K Lindley (Institute of Terrestrial Ecology), R S Smith (Newcastle University), M Garforth (Forestry Commission, Edinburgh), and the Sedbergh Rural Land Use Working Party Group for their assistance during the study, and Janet Crabb for typing the manuscript.

This study was funded by an SRC/SSRC studentship and a six-month grant from the Institute of Terrestrial Ecology for which I am grateful.

LAND USE MODELLING IN THE SEDBERGH DISTRICT OF CUMBRIA

CONTENTS

			Page
Abstract			1
Acknowledgements			2
Table of Contents			3
List of Figures			7
List of Tables			8
Introduction			11
1.	The state of planning in rural areas		14
	1.1	Planning in rural areas	15
	1.2	Organisations concerned with the management and planning of rural land	19
2.	Planning methods		24
	2.1	Introduction	25
	2.2	Descriptive review of statutory planning methods	25
	2.3	The development of statutory planning methods	29
	2.4	Potentially useful methods for planning in rural areas	35
3.	The Sedbergh Rural Land Use Study - application of the modelling approach in a local planning context		43
4.	The land use model		64
	4.1	Introduction	65
	4.2	Features of the land use model	65
	4.3	Format of the land use model	68
	4.4	Model input	70
		4.4.1 Production coefficients	70
		4.4.2 Economic coefficients	71
		4.4.3 Labour requirements	75
		4.4.4 Land area	75
	4.5	Output obtainable from the land use model	76

5./

Page

5. Land allocation in the Sedbergh district - potential use of the land use model 78

5.1 Introduction 79

5.2 The influence of restricting the land area available for change on land allocation 80

5.2.1 Results arising from the model given no pre-determined production specifications 81

5.2.2 Results arising from the model given the need to maintain current production and labour input levels 88

5.2.3 Discussion of the model results exploring the influence of restricting the land area available for change on land allocation 90

5.3 An investigation into the effect of restricting forestry plantings on land allocation 95

6. The influence of objective functions and discount rates on land allocation 101

6.1 Choice of an appropriate objective function 102

6.2 The importance of discounting and its effect on land allocation in the Sedbergh district 114

6.2.1 The use of discounting in land use investment appraisal 114

6.2.2 Suggested land allocation in the Sedbergh district using different discount rates 117

7. The problem and potential use of upland common land - one application of the land use model 121

7.1 Common land and conservation areas in the Sedbergh district 122

7.2 The underutilisation of common land 122

7.3 Conflicts over the use of common land 126

7.4 Increasing the agricultural potential of common land 127

7.5 Suggested land use activities on common land and conservation areas in the Sedbergh district 129

Page

8. Limitations of the land use model 135

8.1 Validity of the model structure and data input 136

8.1.1 The model structure 136

8.1.2 The exclusion of recreation and nature conservation from the land use model 138

8.1.3 Model assumptions 142

8.2 Estimation of the input coefficients and their validity 144

8.2.1 Economic input coefficients 145

8.2.2 Forestry labour input coefficients 164

8.2.3 Forestry production input coefficients 168

8.2.4 Classification of the land types 169

8.2.5 Constraint specification (RHS assessment) 172

8.3 Sensitivity analysis 174

8.3.1 The use of sensitivity analysis 174

8.3.2 Sensitivity of the land use model 176

9. The development of the land use modelling approach 180

9.1 Comparison of the land use models defined for the Sedbergh district 181

9.2 Use of the land use model 191

10. Conclusions and discussion 196

10.1 The potential of the model framework 197

10.2 Problems associated with data requirements 198

10.3 Land use allocation in the Sedbergh district suggested by the land use model 199

10.4 Suggestions for further research 206

10.5 Use of the land use model in planning 207

Appendices/

Page

Appendices

A1 The land classification 209

A1 1 The land classification system 209

A1 2 Description of the land classes defined in the Sedbergh district 210

A2 Model input coefficients 215

A2 1 Production coefficients 215

1.1 Agricultural production coefficients 215

1.1.1 Common land and conservation areas 218

1.1.2 Assumptions 219

1.1.3 Data sources 219

1.2 Forestry production coefficients 219

1.2.1 Assumptions 221

1.2.2 Data sources 222

A2 2 Economic coefficients 222

2.1 Agricultural economic coefficients 222

2.1.1 Common land and conservation areas 225

2.1.2 Assumptions 230

2.1.3 Data sources 230

2.2 Forestry economic coefficients 231

2.2.1 Assumptions 233

2.2.2 Data sources 233

A2 3 Labour requirement coefficients 233

3.1 Agricultural labour coefficients 233

3.1.1 Common land and conservation areas 235

3.2 Forestry labour requirements 235

3.3 Labour assumptions 236

3.4 Data sources 236

A3 List of abbreviations 237

A4 Definition of the land use model 239

BIBLIOGRAPHY 243

LIST OF FIGURES

		Page
Figure 3.1	The Sedbergh district, Cumbria	
	(i) Location of the Sedbergh district	46
	(ii) Sketch map of the Sedbergh district	47
	(iii) Physical characteristics of the Sedbergh district	47
3.2	Distribution of land class groups in the Sedbergh district	51
4.1	The net present value of farming and forestry using a range of discount rates	74
7.1	The distribution of common land and areas recognised as being important for their ecological, archaeological and landscape value in the Sedbergh district	123
8.1	Potential gross margins (£, 1977/78) associated with dairying per land class according to different data sources	147
8.2	Potential gross margins (£, 1977/78) associated with livestock rearing per land class according to different data sources	148
9.1	Suggested land use allocation in the Sedbergh district	190
10.1	Potential forestry areas in the Sedbergh district assuming that all land is available for planting.	202
10.2	Potential forestry areas in the Sedbergh district assuming no afforestation on common land or 'conservation' areas	203
10.3	Likely forestry areas in the Sedbergh district.	204

LIST OF TABLES

		Page
Table 2.1	Activity criteria related to stages of the plan making process	26
2.2	Strategic planning methods	27
4.1	Features of the land use model	66
4.2	Format of the land use model	69
5.1	Land use allocation to land classes (number of squares) for alternative land availability restrictions, given no predetermined production and labour input limits	82
5.2	Production and input levels associated with alternative land availability restrictions, given no predetermined production and labour input levels	85
5.3	Production and input levels associated with alternative land availability restrictions, while maintaining current production and labour input levels	89
5.4	The current land use pattern in the Sedbergh district	92
5.5	Current input and output levels in the Sedbergh district	93
5.6	The effect of restricting forestry planting in the district on land allocation, production and labour input levels, given no predetermined production and labour input limits	97
5.7	The effect of restricting forestry planting in the district on land allocation, production and labour input levels whilst maintaining current production and labour input levels	99
6.1	Suggested land allocation when optimising beef production, with no limits on production and labour input levels	103
6.2	Suggested land allocation when optimising beef production and maintaining current production and labour input levels	105
6.3	Land use allocation to land classes when optimising different objective functions	108

Page

6.4 Production and input levels suggested when optimising different objective functions 112

6.5 Maximum value of objective functions under different constraint specifications 113

6.6 Land use allocation trends 118

7.1 The distribution of common land and conservation areas in the Sedbergh district 124

7.2 Estimated current production and input levels from common land and conservation areas in the Sedbergh district 124

7.3 Estimated potential lost/gained by maintaining common land and recognising conservation areas 131

8.1 Suggested land allocations according to different data sources, given no predetermined production and labour input levels 149

8.2 Production and input levels suggested by different data sources, given no predetermined production and labour input levels 153

8.3 Suggested land allocations according to different data sources while maintaining current production and labour input levels 155

8.4 Production and input levels suggested by different data sources while maintaining current production and labour input levels 159

8.5 Potential increase in the total net present value of production in the district according to different data sources 161

8.6 Labour input associated with forestry activities 165

8.7 Timber production assessments 165

8.8 Estimated levels of current production and value from, and inputs to the Sedbergh district 173

9.1 The development of the land use model 182

Appendix Tables/

			Page
A2 Table	1	Agricultural production coefficients	216
	2	Land use and livestock characteristics by farm type	218
	3	Forestry production coefficients	220
	4	Market prices adopted	223
	5	Agricultural economic coefficients - potential "GM" per annum, (£) per 25 ha, according to different data sources	226
	6	Agricultural economic coefficients - potential "GM" expressed in terms of £000s NPV at r = 3%, per 25 ha, according to different data sources	228
	7	Forestry economic coefficients - potential "GM" expressed in terms of £000s NPV at r = 3%, per 25 ha.	232
	8	Labour requirement coefficients	235

INTRODUCTION

Planning in rural areas is the responsibility of many government organisations, each of whom have their own area of concern. Many of the conflicts and problems that arise between rural land use activities occur at the interface between separate areas of action, but no one group of planners takes responsibility for the overall planning of rural areas. The statutory planning system is not appropriate for considering rural land use activities and is not concerned with the total rural system as shown in Chapter 1. Few planners consider integrated land use planning though many recognise this to be essential for an efficient use of Britain's rural land areas.

An interdisciplinary planning approach is desirable in which all of the interested parties are coordinated and able to express their own views, but there have been few attempts to achieve this. This thesis investigates a potential planning method which looks at the use of land for agricultural activities and forestry by means of a simple modelling approach. New approaches are being used in planning as discussed in Chapter 2, but few are applicable for considering rural land use activities and the conflicts that arise.

The approach examined in this thesis offers one means of coordinating rural planning discussions and exploring future planning strategies. The approach was initially proposed by Bishop (1978) who suggested using a land use model for strategic planning on a regional basis. A land use model was proposed which looked at future land use in Cumbria in terms of land use patterns and levels of productivity. This work although specific to Cumbria was largely concerned with the actual modelling approach. A Working Party Group was set up to discuss the model and its validity, and this led to a further investigation of the model by Cumbria County Council, who organised a study to look at the use of this approach in a local planning context. A model was defined which described a smaller area, the Sedbergh district, where at that time a local plan was being prepared by conventional methods. This study is discussed in Chapter 3.

The land use model is a relatively simple optimisation model based on the common technique of linear programming. The early models defined by Bishop and Cumbria County Council were non-dynamic and resource orientated. They were criticised over their lack of consideration to time as a variable, and the lack of a common unit of measurement such as a monetary value. The current land use model, details of which are presented in Chapter 4, overcomes some of this criticism by incorporating time and economic variables in its framework. It is hoped that this model can be of more direct value to planning discussions.

The remaining chapters of this thesis are devoted to evaluating the land use model and the modelling approach as a planning tool. The land use model has the advantage that it is capable of examining a vast number of situations and could be used to investigate policy proposals or the likely effect of a certain course of action or event. Chapters 5 and 6 illustrate the ability of the model to look at different problems and examines the effect of constraint relaxation on land allocation and the use of different objective functions and discount rates. Chapter 7 discusses one application of the land use model: to look at the potential use of common land in the Sedbergh district. Common land is an important resource in most hill farming areas, offering rough grazing land without which current farming systems would probably have to change. There is a great deal of conflict over the use of upland common land for agriculture or forestry, and the model has been used to look at the influence of maintaining common land and recognising areas of high ecological, archaeological and amenity value on land allocation in the district.

The limitations of the land use model and the degree of uncertainty associated with the method are discussed in Chapter 8. The limitations and uncertainties of the model, must be recognised, as a lack of understanding can lead to misuse and misapplication of the method, possibly resulting in disastrous consequences, and also misrepresentation of the potential value of the modelling approach. The final chapters discuss the development of the land use modelling approach (Chapter 9), and look at the conclusions derived from this study (Chapter 10).

Information on the land classification used is given in Appendix 1, and full details of the model input coefficients and the means of estimation are described in Appendix 2. Abbreviations used are given in Appendix 3. The land use model is defined in Appendix 4.

Chapter 1

THE STATE OF PLANNING IN RURAL AREAS

1.1 PLANNING IN RURAL AREAS

Most people are aware of the considerable planning conflict that arises in the uplands of England and Wales, between competing land uses such as agriculture, forestry, water and mineral extraction, recreation and nature conservation. The number of conflicting objectives and pressures on the land has increased in recent years, and this trend is likely to continue. There has also been an increase in the number of organisations concerned with the planning and management of rural land areas, both government and non-government bodies, but there has been no attempt to develop an integrated land use policy which would act as a planning guideline when trying to resolve these conflicting interests. The planning and management of rural areas is a difficult task and the various planning organisations have each approached the problem in their own manner. They have each defined policies specific to their interests which they aim to achieve, but this does not result in an efficient rural planning system. It has led to the current rural planning process which is weakly formulated, inadequately coordinated, and lacks both coherence and a concern for common goals. Planning has been largely left to the individual owner, and this has resulted in a lack of investment in most rural areas, especially in the uplands.

The pace at which changes in rural land areas occur today and the structure of land tenure are considerably changed from those in the past and this means that planning must play a more important role. There are greater pressures on rural land areas, rapid advances are being made in technology and the traditional landlord/tenant system of farming is being replaced by a more efficient system of owners/occupiers whose main concern is increased profitability and productivity rather than the visual and ecological nature of the land. In the past the countryside has been largely left to itself, and this has resulted in a functional countryside which was accepted and enjoyed by everyone. However, without some planning today, the current semi-natural systems will be not only modified but possibly destroyed. One might argue that the planning of rural land areas should be left to market forces but this could lead to an undesirable countryside. It is likely that good agricultural land would be transferred to urban uses if market forces alone determined the use of the land which would cause an increase in the fragmentation and remoteness of many farms and would result in a decrease in agricultural productivity. Non-tangible elements of land use such as recreation and nature conservation do not have market values, and these factors would not be taken into consideration if planning was left to market forces, and this would not lead to a countryside which was acceptable to the total population.

Planning today is largely at the local or national level and is often divorced from the area concerned. Each region has its own characteristics and associated planning problems, and it is essential to be fully aware of these when making planning decisions. A large number of organisations concerned with the management of rural land areas exist, all of whom have a part to play in the planning of rural areas. The local authorities are regarded by many as the main planning body but in reality they play only a minor role in rural planning. The statutory planning process is not equipped for planning rural areas and upland areas in particular have been neglected, concentration being given to those activities which are under statutory control and in which the statutory planners have greater skill, such as the provision of services and the development of communication networks. It is difficult to escape the fear that sensitive proposals for rural areas may be a disaster when implemented, and an over-protective reaction and a reluctance to formulate positive policies is a natural outcome but neglecting the problem can also be a disaster. In the statutory planning process (Heap, 1978) "development" excludes the two main uses of rural land, ie agricultural activities and forestry. As a result statutory planning gives little consideration to these activities, the planning of which is mostly in the hands of government agencies who offer advice and incentives to the private individual. For example in the current local plan draft for the Sedbergh district prepared by Cumbria County Council, agriculture and forestry are included in 'other topics' when considering issue areas. This represents a mere 7% of the report length, yet the livelihood of most of the district is centred on hill/upland farming activities, the viability of which dictate the economy of the whole district. Agricultural and forestry proposals are not a function of Cumbria County Council. "Development" does however, limit the erection of certain types of buildings, especially in National Parks where attention is given to maintaining the character of the area, and this may limit agricultural enterprises and possible economies of scale, which in turn may reduce potential production.

Each government agency involved in rural land management, such as the Ministry of Agriculture and the Forestry Commission, plans within its own remit and few give any consideration to the total rural area. This planning approach is inefficient making little use of the available expertise in the different organisations and often planning roles overlap. The structural organisation of all these independent organisations is questionable and clearly an integrated organisational structure would be desirable whether this be through a new organisation or a committee (Chapter 9). An integrated planning approach is desirable with improved coordination between planners. The current statutory planning system based on structure plans, though not orientated to rural planning does emphasise the need for liaison between the different planning agencies. To ensure planning consistency between and within authorities, and to make the most of the considerable expertise that has been built up in each field of planning, ie outside local authorites, liaison is necessary. Statutory planning responsibilities at present are divided between authorities, so that County Councils are responsible for the production of structure plans and some local plans, whilst most local plan preparation is carried out by District Councils. The local plan for the Sedbergh district of Cumbria is the responsibility of Cumbria County Council because this district lies within the Yorkshire Dales National Park which does not have its own planning board like the Lake District National Park Special Planning Board. The planning of the Yorkshire Dales National Park is undertaken by a Yorkshire Dales National Park Committee, and it is clearly essential that the local plan in the Sedbergh district is compatible with policy and management plans for the Yorkshire Dales National Park and Cumbria's structure plan. Therefore liaison between planners is vital.

Planning policies form the main framework which govern land use activities, but most of the policies are directed towards the production of single commodities and do not consider land use activities as a whole, neglecting the fact that all rural activities are highly related to each other. There is no land use policy as such and no high level control over land use planning, each government organisation planning to the best of its ability with only limited control. Many of the existing policies are only vaguely defined. There has been the suggestion of a coordinated land use policy on a national scale (Bowman et al, 1978) but this has been much criticised (Whitby and Thomson, 1979) and is unlikely to solve the rural planning problem as this varies between regions according to local characteristics and the country's economic environment. One must consider how best to use the rural resources in each area to meet the national, regional and local strategies, and solve the conflicting interests. One must consider alternative uses of the land and be prepared to change land use activities should government strategy suddenly change, due to for example, the cutting off of particular markets increasing the need for self sufficiency in a certain commodity such as timber.

At present there is a lack of comprehensive positive planning, with few guidelines from central government on the use of rural resources, ie no clear government strategy on food and timber production, recreation and the importance of nature conservation. The planning procedures and policies that do exist are highly likely to be interpreted differently by different planning bodies (and even by different branches within one organisation) according to their character and philosophy, and there is no standard procedure or means of evaluating planning success. This can easily lead to a fragmented form of planning and policy making and results in inconsistent planning, often increasing the degree of conflict between land users. The planning of rural areas is largely achieved through government agencies and indirect control, ie financial measures such as guaranteed prices, market support, subsidies and grants which are used to direct land use changes. Planning using such measures is complex as considerable expertise and administration is necessary to implement these measures successfully. Agriculture and forestry (in the private sector) are highly influenced by financial incentives, and one might regard current land use as being a product of land ownership.

1.2 ORGANISATIONS CONCERNED WITH THE MANAGEMENT AND PLANNING OF RURAL LAND

A large number of agencies have developed, all of which are concerned with the use of rural resources including for example the Ministry of Agriculture, Fisheries and Food, the National Farmers' Union, the Forestry Commission, the Nature Conservancy Council, National Park Boards, the Countryside Commission, Tourist Boards, Water authorities, the Country Landowners Association, Development agencies and local authorities. Each agency in the past particularly, has had a single purpose outlook, and the objectives of all the various organisations often conflict. Every organisation has its own responsibility. For example the Ministry of Agriculture is concerned with the management of agricultural land and food production, the Forestry Commission is concerned with afforestation both in terms of research and timber production by the State and the private owner, and the Countryside Commission is concerned with nature conservation, landscape enhancement and the provision of facilities in the countryside for enjoyment by the public.

Planning ability varies within every organisation and different interpretations of existing policies are likely. Every branch of every organisation has its own character and their remit will be interpreted in the light of their philosophy. It is likely that the objectives of any organisation may become distorted especially if prestige and public image are important, and in practice their objectives may not serve the purpose for which the organisation was set up. Often there is no clear goal and no clear terms of reference defined within organisations, and this can lead to piecemeal public investment which may increase the conflict between land users. Each organisation has only limited control over land use activities and decisions are made to the best of their ability but many management agreements have to be made on a voluntary basis, being based purely on the goodwill of the land owner.

Coordination between planners who are specialists in their own fields, is recognised as being essential to successful planning. A multi-disciplinary approach is necessary to achieve the objectives of the different planning bodies because no one organisation has a high degree of power or control over land use activities, and any decision taken by separate organisations has little effect on rural systems. This is partly because different planning bodies are concerned with different planning questions at different levels of planning. For example, the Ministry of Agriculture are concerned with planning at both regional and farm level, whereas the Countryside Commission is mainly concerned with regional planning and the Nature Conservancy Council with the planning of specific sites. The establishment of Rural Development Boards were regarded as an answer to the difficulties of planning rural issues, but the Northern Pennines Rural Development Board was only shortlived, being disbanded on philosophical grounds after only eighteen months in 1970 (Clout, 1971). The idea of a development board for Mid-Wales was aborted at that time but a Board was established in 1977 and is still in existence. The Northern Pennines Rural Development Board was set up to examine principally, farm restructuring into viable units, the integration of farming, forestry and amenity, the interests of the community and urban dwellers and the provision of social and public services. The Board was heavily criticised for its controversial powers on land use transfer, its attitude to change in rural areas and undue emphasis on agricultural interests (whose representatives dominated the Northern Pennine Board) ignoring other land use activities. It was regarded as introducing yet another administrative unit into the complex system of local government, which had powers of some of the other existing organisations, and in theory, many of the activities of the Rural Development Board could have been carried out by existing organisations (House, 1976).

Cooperation and consultation in planning problems are essential so that one can make the most use of available expertise and formulate a plan which will satisfy all those concerned, though some may have to modify their extreme views and accept that a degree of change is inevitable. Conflict between planners may arise over a number of issues which might be concerned with technical, political or procedural arrangements in planning, but all planners from whichever organisation have a common task, the operation of the planning system. There is a need for a common language which can be understood by all planners at whatever level of, and in whatever field of planning, avoiding so-called 'planners' jargon' which can be used to confuse, mislead and disguise errors and assumptions. Mutual understanding is necessary with a clear definition of task and terms of reference. There needs to be continuous monitoring and review of policies, which implies coordinated planning and regular information flow.

Flexible arrangements are desirable with both formal and informal contact between planners. Under the current planning system joint consultative working arrangements such as Working Parties and Committees have often been established with members from the different organisations concerned, to discuss particular planning problems. A Working Party, for example, including academics and members from both government and non-government bodies was set up (1977) to discuss the research on the land use model which is the basis of this thesis. The comments of the Working Party Group on the validity, and criticism of the model has proved valuable in the development of this planning approach. The group showed a willingness to cooperate but this was restricted by the limited powers and objectives of each interested organisation. Many committees have made contributions to the controversy on land use in rural areas such as the Scott Committee on Land Utilisation in Rural Areas which examined rural planning in England and Wales (1942), the Select Committee on Scottish Affairs which investigated land resource use in Scotland (1973), the Countryside Review Committee established (1974) to review the state of the countryside in England and Wales and the pressures upon it (the Committee being largely concerned with policies and published a series of discussion papers) and the Standing Committee on Rural Land Use in Scotland which has taken an initiative in relation to land classification and information on rural land. These arrangements improve liaison between planners and increase their awareness to the total planning situation.

Projects like the Upland Management Experiment (UMEX) (Countryside Commission, 1976) and the current Fellside project (Eden District Council) are attempts to link the different organisations concerned with land use activities and obtain an acceptable solution to the planning problem. UMEX was a joint venture by the Countryside Commission and the Ministry of Agriculture started in 1969, to look at means of reconciling recreation, conservation and agricultural interests. The East Fellside and Alston Moor Project (1979/80) was set up by Eden District Council to achieve positive action to reverse the continuing social, economic and environmental deterioration in the area. This project is concerned initially with information gathering and assessment and later with the stimulation of possible courses of action by local communities and participating agencies.

Most planning ventures such as the projects mentioned above and general plan preparation involve information collection, as the data available in most situations are inadequate and patchy in availability. Insufficient information is available on land classification systems many of which are not suitable for considering rural land areas, and there is little physical, economic and social information on land use activities which are essential to any study looking at the future potential of rural areas. Often data is collected such as the annual agricultural returns, but rarely used in planning problems because confidentiality limits availability and generalisation of results loses some of the flexibility of the data. Poor communications between interested parties who possess different information, can result in a costly planning process, delaying planning procedure especially if the required information is recollected because someone was unaware of its existence within another organisation. Information collection is a costly and time consuming business which could be reduced with improved communications between planners and widespread dissemination of results. Often more time is given to the process of data collection than to the actual consideration of possible strategies, policies and planning alternatives, and their implementation and likely impact in the area concerned.

All planners whatever their interest are trying to satisfy as many of the land users as possible. They are aiming at a trade-off which offers an economic and viable life style for the local community (improving where possible the economic base of all activities for which export potential in hill country is generated), gives an acceptable balance between domestic and imported food and timber, and which provides amenity facilities for both those in the local community and the urban dwellers. A balance has to be struck between land use activities in the area concerned and outside demands, and the ability of local resources to meet them. The planning process is considerably influenced by political pressures, and the planners with limited responsibilities and power can only try to influence the decision of the private individual, ie the land user. Planners, particularly those with an interest in rural land management, are coming to recognise the need for coordinating policies and expertise and to collect feedback on the success of planning approaches and policies. This has led to renewed interest in planning methods which may provide useful aids when studying complex systems, though many of those developed are not directly applicable to the conflicts that arise in rural areas where changes have been slow and where a sensitive planning approach is needed.

Chapter 2

PLANNING METHODS

2.1 INTRODUCTION

Statutory planning practice in Great Britain has been criticised considerably over its subjective nature and the seemingly ad-hoc approach to any planning problem, personal intuition and professional judgement playing a vital role. There appears to be a lack of standard planning procedure and in many situations a satisficing approach seems to be adopted, resulting in whatever compromise causes 'least offence', regardless of how efficient a solution may be.

Planning in any context, whether it be concerned with urban or rural areas is, and will always be concerned with complex systems, and no one individual planner could ever hope to look at all of the planning options available. Reality is incredibly complicated, full of intricacies and irrelevancies, and to understand a situation completely, let alone to plan it completely, would be out of the question. One must use concepts which are simpler, more unified and less detailed than any particular reality. For many years the plan making process followed the survey-then-plan paradigm, and it was not until fifteen to twenty years ago that planners adopted more systematic approaches to planning and started to develop decision-orientated methods which helped to simplify and explain the planning problem.

This chapter begins by examining the range of statutory planning methods that have been developed and looks at factors which limit the development and application of new approaches. It then looks at potential newer methods based on modelling approaches, which might be of value to planning particularly in rural areas.

2.2 DESCRIPTIVE REVIEW OF STATUTORY PLANNING METHODS

A vast amount of literature exists on strategic planning methods, much of which is not directly applicable to rural areas. No single method is a suitable framework in which to examine every planning problem and different methods have been developed to aid planning at different stages of the plan-making process. Batey and Breheny have classified strategic methods according to activity criteria, ie those of similar methodological and technical content, each activity being related to stages of the plan-making process (Table 2.1).

Table 2.1 Activity criteria related to stages of the plan-making process

Policy	Defining aim of the plan	(1)*
	Evaluating alternatives	(6)
	Selecting a strategy	(7)
	Implementing the plan	(9)
Design	Identifying the main policy option	(3)
	Generating alternative strategies	(4)
	Preparing the plan	(8)
Analysis	Assembling and analysing information	(2)
	Elaborating alternative strategies	(5)
	Monitoring and review	(10)

* numbers represent the stages of a generalised plan making process.

(Taken from Batey and Breheny, 1978a, p.265).

Table 2.2 shows the range of methods used in strategic planning practice classified according to Batey and Breheny (1978a) and indicates the main characteristics of each method. Many of the methods are based on expertise from other disciplines. Analysis methods such as input-output and social area analysis are based on information "borrowed" from the disciplines of economics and geography, and in the case of policy and design methods, the main sources of information are economics and operational research. Some methods have been developed outside the statutory planning sphere such as those based on optimisation methods and cost benefit analysis, whereas others including the planning balance sheet have been developed primarily for use in planning.

Table 2.2 Strategic Planning Methods[1]

(a) Analysis

Method	Function	Subject	Theory	Space
Activity-Commodity Framework	1/2	C		A/S
Capacity Restraint Assignment	2	T	N	A
Cohort Survival and Extensions	2	P	N	A/S
Concentration Specialisation Measures	1	E	N	A/S
Dynamic Simulation Model	2	C		A
Economic Base Analysis	1/2	E		A
Forecasting frameworks	2	P/E		A
Housing Requirements: Assessment	1/2	P	N	A
Input-Output Analysis	1/2	E		A
Integrated Land Use Transport Model	1/2	C		S
Lowry Model	1/2	P/E		S
Migration: Regression	1/2	P	N	S
Modal Choice: Dissaggregate	2	T		A
Modal Split: Logistic Curve	2	T	N	A
Problem Identification Surveys	1	C	N	A
Ratio and Apportionment	2	P/E	N	A
Retail Forecasts: Step-by-step	2	E	N	A
Shift and Share Analysis	1/2	E		A
Shopping: Gravity	1/2	E		S
Social Area Analysis	1	C		S
Traffic Assignment: All-or-nothing	2	T		S
Trip Distribution: Gravity	1/2	T		S
Trip Distribution: Growth Factor	2	T	N	S
Trip Generation: Category Analysis	2	T	N	A
Trip Generation: Regression	1/2	T	N	A

(b)/

Table 2.2 (continued)

(b) Design

Method	Function	Subject	Theory	Space
AIDA[2]	1/3	-		A
Decision Optimising Technique	3	-		A
Environment Impact Analysis	1/3	-		A
Linear Programming	3	-		A
Potential Surface Analysis	2/3	-		S
Scenario Writing	2	-	N	A
Sieve Map	1/3	-	N	S
Simulation	2/3	-		A

(c) Policy

Method	Function	Subject	Theory	Space
Accessibility: Potential	1/2	-		S
Accessibility: Spatial Opportunity	1/2	-		S
Checklist of Criteria	1	-	N	A/S
Community Preference Surveys	3	-	N	A
Financial Investment Analysis	1	-		A
Goals Achievement Matrix	1	-	N	A
Planning Balance Sheet	1	-	N	A
Robustness Analysis	1	-	N	A
Social Cost Benefit Analysis	1	-		A
Threshold Analysis	1	-		S
User Benefit Measure	1	-		A/S

Key: Function: 1. Description; 2. Prediction; 3. Prescription.
Subject: P. Population and/or Housing; E. Economic Activity; T. Transport; C. Comprehensive.
Theory: N. No discernible theoretical content.
Space: S. Spatial; A. Aspatial

Notes

1. Table based on classification of strategic planning methods by Batey and Breheny, 1978a, p.269.

2. AIDA represents the Analysis of Interconnected Decision Areas.

Often planning methods have a range of functions and can therefore be used at various stages throughout the planning process. This is particularly the case for models developed for 'predictive' purposes. These methods are able to describe the state of a system and also investigate the effect of 'present trends continuing' and conditional predictions, which enable the planner to gauge the effect of some proposed action and answer the question 'what would happen if ...?'.

2.3 THE DEVELOPMENT OF STATUTORY PLANNING METHODS

Systematic approaches to planning were introduced in the early 1970s when sub-regional studies came into being. At this time there was more interest in the development of new methods as opposed to actual planning policies and proposals, ie more concern with the technical rather than the practical development of methods. Planners were concerned with acquiring the expertise to use and develop the new methods rather than consider the purpose which the methods were supposed to serve.

Over-enthusiastic planners regarded the new methods as being the answer to strategic planning and believed that once suitable techniques had been developed, then planning would become a purely rational process. No overall planning framework was considered such as a hierarchy of methods in which each subsystem serves a defined purpose. New approaches were often chosen for their novelty value, and few attempts were made to link the chosen method to the planning problem which led to considerable misuse of potential methods. Many of the early methods used were one-off exercises, ie specific to a certain problem, and all were basically descriptive, spatial methods with clearly defined boundaries, such as the Lowry model.

The development, application and generation of results from any one method involve a considerable time lag and many of the methods applied to planning were not applicable to the prevailing planning problem. Planning problems change considerably through time, different emphasis being placed on different aspects of planning. Early planners concentrated on descriptive, spatial growth methods looking at 'key growth' areas such as urban and transportation systems, whereas today there is greater concentration on predictive, aspatial methods looking at socio-economic problems. Many of the early systematic methods were incorrectly used and the results were rarely questioned as it was felt that this might undermine the planning case. There was often no indication of how accurate or effective the methods were and how much time and resources, including manpower, were necessary to adopt that method. The method, results and success of any one technique were rarely documented and communications between different planners were limited. This, together with the general lack of expertise and experience in using analytical methods increased the likelihood of misusing a potentially useful method.

The early naiveté and over-enthusiasm of planners have now been tempered and more reasonable views are held on the role of methods in planning. The planning process is no longer regarded as merely a technical process, and planners are aware of the importance of carefully selecting a method to serve the planning purpose in hand and to consider the limitations of each approach. More care is taken over the choice of an appropriate method and the presentation of results and assumptions, and there is greater expertise and skill in the use of systematic approaches. Planning methods developed in other disciplines and used in industry are being explored and if feasible used in statutory planning.

The actual adoption of systematic methods is influenced by several factors (Wade, 1971) which may be described as organisational constraints, technical and theoretical problems.

(a) Organisational constraints

The nature of the organisation within which strategic planning is taking place has an important influence on the use of systematic methods. A positive attitude to systematic methods is necessary by both top management who control the use of internal resources, and the actual users of the method. The fewer the resources in terms of time, finance, expertise and facilities, and the smaller the degree of organisational change, ie the closer the approach relates to the basis on which the planner works, the more likely a new approach will be adopted in planning. Models are often regarded with suspicion because of the associated risk and the possible loss in personal prestige and more conventional techniques are adopted. This apprehension can only be overcome if the planners are fully aware of the potential and limitations of different methods, which implies a need for good communication between all those concerned. Each method only examines part of the planning problem and a combination of approaches is most appropriate. At present there is often a gap between the modeller and the planner who is the model user, but without the breakdown of this barrier there is no clear communication on the meaning of the model and the purpose for which it was meant to be used.

Models and planning methods are often inadequately reported, insufficient detail being given to the objectives, the number of variables and constraints, and model sensitivity. To be of most use, information relating to the success or failure and the difficulties of using particular planning methods must be disseminated widely, both between and within organisations, and feedback collected. Any model is more likely to be used if it is well documented and is known to have been successfully used elsewhere for similar planning purposes. The acceptance of particular model results is likely to depend on the plausibility of the results themselves and whether they are politically and socially acceptable, extreme suggestions being regarded with suspicion. A model considering land use activities for example, which did not suggest any degree of change from the current situation is likely to be surrounded in doubt, but similarly if the transactions suggested by the model are difficult to achieve through limited resource availability or limited control over land use activities, the model results might not be acceptable.

(b) Technical problems

Technical limitations are likely to play an important role in the adoption of new techniques, particularly that concerning the documentation of the method as mentioned above, and the availability and quality of input data. The availability of appropriate data is often limited due to confidentiality or because the data available are too generalised; any model must make maximum use of existing data in their current form. A wide range of measurement criteria is used in different planning methods, some of which are very subjective or derived using controversial methods, eg the assessment of intangibles such as recreation and nature conservation, and it is important that the criteria used are clearly explained. It is essential in any method to be aware of the underlying assumptions and the degree of uncertainty associated with both the method and the input data. The use of sensitivity analysis is vital to look at the accuracy of any method. These details are often omitted from the presentation of results and may lead to misinterpretation which could result in taking the wrong planning decision, sometimes leading to disastrous consequences.

(c) Theoretical problems

Early systematic methods were taken to be worth using if the results were regarded as reasonable and accurate, whether the method had a sound theoretical basis or not. An accurate theoretical basis is vitally important especially the structural basis, as any form of bias or omission of variables can considerably distort the results. It is on the basis of nonexistent or inadequate theory that much of the criticism of methods rests. From the point of view of an operational model, simplicity is often preferred where one can fully understand the structural basis, and individuals are usually wary of large computerised models which they cannot fully understand. In general, a simple flexible structure is preferred which has proved to be robust. A linear programming model for example is a simple structure and is likely to arouse more interest and be more widely used than a complex simulation model requiring numerous facilities and a large data input which are often not available. Planning is regularly carried out in a haste because there is only limited time available, and this goes against the use of large complex models.

The availability of results from systematic methods is often given far greater consideration than the quality of the results which is vitally important. Little consideration is generally given to the limitations of the method adopted or the likely degree of error associated with results, which could have an important influence on the final decision. More concern is being taken now, and it is realised that results may be interpreted in a number of different ways, according to the values and preferences of the planner and politician.

The planning methods used at any one time generally reflect prevailing methodologies or views of the planning process. The method reflects statutory requirements, current issues, theoretical and conceptual views and technical fashions. A distinct change in planning methods arose with the introduction of systems analysis to planning. This led to more explicit, aspatial methods which aimed at breaking the rigid barrier that had developed between planning disciplines. The systems concept proved powerful in understanding the complex multiple control situation that arises in planning problems particularly in upland areas (Collins and Thomas, 1973). However, it offers no aid to the choice or implementation of strategies, ie no means of looking at planning options or the impact of certain events without which one cannot plan efficiently the designed course of action. Systems analysis is merely a statement of relationships and processes looking at the relative importance of changes within the system defined. It looks at all aspects of the system in equal depth and at what combination of changes are needed to effect an improvement, as opposed to looking for crucial factors. Systems methodology has been subject to criticism (McDougall, 1973) partly because it was regarded as not appropriate to planning, but in many methods currently being used, it does offer a means of defining the system concerned in the first instance.

With the introduction of the structure plan process there was increased interest in explicit aspatial models. This reflects the nature of structure plans which are to include planners intentions for the next twenty years, or longer when appropriate, ie present policies to meet "future needs" (Massey and Cordey-Hayes, 1971).

There was an increase in the development of models investigating policy and design criteria (Table 2.2), particularly predictive models which are able to give an estimate of the effect of "present trends continuing". This trend implies the end of the single end-state model on an areal basis and the development of flexible, continuous frameworks which integrate the different planning sectors. However, in many situations planners still prefer to retain conventional planning approaches analysing present circumstances as opposed to future land use changes, which may not be directly applicable or the most suitable to the planning problem. There is increased interest in inter-agency coordination and policy-making as the importance of inter-relationships between different systems has been recognised. This has led to interest in more dynamic, integrated methods, many of which were not proposed specifically for planning and although less well known at present, may fit into the future methodological context anticipated. In the future, focus is likely to centre on those models that are able to help in reviewing and monitoring structure plans.

A wide range of techniques are currently being used in association with the preparation of structure plans (Booth and Jaffe, 1978). Matrix methodologies are often used such as the goal achievement matrix (Hill, 1968). Adjustments may be made to matrix methods to take uncertainty into consideration and weighting procedures may be adopted, but overall such a framework offers little aid to the planner for looking at the generation and evaluation of alternative strategies or future trends. Scenario writing (Hall, 1974) and Delphi techniques (Earwicker, 1974; Countryside Commission, 1974) are techniques which are increasingly being used but these involve a high degree of subjectivity and are not able to present the entire set of possibilities or give any aid to the selection of a future from the alternatives defined.

Cost benefit analysis is useful in certain planning circumstances but the method is often abused due to the difficulty of enumeration and evaluation of the costs and benefits, and the omission of certain elements which can easily lead to results of spurious accuracy. Cost benefit analysis is not often used in routine planning, alternative approaches being preferred. Many of the newer methods being proposed are based on a modelling approach using simulation and linear programming techniques.

Linear programming was introduced into urban planning in Great Britain through the AIDA approach (the Analysis of Interconnected Decision Areas) which was used in some structure plans (Hickling, 1978), and later through the modified DOT methodology (the Decision Optimising Technique) (Openshaw and Whitehead, 1975, 1977, 1979). Great confidence has been put in this methodology in many situations without indicating a thorough awareness of the limitations of the technique, and it has come under considerable criticism (Willis and Thomson, 1980). Great care is necessary when borrowing methodologies from other disciplines, but one should not underestimate the contribution that can be made to planning through adopting such an approach (Parry and Lewis, 1970). Many methods based on modelling approaches have been investigated, both hypothetically and in true planning situations. These may prove to be highly valuable to future planning, particularly as they may be developed to aid planning in rural areas whereas past methods have on the whole been concerned with the planning of urban and urban fringe areas.

2.4 POTENTIALLY USEFUL METHODS FOR PLANNING IN RURAL AREAS

Rural planning systems are different from urban planning systems and involve a vast number of planners, each of whom is concerned with different aspects of planning. The statutory planner has considerable control over activities in urban areas but very little power in rural planning, other government bodies being concerned with particular land use activities. The Ministry of Agriculture, Fisheries and Food for example, is concerned with agricultural activities, and the Forestry Commission with forestry enterprises, each of which forms a small part of the total rural system. The statutory planner does not have the statutory responsibility to consider those activities for which separate government bodies exist and concentrates on the planning of settlement and communication networks, using familiar techniques which have proved helpful to such problems in the past.

Each planning organisation has its own responsibilities and perspectives on the problem, and each carries out its activities according to their individual policies, as at present there is no overall policy relating to rural development. Certain organisations are concerned with strategic planning such as the National Park Committees and local authorities, whereas others are only concerned with planning specific sites eg the Nature Conservancy Council, and this difference tends to increase the degree of conflict between planning bodies. Every planning organisation is a separate entity but in rural planning one needs to look at the total system and separate organisations need to combine their expertise. All rural activities are highly dependent on each other, and it is recognised that greater cooperation is necessary between all the 'planners' to achieve efficient use of resources. For example, unless employment opportunities exist which are related to land use activities, areas will become depopulated and settlements, and in turn rural areas as a whole, will decline. Consideration needs to be given to the planning of all aspects of rural life avoiding emphasis on any one activity such as recreation, and a planning approach is necessary which would allow one to compare different rural land use activities.

To help planning in rural areas new methods are being suggested (many of which are theoretical at present) based on a modelling approach, which have been developed and used in other disciplines particularly Operational Research. Many planners are sceptical of so-called 'models' and avoid any modelling procedures, but a great detail of experience has been developed in other disciplines and such an approach is potentially useful to planning. Modelling is not an esoteric aid carried out by 'computer mad technocrats' (Collins and Thomas, 1973), as every decision however informal requires some modelling process. It is merely a management aid and is one of a series of approaches necessary to gain a complete understanding of any planning problem.

Modelling is the process of describing and understanding a real world system by analogy. A model of the real situation is built which is something like reality in all important respects (the latter defined according to the purpose of the model). This enables one to experiment with an analogy to the real situation as opposed to the real situation which could prove to be disastrous, ie the model represents a parallel conceptual system and it is only within this latter system that the results are applicable. Modelling offers a means of structuring problems in a logical manner, defining and measuring variables from which one can learn a great deal about the system being investigated. One cannot get more out of a model in the way of deductions and results than one puts in as assumptions and data. Logical deductions are made which state that such and such will happen as long as the model's assumptions and structure are correct. Information and data collection is an important part of any modelling exercise. Similarly, the use of sensitivity analysis is important, as the validation of any model is difficult.

Not every system can be modelled at once. No one model could cope with all levels of planning and different models are used to serve different purposes. A hierarchy of models is often required to look at different planning levels from the overall structure and policy making level down to the micro-level and specific management activities. These different models may need to be coordinated as results from one sub-system model may provide the input to a model elsewhere. Any user must be aware that the model concerned only examines part of the real system and that wider implications of the suggestions arising from the model, eg the multiplier effects in particular industries, must also be considered. The modelling approach may not only be used to look at systems at different levels of detail but also to consider a wide range of interests and resources uses. Modelling procedures also have the advantage that results may be replicated and problems reformulated if new uses or strategies are proposed. Planning is a continuous process and no strategy will remain appropriate for a long time period. Short-term modelling with incremental decision making and regular monitoring is of more value than long term decision making, where one decision is taken on the basis of current trends and remains in force for a considerable time. Reassessment and reformulation of strategies are necessary on a regular basis.

All interested parties may be involved in modelling methods and any model offers a means of communication between the different parties. The model may be used as a basis to planning discussions, suggesting alternative planning options to be considered, many of which might not have been obvious at the initial stage of the study. Modelling cannot give any aid with respect to implementation of any plan, but it offers one means of exploring problems, looking for alternative solutions which may then be discussed by the decision makers concerned. It is not a substitute for planning but an additional aid to part of the planning problem and is in no way a replacement for existing planning techniques and group discussion with all land use interests represented.

Many models suggested are hypothetical and have not been applied in a true planning context, and others have not been proposed specifically with respect to planning problems. Micro-economic models looking at financial and economic aspects of different decisions with respect to a specific problem and behavioural models, have been used to investigate problems concerned with a single planning activity but they are difficult to construct demanding a high quality of data input which is difficult to validate. Many of the models which have been suggested (Collins and Thomas, 1973) such as gaming models which might look at the control of land areas by different bodies, are theoretical and highly dependent on the modelling of human behaviour which is not only difficult but very subjective. The use of Markov Chains is often suggested as a potential planning method, but a model of this nature would require the derivation of a matrix or several matrices of transition probabilities which would be exceptionally difficult. The probabilities could be regarded as fixed but this would considerably reduce the applicability of the model. The most widely suggested models appropriate to planning are associated with simulation and optimisation techniques, which are more directly related to decision making because the variables they manipulate represent decisions of some kind.

Simulation as a planning tool was suggested by Dye (1973) in a sub-regional context in an upland area of Yorkshire, where there is strong competition for land. A computer simulation model was suggested as offering a partial solution to the conflicting interests for rural land, in which those elements which could be quantified were included. This would leave the politician free to exercise his judgement on the desirability of alternative planning possibilities from the competing environmental and other viewpoints not considered in the model. Changes were made to input variables, such as agricultural prices, to show the considerable interaction in practice, and the changes in net benefit accruing to owners of property rights in land, the labour implication of changes in land use, and the effects on the size of agricultural holding and livestock numbers. The model output is of less importance than the actual approach proposed and before it could be used in a true planning situation, further developments are necessary particularly with regard to the nature of the data input. However, it is questionable as to whether such a method would be too complex for widespread planning use, as it might not be handled with confidence.

Simulation techniques also form the basis of a model looking at the integration of forestry and agriculture, which has been developed in response to the growing conflict between these two activities in upland areas, by the Hill Farming Research Organisation (HFRO). The model is largely hypothetical looking at the allocation of land between these land use activities and the theoretical pattern that one should ideally achieve in the future to make the most efficient use of resources. It examines the benefits to be gained from integrated and non-integrated schemes between sheep farming and forestry production, over sixty years. This model is akin to farm management models based on linear programming which have been in use for some time (McFarquhar, 1961), and is not orientated directly towards regional policy making. It looks at the outcome of stated objectives and constraints concerned with integration, and this information could prove valuable to policy making.

Considerable work on land use modelling has been undertaken in Australia both at the farm level, looking for example at the role of poplars on the farm (Sinden, 1970) and on a wider scale looking at the interaction of forestry and agriculture and other multiple activities (Sinden and Kingma, 1972; Kingma and Sinden, 1975). In other research studies both simulation and linear programming techniques have been combined into one model in order to consider the importance of uncertainty and time on land allocation (Hitchens et al, 1978; also see Swartzmann and van Dyne, 1972). This model framework (Hitchens et al, 1978) has been adapted to look at both tangible and non-tangible elements of rural activities (Thampapillai and Sinden, 1979). Such elements of rural land use can also be investigated using an approach termed goal programming, which is a variant on linear programming in which land use needs are identified and means determined for fulfilling these needs (Ignizio, 1978). This approach has been used experimentally in Canada to look at land use in the Mount Hood National Forest (Dane et al, 1977). However, this approach can lead to a large scale complex model which requires a vast amount of data input some of which is impossible to obtain accurately, and demands prior decisions on the valuation and priority of goals. Also, considerable care must be taken when interpreting the results (Dyer et al, 1979). This method is not ideally suitable for routine planning and simpler models would appear to have the greatest potential value.

Models based on linear programming are less sophisticated than simulation models and in many ways are more likely to be of practical use in planning. Using the technique of linear programming offers a framework in which a large number of variables can be considered. Rural planning involves considering a wide range of interests many of which could be built into such a framework if performance measurements could be obtained from available statistics. A linear programming model could be applied at any level of planning, ie at a micro or macro level, according to the purpose of the model itself and the availability of data. The first application of linear programming was associated with farm management problems but the technique is now widely used in many disciplines.

Linear programming is a simple optimisation technique which could be used to sort out the complexity of any one system according to the objectives defined. It involves no preconceived ideas or decisions and is merely a logical deduction, based on the assumptions and data built into the model, looking for alternative solutions to the given problem. It may be argued that the technique is too simplistic especially with respect to the limitation that all of the relationships defined are linear, but with the limited availability of data and uncertainty of the assumptions, it is questionable whether a model of greater complexity would offer any great advantage. Simple models are rarely analysed in detail as they are often not regarded of any value to planning, but these may offer a more flexible planning procedure. Greater emphasis is generally given to high powered, ambitious models with a high degree of complexity, and which require data input that involves prior decisions about courses of action. The degree of error associated with more complex models is likely to be higher, though one would be able to express inter-dependencies between systems which are not possible using linear programming, eg the effect of economies of scale and links between upland and lowland farming activities. Linear programming models are often combined with other models such as simulation models, in order to make the models more realistic. Combining techniques often allows one to build dynamic models to take factors such as risk, uncertainty and intangible variables into consideration. Increasing the degree of complexity of any model increases the likely degree of error, and one must find an acceptable compromise.

Standard computer packages capable of optimisation procedures are available, and each has facilities with which one can investigate the sensitivity of the model, ie the robustness of the model and accuracy of the suggested solution. Planning is a continuous process and a model based on linear programming would be useful to monitor and review any planning policy or strategy, as the model results could be reformulated if part of the system changes. The format of a linear programming model can easily be adjusted, and a model could be used to investigate different objectives or different priority of objectives, or different restrictions on the system concerned. Like all modelling approaches any linear programming model offers the opportunity to link different aspects of planning. Each 'planner' could be involved in the identification of a specific aspect of the system providing advice and data information, and as all stages of the model can be explained in simple language familiar to all concerned, the model could then act as a basis for planning discussions.

Bishop (1978) proposed the idea of using a land use model based on linear programming, in strategic planning. The model defined looked at future land use in Cumbria given a set of objectives which included high agricultural and/or forestry production and the maintenance of rural employment. The land area, Cumbria, was classified on a grid basis into a series of land classes, each of which was assessed for its potential productivity under different forms of land use to a series of variables including food production and the level of energy input. The associated value of recreation and ecological values were also considered. The model was used to investigate the effect of regional policy proposals on land use patterns, production and input levels. Single and multiple objectives were considered, though the advantage of investigating the latter is questionable as there is little consensus within and between planning organisations on objectives, and this introduces an element of bias into the strategies proposed.

This work although specific to Cumbria was mostly concerned with the actual modelling approach to planning and outlined a potential framework. Interest was shown by different planning organisations and an investigation was undertaken by Cumbria County Council to look at the use of this approach in a local planning context. This study to be outlined in Chapter 3, led to the recognition of the limitations of the model which is basically non-dynamic and resource orientated. Prior to acceptance by the planners concerned, as an approach feasible for use in planning, further developments in the framework were necessary. The development of this approach is the subject of this thesis, and it is hoped that this work will fully explain the structure and potential application of the land use modelling approach. The planners need to fully understand this method before considering how, and if, it can be of direct value to planning.

Chapter 3

THE SEDBERGH RURAL LAND USE STUDY - APPLICATION OF THE MODELLING APPROACH IN A LOCAL PLANNING CONTEXT

3. THE SEDBERGH RURAL LAND USE STUDY

In 1978, work began on the preparation of a local plan for the Sedbergh district of Cumbria, following standard planning procedures (Biggs, 1980). Parallel to this work was a study looking at the present and potential use of rural land in the district using a linear programming model, the idea of which was first proposed by Bishop (1978). This study was undertaken to assess the usefulness of a modelling approach to rural planning, and it was anticipated that any useful conclusions arising from the study could be incorporated into the conventional local plan. Both studies were undertaken by Cumbria County Council though many other interested parties were directly involved in the latter study by providing data and advice, including the Institute of Terrestrial Ecology, the Ministry of Agriculture, Fisheries and Food, the Forestry Commission, the National Farmers' Union, the Nature Conservancy Council, the Countryside Commission, the Country Landowners Association, the Soil Survey of England and Wales and the Yorkshire Dales National Park Authority.

It was anticipated that the modelling approach would be able to provide information and ideas on land use activities in the area additional to that collected by the more conventional means. This extra information would be helpful to the planners when discussing how to achieve the following objectives of the local plan:

1. To develop the policy and general proposals of the Cumbria and Lake District Joint Structure Plan (Biggs and Taylor, 1980) and to relate them to precise areas of land. The relevant Structure Plan policies are concerned with:

   - the protection of the best agricultural land (policy 8.1)
   - assisting upland agriculture through tourism (policies 8.3 and 8.6)
   - the location of major afforestation (policy 8.9) and smaller forestry schemes (policy 8.8)
   - the maintenance of the existing pattern of trees and woodlands (policy 8.13)
   - the protection of important nature conservation sites (policies 8.25 and 8.26).

2. To promote a detailed basis for coordinating the development and other use of land, within the framework of the Structure Plan and the Yorkshire Dales National Park Plan (Harvey, 1978).

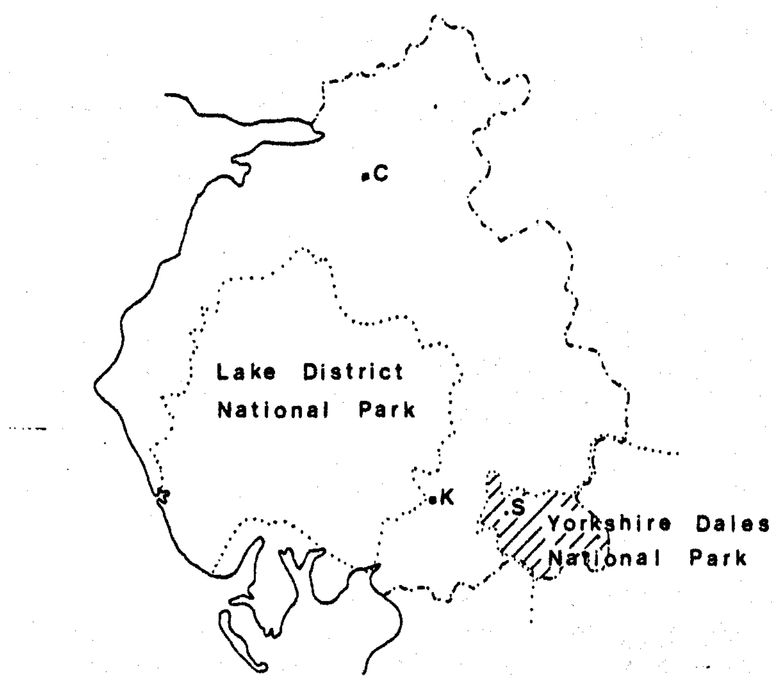
3. To consider management guidelines that will attempt to stimulate the agricultural economy of the upland areas.

The Sedbergh district is an isolated rural area in the extreme south-east of Cumbria (Figure 3.1). Its land area, approximately two hundred and twenty six square kilometres, is predominantly upland in nature with over two-thirds lying at, or over, 250 metres, and includes the upland valleys of the rivers Dee (Dentdale), Clough (Garsdale), Rawthey and Lune. The head of Dentdale, shown in illustration 1 (page 48) illustrates the physical characteristics of the district. The valleys radiate out from the town of Sedbergh and separate the Howgill Fells from the carboniferous fells of Baugh Fell, Rise Hill, Towns Fell, Whernside and Widdale Fell. Most of the land area is used for livestock rearing, the lower land being devoted to cattle enterprises and the higher slopes much of which is open common land, being used for sheep grazing. Not all of the land in the district is efficiently managed and some pastures are reverting to natural vegetation and becoming infested with bracken (illustration 2, page 49). The characteristic farm is small in size (about 32 hectares) and over the past few years there has been an increase in the number of small part-time farms ie those providing less than 250 SMD/annum. Hill farming is at present the main land use activity, but there is a continuous search for alternative employment. A small proportion (3%) of the land area is at present under commercial woodland and a few new plantings are being undertaken (illustration 3, page 49).

The district lies within the Yorkshire Dales National Park (YDNP) which puts external constraints on land use activities and means that planning decisions are more critical from an aesthetic point of view. Recently (April 1980) a bid to afforest part of the Yorkshire Dales National Park near Ingleborough was halted by government ministers, because they thought it would represent an

Figure 3.1 The Sedbergh District, Cumbria

(i) Location of the Sedbergh district



Key:

C Carlisle

K Kendal

S Sedbergh

Boundaries:

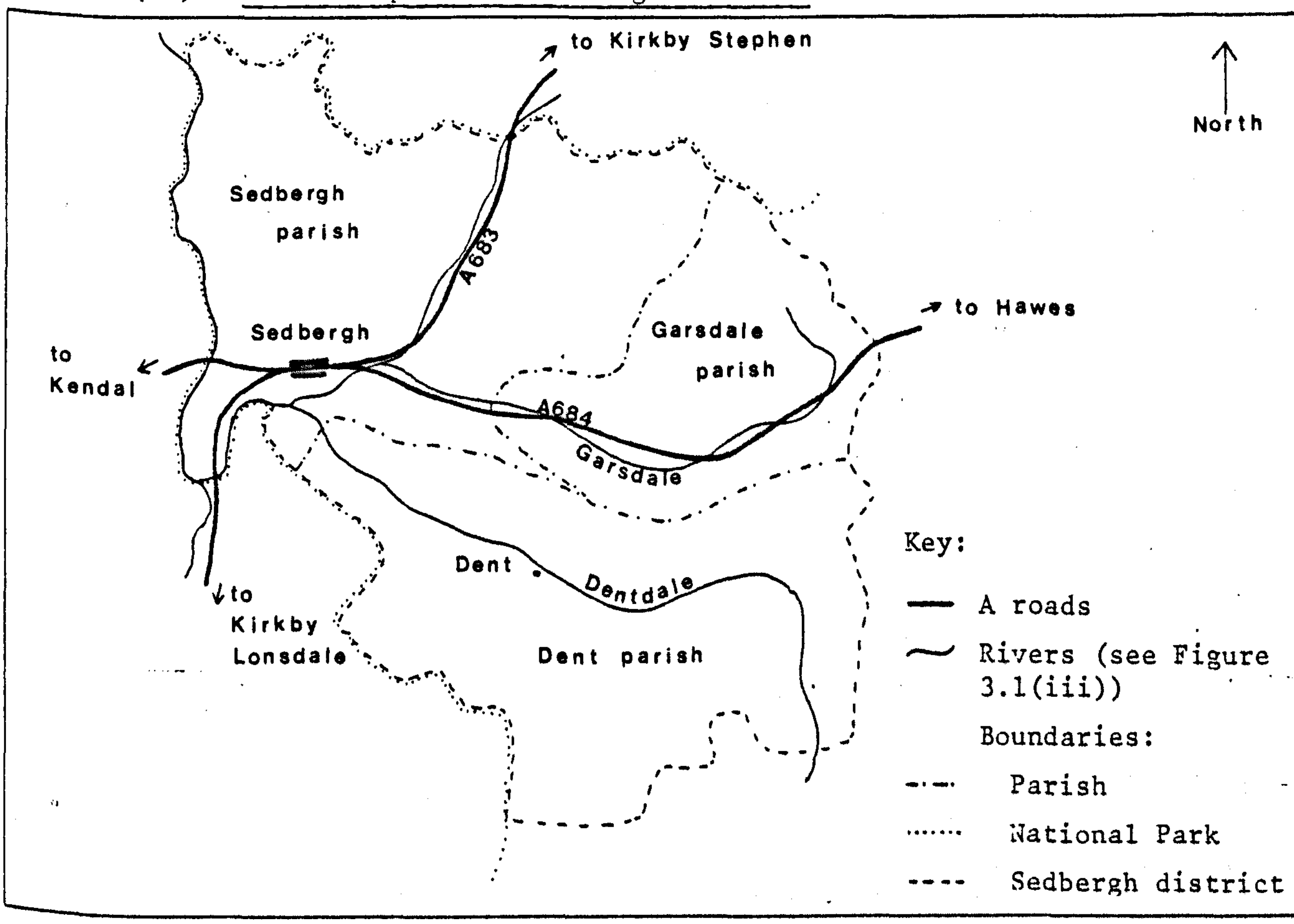
-·-·- County

······· National Park

▨ Sedbergh district

Figure 3.1 (continued)

(ii) Sketch map of the Sedbergh district



(iii) Physical characteristics of the Sedbergh district

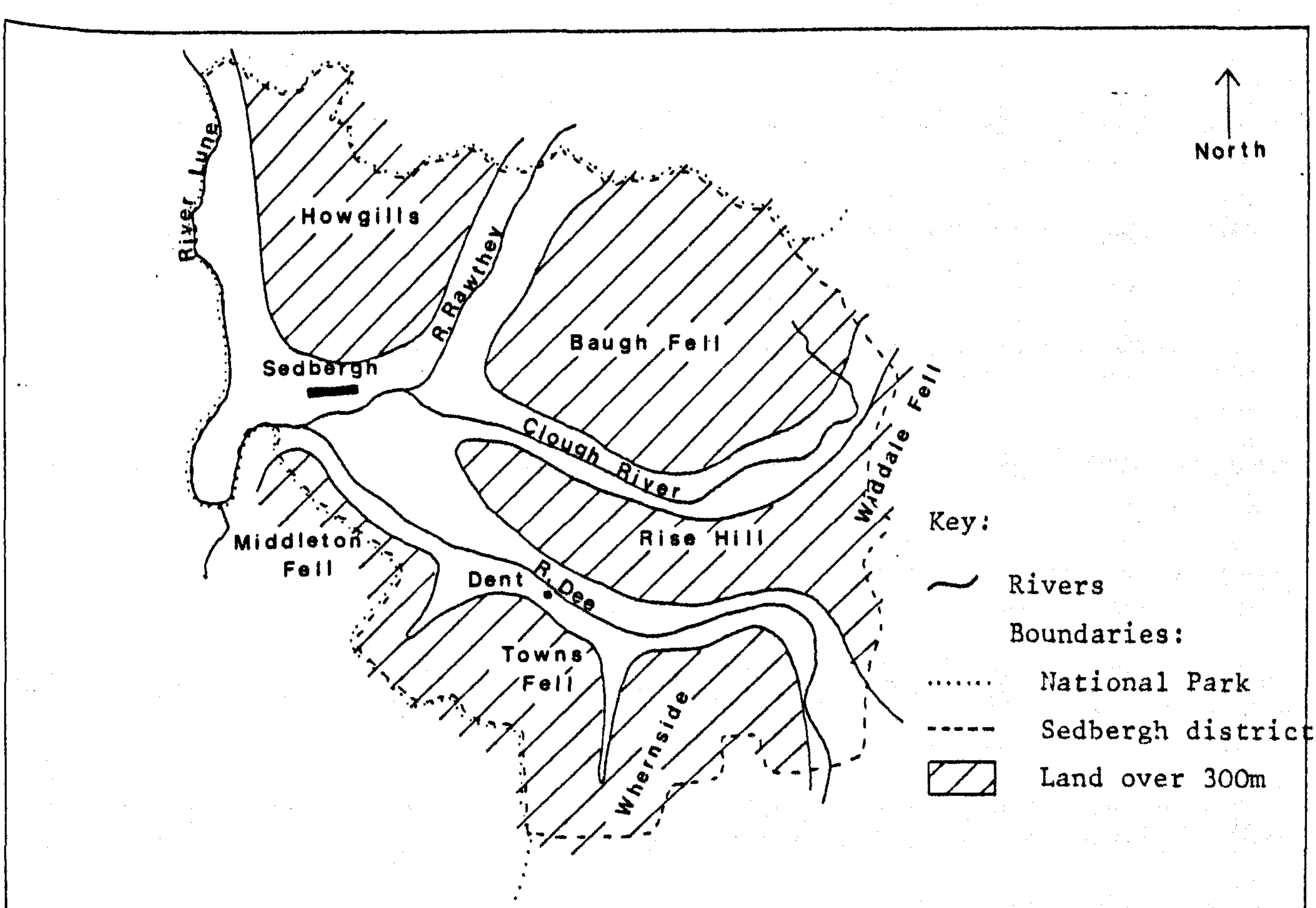


Illustration 1 Head of Dentdale

Illustration 2 South Facing Slope of Dentdale, near Sedbergh

Illustration 3 North Facing Slope at the Head of Dentdale

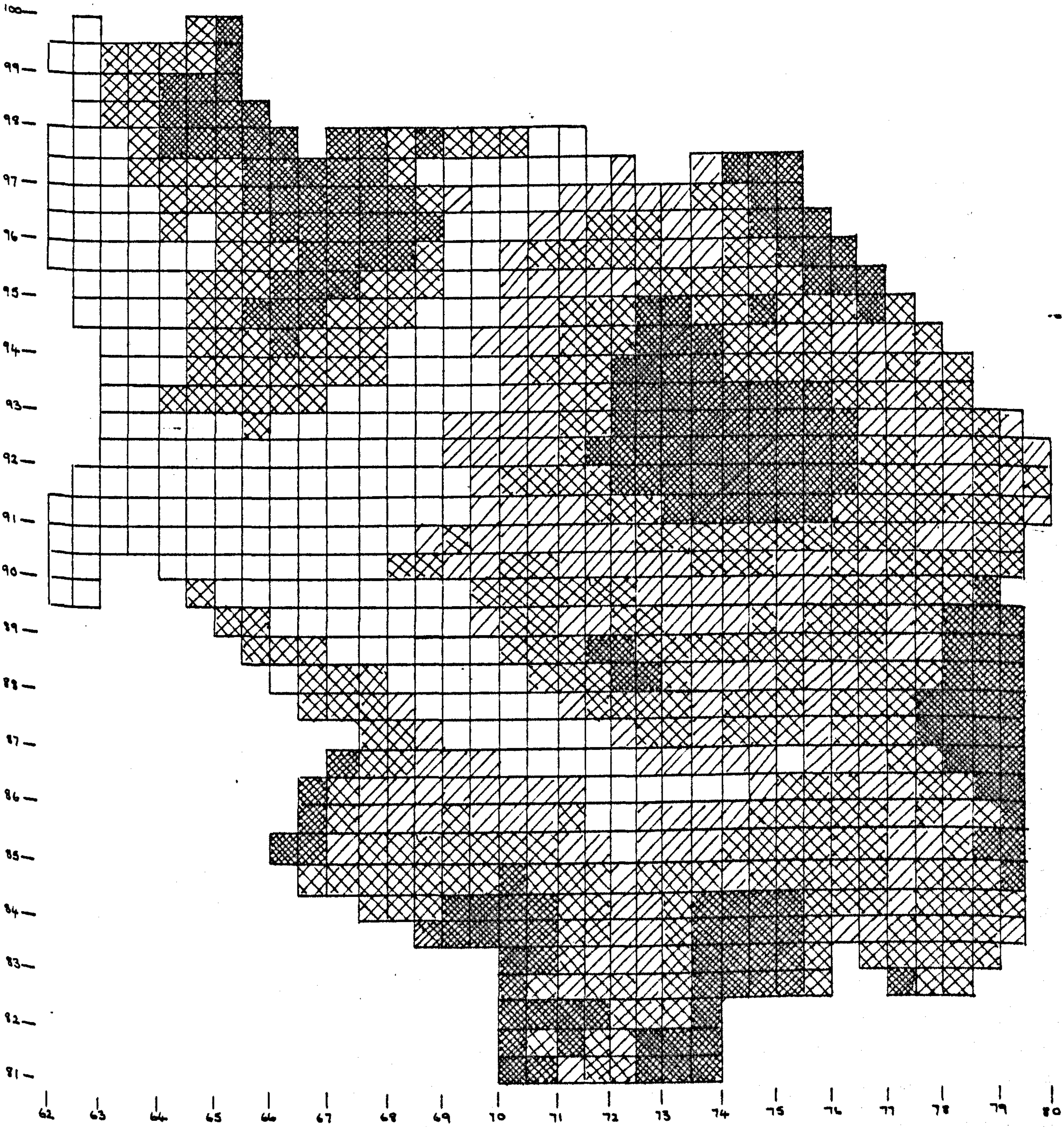
Land prepared for forestry planting

unacceptable intrusion into a particularly sensitive part of the national park. When local government was reorganised in 1974, the Sedbergh district became part of Cumbria, and Cumbria County Council is now responsible for the preparation of any local plans in this area. The Yorkshire Dales National Park does not have a unitary planning body like the Lake District National Park, and the planning of the rest of the National Park is delegated to a Yorkshire Dales National Park Committee, which means that liaison between all of the planners is important (Leach, 1979). The modelling approach, exploring the use of different types of land for different activities, offers a means of linking and improving communications between different planning bodies. Collecting the models' data requirements and discussions on the various strategies to be explored and the suggested outcomes from the model, lead to greater contact between those concerned with planning and a greater awareness of the planning problem.

The modelling approach (Bishop, Section 2.4) centres on a land classification which divides the land area up on a grid square basis into a series of land classes. Each land class is assessed for its potential contribution in terms of productivity, to a series of land use activities. The land use model looks at the optimisation of a defined objective such as the maximisation of meat production, subject to a series of constraints and is able to provide information on optimal land use patterns and production levels. Such information could act as positive and useful guidelines in determining management policies.

The land classification used (Bunce, Morell and Stel, 1975) is based on a ¼-square km grid as opposed to a 1-square km grid previously used by Bishop, who was interested in a larger land area (Cumbria). Sixteen land classes were identified initially, but later it was felt more sensible to amalgamate these land classes into seven land class groups as certain land classes were almost identical in terms of productivity (Appendix 1). The upland and lowland land classes identified form discrete blocks in the district (Figure 3.2) and can be defined as follows:

Figure 3.2 <u>Distribution of land class groups in the Sedbergh district</u>



Key:

- Lowland valley areas (land classes 4, 5, 6 and 7)
- Lower middle slopes (land class 3)
- Upper middle slopes (land class 1)
- Hill tops (land class 2)

(Figures on axes are Ordnance Survey National Grid numbers)

1. <u>Hill tops</u> (Land class 2)

   This area lies mostly over 488 metres (1600 ft) and is basically moorland vegetation with upland grassland and bogs, though in better drained areas drier grassland occurs which may be grazed. This area appears little different from the upper middle slopes in upland character.

2. <u>Upper middle slopes</u> (Land class 1)

   This land area centres around the 351 metre contour (1150 ft). Much of the area is rush-infested with bracken, matgrass and occasional blanket bogs, but this gives way to a wider range of vegetation at lower levels, which may be described as grazing heath.

3. <u>Lower middle slopes</u> (Land class 3)

   This land class group is in general, gently sloping lying mostly between 184 - 518 metres (604 - 1700 ft) and encompasses settlements and means of communication. There is a wide range of vegetation types but many are improved grassland used for grazing. It can best be described as marginal land, representing a transitional area between land of upland and lowland character, exhibiting properties of both extremes.

4. <u>Lowland valley areas</u> (Land classes 4, 5, 6 and 7)

   This area mostly lies below 250 metres, has low gradients and forms a discrete block encompassing the best agricultural land, particularly land classes 4 and 5. It is mostly meadow land, much of which is intensively managed. Good accessibility.

The model used in the Sedbergh study looks at the allocation of land to six different forms of land use, forestry, specialist dairying, mainly dairying, livestock rearing - mostly cattle, cattle and sheep, and mostly sheep, when optimising to maximise total production from the district of either milk, meat, wool or timber, or to maximise labour requirements. These land use categories defined are more realistic than the uses adopted by Bishop (Table 9.1) as they are taken from the MAFF farm classification on which most agricultural surveys are based. Each type of farming enterprise produces a combination of output products, no one farming type being solely concerned with the production of any one output such as milk, meat or wool. The proportion of each type of farming devoted to each form of output was estimated (Appendix 2, 1.1) and with information obtained on the potential productivity of each land class, estimates were made of the potential level of output of every product considered in the model, from each land class associated with each type of farming category. In other words, for 25 ha of each land class for each land use category, the potential output of milk, meat, wool, timber, and the potential input of labour was defined.

Estimation of the potential productivity of each land class was based on information collected from a series of surveys looking at the soil and agricultural capability of the area, vegetation groups and nature conservation habitats, which were carried out by the separate organisations assisting in the study. Assessments were initially made of the potential grazing livestock units in each land class, assuming that each land capability class was under the most common form of land usage, ie beef store cattle were kept on land of agricultural capability 5, beef fattening cattle capability class 6, and dairy farming practised on capability 4 and 5 land, from which the potential output levels were estimated.

Estimating the production potential of each land class ie the production coefficients, is beset with problems and numerous assumptions have to be made. The coefficients were validated where possible, with alternative data sources. Comparisons were made between the estimated total current production in the district of meat, milk and wool, according to the model input coefficients and alternative data sources, and the degree of error was found to range from -3 to +8% (Cumbria County Council, 1980, p.34). However, individual coefficients are liable to a greater degree of error if any one assumption or statistic is unreliable. There was no investigation into the sensitivity of the coefficients or the importance of particular assumptions which could influence the model results. For example, all of the production estimates are based on the estimated farm characteristics of each type of farming category which were based on grazing livestock unit (GLU) measurements, but differences may arise if the farm characteristics are based on labour (standard man-day) requirements.

The accuracy of the assessment of timber production and labour requirements associated with forestry operations used in the model is questionable. To any forestry operation, time and economic value are important factors, but these were neglected in the estimation of both forestry and agricultural production coefficients. Timber production was assessed in the model on an annual basis ignoring the fact that a threshold value exists below which timber production is of no real value. Forestry rotation cycles run for on average fifty to sixty years and most of the timber value is economically speaking, realised at the end of the rotation cycle when timber is clear felled. Timber grown for use as a form of energy is anticipated to have a shorter rotation cycle of approximately twenty years, but at present most forestry plantations are managed for the production of sawn timber which means a cycle of approximately fifty years, during which time the only timber output is in the form of thinnings. This means that timber output only arises when it is regarded as economic to fell or thin a forest area.

The model considers timber production from both coniferous and deciduous forestry but one questions the validity of incorporating production from deciduous woodland. Hardwoods unless planted commercially, although this is unlikely to due their slow rate of growth, do not offer a contribution to timber production levels. The latter are sparsely distributed throughout the district and may be regarded as being of only amenity, game, shelter and landscape value.

Forestry operations demand high levels of labour at the beginning and end of forestry rotations to prepare the land for planting and fell the timber respectively, and during the intervening years a lower level of input is required for routine maintenance operations. This variable demand for labour leads to problems when assessing the annual labour requirement in forestry operations. Afforestation does not offer continuous employment opportunities unless there is a substantial area of forestry, of mixed aged structure. Agricultural activities similarly demand variable input levels of labour throughout the year, but this is on a much smaller time scale than that associated with forestry operations, which in most areas can only be regarded as providing part-time employment.

Forestry and agricultural activities are treated in the same manner in the model, ignoring the importance of time, economics, and other social and political factors to each land use activity, which in reality determine the use of the land. Alternative means are necessary to measure, and incorporate both forestry and agricultural activities into one model framework where one can look at a wider range of factors which influence land management.

The model was used in the study to investigate the maximisation of each of the output (and input) variables considered. However, not every optimisation which was explored is realistic and useful to planners. The provision of rural employment is important to maintain the viability of rural areas and looking at the optimisation of labour input under particular conditions may provide useful information to planners. Maximising labour input requirements is only realistic if one assumes that current labour requirements associated with each land use activity will continue, ie one is optimising labour input requirements given no changes in technology. To increase the level of employment one might argue that current technology should be changed to more labour intensive methods, and that new labour intensive uses should be introduced to the area, but at present these are socially and economically infeasible solutions. When optimising different objectives, the model is capable of providing useful information on the number of individuals that could be employed by a particular land use distribution given current labour productivity, which reflects the potential employment opportunities associated with that optimisation. The model when used to explore the optimisation of labour input requirements needs careful interpretation as the results are valid in a limited sense.

The results associated with optimising wool production however, are not valid in the agricultural systems defined in the Sedbergh study. The most important output from sheep enterprises in Great Britain is meat production. Wool production is of minor importance and may be regarded as a by-product of the enterprise. After the decline of the wool industry in Britain, sheep were reared for mutton and lamb production and were sheared mainly for veterinary reasons. In recent years it has been recognised that the wool clip offers a substantial form of income to farmers, and it is believed that wool prices will be significantly increased over the next five years which may lead to changes in sheep rearing systems. If wool production was to become a viable enterprise and demand was assured, different sheep production systems would be adopted, different breeds and management schemes being introduced. Nevertheless, in the production system assumed in the Sedbergh district, wool is a by-product, only offering an added economic bonus to the sheep enterprise, and regarding wool production as an objective in the model is unrealistic.

One may also regard it as unrealistic to optimise total meat production. Meat production arising from dairy cattle in the Sedbergh district is mostly through culled animals and may therefore be seen as a by-product to the major enterprise. (Beef production from the dairy herd is usually seen as a subsidiary beef enterprise). However, beef and sheep meat production are major enterprises, the viability of which is seriously affected by market conditions. Therefore, it would be more realistic and more useful to the planner, to divide the input coefficients into each form of meat output and look at the optimisation of beef and sheep meat (mutton and lamb) production separately.

The Sedbergh model (defined in the study undertaken by the County Council) was used to investigate the effect of adopting a particular land use strategy on land use activities in the district. The individual organisations assisting in the study each proposed land use strategies which they would like to see adopted in the district (Cumbria County Council, 1980). Many of the elements in each of the strategies conflicted but there were similarities, different emphasis being placed on different management aspects by different organisations. The strategies proposed all contain elements which could not be included in the land use model and which are more relevant to the actual implementation of a chosen strategy such as:

- avoid farm amalgamation
- ensure the maintenance of the present level of access, especially to particular sites and features
- avoid changes which might encourage the development of inappropriate recreational and tourist developments.

The common elements of each strategy were identified and where possible built into the model by adjusting the input coefficients. The model was then used to explore the effect of three likely restrictions on land availability in the district, which were regarded as three different strategies. These strategies are given below.

Strategy 1

Assumes that land use was restricted, no land use changes being acceptable on common land, sites of special scientific interest (SSSI), nature reserves, archaeological sites and areas identified as being of value for landscape reasons.

Strategy 2

Assumes that land use was partially restricted in the district; Whernside site of special scientific interest, nature reserves and other areas for landscape reasons being restricted to their current land use activities and not being available for allocation to other activities. (NB Common land available for allocating to any land use activity).

Strategy 3

Assumes that there were no restrictions on land use; all of the land in the district being available for allocation to any land use activity.

Each strategy investigated only looks at production in that area where changes in land allocation are acceptable, and to compare each strategy it is necessary to look at total production in the district, ie include the estimated level of current production from the land areas which are restricted to their current form of land use. This means that to assess total production in the district, the results must be adjusted after optimisation. In each strategy, land allocation was examined when meat, timber, wool, milk production or labour input was optimised.

Using the model to explore the effect of a particular strategy on land use activities in the district should provide useful information to planning bodies, though it may be difficult to express the strategy in a realistic form that can be incorporated into the model. The significance of the coefficients used to express the proposed strategy in the study by Cumbria County Council, ie those built into the land use model, are questionable, particularly as the forestry coefficients relate to a form of land use which includes forestry, mainly dairying and hill sheep enterprises, ie mixed land use activities. The four basic elements of the proposed strategy (the common elements) which are expressed in the model coefficients are:

1. The preservation of broadleaved tree species.
2. The preservation of inbye land, ie capability classes 4 and 5, for agricultural activities.
3. Common land and areas of value to nature conservation and the maintenance of the landscape, are restricted to their current form of land use.
4. To maintain current agricultural production and labour input from/to the whole district.

The protection of inbye land and good agricultural land (2) is accommodated in the model by "reducing the timber outputs from the forestry land use category, by the amount of timber obtained from land in land capability classes 4 and 5. Meat, milk, wool and food energy outputs (and labour input) are allocated to this use, on the assumption that this capability class 4 and 5 land is used for mainly dairy farming and that unplanted land in capability class 6 is used for livestock rearing (mostly sheep)" (Cumbria County Council, 1980, p.38). Forestry as a form of land use in this strategy, therefore implies mixed land use activities in which land of the best capability is devoted to mainly dairying activities and the poorer areas to forestry and sheep enterprises. Combining such activities on a small scale, each land class grid square being 25 hectares, is infeasible both economically and in practical terms. Integrating land use activities is influenced by many factors including economic and technical considerations and the attitude of the individual concerned, and any forestry operation is unlikely to be feasible or acceptable on such a small scale. It is important to recognise the meaning of 'forestry' as an activity in the study, as when interpreting the results from the model, 'forestry' in the better lowland areas ie land classes 4 and 5, implies no actual timber production because the land area in these land classes belongs to capability classes 4 and 5, which are devoted to mainly dairying activities.

The model suggests that irrespective of which strategy is being explored (1 - 3), a significant increase in timber production from the district could be achieved and the current level of agricultural output and labour input maintained, if land was devoted to forestry. Increasing the land available for allocation to any land use, illustrated by examining the three strategies, leads in most optimisations to a greater increase in potential timber production, in the order of 2 - 3,000% over present production levels. The greatest increase in timber production is suggested in association with strategy 3, ie no restrictions on land use. The levels suggested in some optimisations explored under this strategy is twice that suggested under strategy 1 where common land, sites of special scientific interest, nature reserves and areas maintained for landscape reasons are restricted to their current form of land use. This suggests that those land areas restricted to their current land use activities in strategy 1, are to some extent potential forestry land areas. This raises the question of whether afforestation would be allowed in these land areas and to what extent, due to the so-called adverse effects that afforestation has on recreation, landscape and nature conservation. Optimising timber production and labour requirements led to the highest increases in timber production, over 25,000%, irrespective of which strategy was being explored. The potential increases in timber production suggested are dramatic because at present little of the district is under forestry as it has been prevented by the planning authorities concerned.

Increased meat production is also suggested by the model if land use activities were practised on particular land areas, but such increases (approximately 12% over present levels) are not as significant as the suggested increase in timber production. Similarly, the total labour input required for all of the activities is shown to increase particularly if timber production is maximised (increase of approximately 40%). However, if this is translated to the actual number of men employed, the impact of the potential increase in employment is reduced. The present land use distribution in the district suggests employment for about 172 individuals (estimate based on the model input coefficients), whereas that suggested by the model associated with agricultural optimisations is of the order of 179 - 185 according to the strategy examined, and that with timber optimisations of the order of 220 - 240 individuals.

The Sedbergh study did not involve any sensitivity analysis which means that there is no indication of the validity of the results and the limits within which the optimal allocations are true. The input coefficients themselves are questionable particularly the potential timber production and labour input levels, and therefore one cannot determine the accuracy of the potential production (and input) increases suggested, or the optimal land use distributions.

The land use allocation associated with each optimisation explored varied slightly but certain optimisations suggested similar patterns. The different strategies explored showed a tendency to the following distribution of land use:

Land Class	Land Use
1	Sheep rearing, some 'forestry'
2	'Forestry'
3	'Forestry' - sheep rearing
4	'Forestry' mostly, with livestock rearing (sheep, cattle and sheep)
5	'Forestry' and sheep rearing
6	Sheep rearing
7	'Forestry' - sheep rearing

NB 'Forestry' represents mixed land use activities, a combination of forestry, mainly dairying and hill sheep enterprises. 'Forestry' in land classes 4 and 5 implies mainly dairying activities only as the coefficients include no timber production from these land classes.

To illustrate the suggested land use allocations the present and proposed land use patterns were compared by means of a series of maps. The observed differences between the suggested allocations and the current land use pattern were classified into four categories:

- area of search for major afforestation
- area of search for minor afforestation
- area of change within agriculture
- no change

Changes within agriculture were indicated in the suggested land use allocations associated with each optimisation, but no attempt was made to express these changes spatially because of the importance of "the structure of farming, the pattern of ownerships and personal choices" to agricultural decisions which are not considered in the model (Cumbria County Council, 1980, p.44). Such factors also play a significant role in the decision for afforestation but this is represented spatially. The maps define areas where changes in agricultural activities or changes to forestry are suggested ie indicates those areas in which one must look for land which could be used for the suggested activity.

A major emphasis is attached to forestry land use because of the potentially high levels of timber production and increased employment levels suggested by the model, but with no consideration of the time element and lack of financial assessment the results are of little direct value to planning. The presentation of the maps involves allocating land use activities to actual land class locations, but no guidelines are given. The model is unable to give a spatial location for each land class and the decision-maker must make this subjective assignment based on personal knowledge and experience.

The modelling approach first suggested by Bishop was not intended to locate different land use activities to specific land areas, but to look at in general terms, what type of land should ideally be under which use, and thus present a pattern which planners could discuss and if selected, aim to achieve. It is not concerned with the actual implementation of any one land use pattern, and only looks at possible alternatives, leaving the problem of how and where to make any change to the planners. The model offers the opportunity to explore the effect of particular actions or policies.

It has been recognised that to be of any use to the planners, the general trend of changes in land use observed for the model results must be evaluated against landscape values, recreational resources, farm structure, economics and other factors, all of which influence the location of land use activities. Given the model framework used in the study undertaken by Cumbria County Council, considerable post-optimal analysis is necessary and the decision-makers must still exercise judgement on a wide range of aspects of land use management. If any of these aspects could be incorporated into the actual model framework, the alternative land use options suggested would encompass a wider range of factors which determine land use, and the decision makers would make fewer personal assessments.

The Working Party Group involved with this study who met to discuss the model and its validity, expressed interest in the approach but the model itself was subject to considerable criticism through its lack of consideration of time and the lack of a common unit of measurement such as a monetary value. These limitations restricted the amount of useful discussions possible because interpretation of the results was difficult. This thesis is concerned with developing the modelling approach by defining a more realistic model which can be of more direct value to planning discussions. The subsequent chapters outline the current land use model which has been defined, its features and structure which can be adjusted to explore a wide range of situations, and discusses the limitations and possible applications of the land use model in planning.

Chapter 4

THE LAND USE MODEL

4.1 INTRODUCTION

The land use model is regarded as being of use in strategic planning at both local and regional levels. It may be used in planning as a management aid, in different areas and at different scales. To illustrate the use and versatility of the model, this thesis is concerned with the application of the land use model to one particular district, the Sedbergh district of Cumbria, which was the subject of a study undertaken by Cumbria County Council (Chapter 3). In strategic planning a wide range of interests needs to be considered, and the land use model offers a partial solution to this problem in which different organisations concerned with rural land use can be directly involved. The model structure and parameters can easily be adjusted, and this means that it is capable of examining a range of questions. Questions regarding the loss of productive land, the restriction of land use activities in defined areas or possible new forms of land usage and management systems may be considered by the model, which looks at the effect such questions might have on the district, in terms of the level of total production, input requirements, production value and land allocation.

The modelling approach is the same as that used by Cumbria County Council (Chapter 3) but the model structure has been altered to examine land use activities over a single fifty year time period. Economic factors have been incorporated alongside production measurements, input requirements and constraints on the land area available, all of which have been expressed in greater detail to that in the previous model. This means that for each land use activity in each land class, an economic value and a series of production and input estimates have been defined.

4.2 FEATURES OF THE LAND USE MODEL

The main features of the land use model are shown in Table 4.1. The model looks at the allocation of land uses to different types of land in the district which are expressed in terms of seven land classes (Chapter 3, Appendix 1). It examines a range of agricultural

Table 4.1 Features of the land use model

Seven land classes.			
Eight land uses:	PW	-	Private Woodland
	SD	-	Specialist Dairying
	MD	-	Mainly Dairying
	Livestock Rearing:		
	C	-	Mostly Cattle
	CS	-	Cattle and Sheep
	S	-	Mostly Sheep
	KS	-	Sheep farming on common land
	PS	-	Sheep farming on 'conservation areas'[1]
Primary forms of output:	Beef		
	Sheep		
	Milk		
	Timber		
	Total net present value (TNPV)[2]		
	Agricultural net present value (ANPV)		
	Forestry net present value (FNPV)		
Other forms of output:	Wool		
	Dairy meat		
	Food energy		
Inputs:	Agricultural labour		
	Forestry labour		
	Total labour		
	Agricultural subsidies		
	Forestry subsidies		

1. Conservation areas refer to those land areas which are recognised as being important for their ecological, historical and amenity value.

2. TNPV (total net present value) is the present value of future cash transactions assuming a desired rate of return, arising from all land use activities.

activities and forestry, all of which are considered from the point of view of the private individual. This is important with regard to economic details. Private costs are considerably different from social costs, and forestry may for example be in the hands of the State via the Forestry Commission or the private individual. Most of the land in the Sedbergh district is managed by private individuals whether they be owners or occupiers, and at present little land is in the hands of the State. The existing forestry areas are mostly privately owned and managed through organisations such as the Economic Forestry Group (EFG).

A large proportion of the total area (34%) is currently designated as common land, and this is important to the viability of the farming communities (Chapter 7). There are also a number of sites in the district which are recognised as being of value to ecology, archaeology and to the maintenance of the landscape, such as Whernside, a site of special scientific interest (SSSI). Land use in these areas is important and for this reason they are defined separately in the model. Under current legislation land use activities in such areas are limited and it is difficult to implement any form of land improvement scheme which means that these land areas are only likely to be used for sheep grazing. The economics associated with farming enterprises in these areas will differ from other land areas due to the restrictions on land use, and for these reasons sheep grazing on common land and areas regarded as having a high ecological, historical and amenity value are treated as separate land uses in the model, KS and PS respectively.

Each land class under each land use is assessed for its potential contribution to a series of variables associated with the enterprises considered in the land use model. For example, the potential level of beef production is estimated in land class 4 under that activity classified as livestock rearing - mostly cattle, together with the potential output of sheep, milk, etc, and the potential labour requirements and input of subsidies. The output variables considered may be divided into "primary" forms of output, such as the output of beef and sheep meat, and "other" forms of output such as wool production as shown in Table 4.1. The "other" forms of output are secondary products arising from the main agricultural enterprise. The model has been used to look at the optimisation of the so-called "primary" forms of output and labour requirements, but it is also able to provide information on the production levels of the other forms of output not being optimised, and the input levels of labour and subsidies associated with the optimal solution.

The model does not include intangible variables such as nature conservation, recreation and social elements of land use because of the difficulty of defining and quantifying these factors satisfactorily (Section 8.1.2). The decision maker must use his own judgement when considering the alternatives from the view-points not considered in the model.

4.3 FORMAT OF THE LAND USE MODEL

The land use model follows the standard format of any linear program, ie the optimisation (maximisation) of a linear objective function subject to constraint and non-negativity restrictions, as shown in Table 4.2 (Williams, 1978). The model was run at the University of Manchester Regional Computer Centre (CD 7600) using the standard MPOS (Multi-purpose optimisation system) package available. The REGULAR algorithm was used in which all of the variables are continuous and the optimal solution, ie the number of squares in each land class allocated to each land use, is expressed in terms of fractions of squares. When interpreting the land use patterns suggested by the model it is easier to consider the solutions in terms of complete grid squares. This may violate some of the constraints and one might regard a mixed integer program to be more suitable. However it is questionable whether a mixed integer program would offer any advantage due to the errors accepted to be within the model through the data input and limitations of the technique of linear programming itself (Chapter 8). It was regarded more desirable to use the conventional, simpler linear programming algorithm with continuous variables.

Table 4.2 Format of the land use model

Maximise:	Single objective, eg total economic value, or timber production
Subject to:	Production constraints (Beef, Sheep, Milk, Timber)
	Economic constraints (TNPV, ANPV, FNPV, Type of Farming NPV)
	Labour input constraints (Agricultural labour, Forestry labour, Total labour)
	Total land area available constraints
	Specific land area restrictions (Common land, conservation areas)
	Existing forestry areas constraint

The model is only concerned with the maximisation of single objective functions, such as the total net present value of every land use activity considered in the district over 50 years, subject to a series of constraints, but the objective function and constraints may be interchanged and specified constraints optimised. This interchanging of objectives and constraints enables one to examine the options suggested according to different objectives, and overcomes any problem of determining a multiple objective which is exceptionally difficult. No clearly defined weightings for each single objective, from which one could define a multiple objective, are possible because of the lack of consensus on objectives within and between planning bodies and the lack of policy on rural land use. It is regarded as preferable to use a single objective model which will lead to a range of solutions which can act as a basis for discussion, rather than use a multiple objective and obtain, and possibly implement, a once-only solution. This type of approach may appear unusual to the planning profession, who are in general concerned with the task of achieving a multiple objective. However, strategic planning problems are rarely well defined and could be described as "woolly" (Openshaw and Whitehead, 1979), and documentary reports are often confusing to outsiders because there is no clear identification as to the planning objective.

When considering land use activities, one is often interested in the effect of particular constraints on land use. Constraints in the model may easily be adjusted or expanded according to the purpose of the model. For example, if one argues that any change in the pattern of land use activities is only justified if current levels of agricultural production are maintained, the production constraints may be set to achieve this level or more, or alternatively one could look at total production in the district if there were no predetermined limits on production levels. The land area in the district is finite and the model assumes that any land use activity can be allocated to any land class, unless this is restricted by a particular constraint. Constraints may be built into the model to restrict the use of land in particular land classes such as on that land designated as common land, or to restrict the total land area available. The land use model is structured such that those areas currently afforested will remain under forestry for the time period considered in the model. This is highly likely as these areas are on the whole relatively young in age and are in the hands of private owners under dedication schemes, which implies that the forestry rotation cycle must be completed.

4.4 MODEL INPUT

The model requires input data on the levels of potential production or input requirements for each variable examined, associated with each land use activity in each land class. In other words, potential coefficients are defined for every production variable, economic value and labour requirement considered in the model, together with the desired limit on each constraint, ie right-hand-side value.

4.4.1 Production coefficients

The potential production coefficients define the potential level of production from each land use activity per annum in each land class. These estimations taken from the study by Cumbria County Council are based on the capability of the land class, current land management practices in the district and average yields. The coefficients (Appendix 2.1) have been modified from those used in the study undertaken by Cumbria County Council in certain circumstances to increase their accuracy. One of the most notable changes in the coefficients is the subdivision of the previous so-called meat production category into its constituent parts, ie production of beef, sheep and dairy (culled beasts) meat.

The model format is organised so that given improved information on the farming systems in the Sedbergh district, more accurate production coefficients could replace the existing coefficients in the model and other potentially viable systems could be incorporated into the framework.

4.4.2 Economic coefficients

The economic value of different land use activities in different land classes is only considered from the point of view of the private individual because of the difficulty of quantifying 'social benefits and costs' associated with State activities. The coefficients include an allowance for agricultural subsidy payments in the form of livestock headage payments, forestry establishment and management grants, and forestry cost reductions through tax concessions which mainly affect forestry activities. These allowances are included in the valuations as the private individual is considerably influenced by financial incentives and support schemes. Planners, whatever their interest, whether they be statutory planners or from the Ministry of Agriculture (MAFF), have little direct control over the use of rural land, and one might regard the only planning that does occur to arise indirectly through financial aid and advice.

Estimation of the economic value of using different land areas for different land use activities was based on published statistics specific where possible to the district itself or the Northern Region of England. Most of the agricultural economic data are based on information from the Farm Management Survey (FMS-Newcastle University) taken from MAFF publications, which despite numerous assumptions appear to be the best data available to date. Alternative sources are continually being sought, particularly as no satisfactory means of validating the economic coefficients has been found. The agricultural costings are taken from several sources, one of which is the publication 'Financial Results and Measures of Efficiency for the Northern Region' (ADAS/ Newcastle University, 1979). Estimates of agricultural revenue are based on the potential production coefficients defined in the study undertaken by Cumbria County Council and current market prices for the year 1977/78. The use of alternative data sources and their effect on suggested land use allocation are investigated later in Section 8.2.

All of the forestry economic data were obtained from the Forestry Commission (Edinburgh) and are based on information from the North-West Conservancy, which in turn were related to the land characteristics in the Sedbergh district.

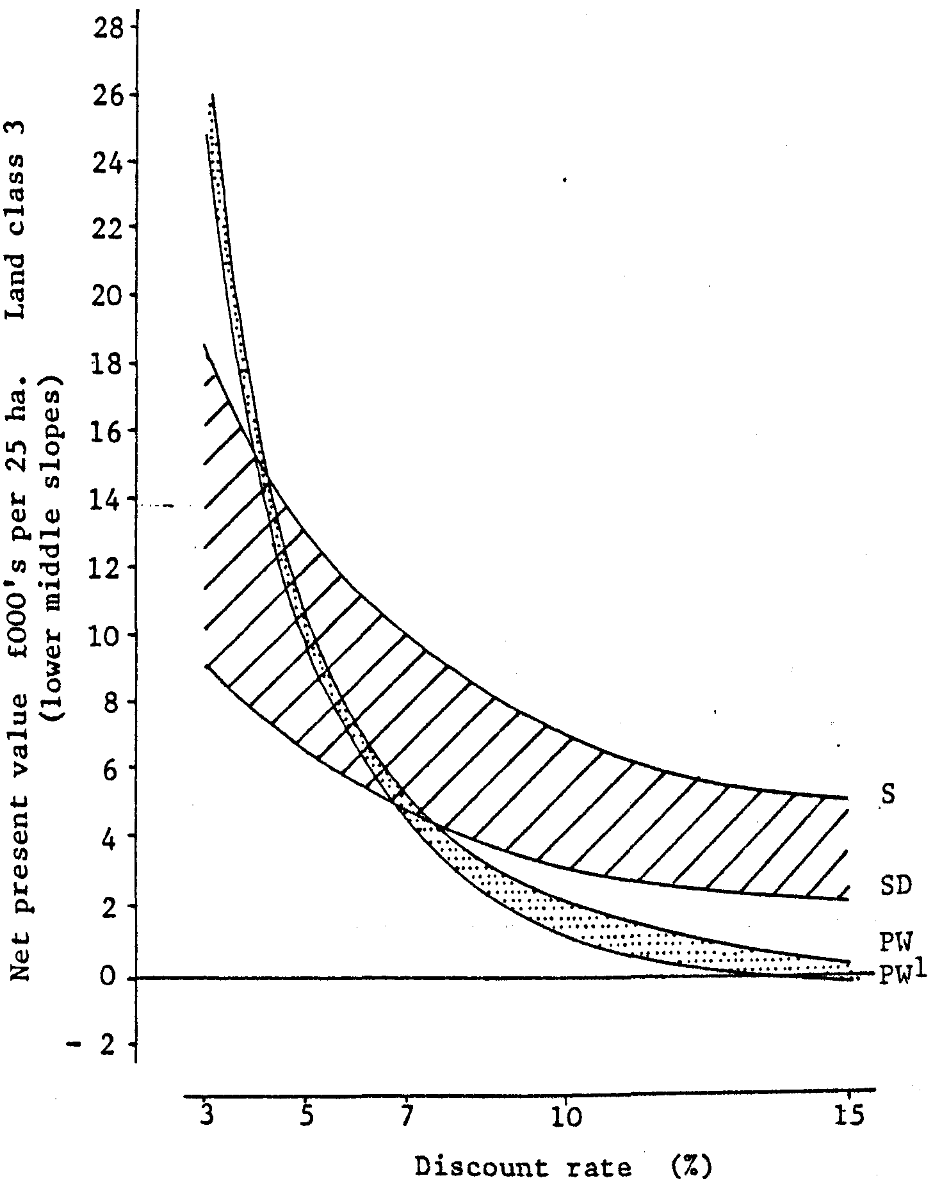
The coefficients defining economic value (Appendix 2,2) are expressed in terms of 'gross margins' ie take variable costs into consideration. However, it is not a straight gross margin value as to ensure compatibility between all land use activities the cost of manual labour including that of the farmer and his wife is included in the coefficients.

The land use activities included in the model have widely differing production cycles and to compare such diverse activities, the land use model must look at potential land use activities over a period of time appropriate to each activity considered. As total forestry benefits are not realised until the end of the forestry rotation cycle which in general runs for fifty years, as opposed to the annual benefits from most agricultural activities, this is the time period over which land use activities should be investigated. Adopting a long time period is necessary with any comparison between agriculture and forestry (James, 1964, 'financial rotation' 40 - 50 years; Maxwell et al, 1979, 60 years), and this means accepting a large number of simplifying assumptions, the most important of which is that constant real, relative prices, and constant productivity exists during the time period examined.

To take this time factor into consideration, the economic coefficients have to be discounted and expressed in terms of their present value, which is the present value of future cash transactions assuming a desired rate of return, arising from each land use activity. This leads to questions as to the choice of an appropriate discount rate. Traditionally, lower rates of return are expected from land using activities than in most industries due to the associated fringe benefits such as the security of land as an investment and the 'love' of the countryside. Individual owners may adopt a lower or higher rate of return to the government's 'test rate of discount' according to their personal objectives. The Forestry Commission (State forestry organisation) has at present a target rate of return of 3% for acquisition purposes and performance assessment, which is lower than the government test rate (5%) because it takes other social benefits into consideration, such as maintaining employment in rural areas and providing recreational facilities.

The choice of discount rate will considerably influence the contribution that each land use activity makes to the total net present value. Figure 4.1 shows the potential Net Present Value (NPV) estimated for each land use activity on the lower middle slopes (land class 3) according to different discount rates, ie the economic valuation of that area of land under each land use using different discount rates. This shows that high discount rates favour agricultural activities which produce benefits earlier rather than later and works against forestry which involves high establishment costs and low recurring costs; all potential agricultural activities in this land class at high discount rates give a higher economic value than forestry, sheep farming offering the highest value. Private woodland on this land type appears to be only favourable if one uses a discount rate of 3% as at higher rates sheep farming offers a higher Net Present Value. Owing to this problem of defining an acceptable discount rate, the land use model has been used to investigate land allocation when different rates are adopted. A low discount rate is the most acceptable in the current economic climate but the model has investigated the effect of adopting a rate of 3% (the return the Forestry Commission expects) and also higher rates, up to 15%.

Figure 4.1 <u>The net present value of farming and forestry using a range of discount rates</u>



Key:

PW Private woodland

PW[1] Private woodland with 20% increased costs

S Livestock rearing - mostly sheep

SD Specialist Dairying

Farming) Range in net present value shown according to the criteria
Forestry) defined.

Estimates of the level of subsidies and grants given to each land use activity in each land class are included in the model at the appropriate discount rate, which gives limited information on the level of financial aid associated with each of the suggested land use allocations.

4.4.3 Labour requirements

The input coefficients defining potential labour requirements are based on those estimated in the study undertaken by Cumbria County Council. The agricultural labour requirement coefficients are taken directly from that study and define the number of standard man days (SMD) required per annum for each farming activity in each land class (Appendix 2,3). (One standard man day is the equivalent of eight hours' work by an adult worker).

Assessing the labour requirements associated with forestry activities on an annual basis is more difficult due to the timing of forestry operations. Most of the labour requirements arise during the initial establishment and final felling stages of the forestry rotation with only limited demand for labour during the intervening years. The labour coefficients used in the model are based on information from the Forestry Commission (Edinburgh) who supplied the forestry financial details. The validity of these coefficients is questionable, and one may argue that the forestry labour coefficients are too high. Alternative means of estimating the coefficients were examined and are discussed in Section 8.2.2, but no satisfactory measurement has been derived.

4.4.4 The land area

The total land area is divided on a grid classification based on ¼ sq.km. units (25 hectares) into seven land classes (Chapter 3, Appendix 1). The total number of squares defined is 904, which are distributed through the seven land classes as follows:

Land Class	Number of squares defined
1	333
2	194
3	168
4	73
5	48
6	21
7	67
Total	904

The distribution of the land class groups in the district is shown in Figure 3.2. The land area designated as common land and as being of conservation value has been defined (Chapter 7) and may or may not be restricted to its current agricultural activities in the land use model according to the problem being explored (Section 4.2). The model defines those land areas which are at present under forestry. This land area is constrained to forestry and cannot be allocated to any alternative land use activity (Section 4.3).

The coefficients described in Section 4.4 may all be estimated by various methods using different data sources, and the influence of such variations on the model solutions and the sensitivity of the coefficients themselves are discussed later (Chapter 8).

4.5 OUTPUT OBTAINABLE FROM THE LAND USE MODEL

The land use model provides a great deal of information which could be of use to planning organisations. The output includes:

- the optimal value of the objective function, eg the maximum total net present value of potential 'gross margins' from the district from all of the land uses considered in the model. (One must remember that the optimal solution is only optimal for the problem under consideration, ie for the specified constraints and assumptions).
- the optimal land use pattern to achieve the given objective, ie the number of squares in each land class which should be allocated to each land use activity.
- indication is given if there are alternate solutions to the problem, ie a unique solution does not exist and alternative land use allocations will give the same optimal value. This is recognised by one of the following properties of the optimal solution:

  (i) a binding constraint with zero opportunity cost
  (ii) a variable at zero level with zero opportunity cost

Alternate solutions are quite common in linear programming. Characterisation of all of the optimal solutions is often very difficult but if one optimal solution is unacceptable and the phenomena recognised, one can look for another solution without downgrading the objective.

- the input and output values associated with the optimal land use pattern for the whole district, eg labour requirements, sheep production output levels.
- the quantity of resources which are unused and those resources which are fully used.
- opportunity costs, ie the cost of foregone opportunities by choosing that particular alternative (associated with non-basic variables only).
- details which give an indication of the sensitivity of the variables and the limits within which the optimal solution is true, ie ranging information. This information is useful to assess the robustness of the solution.

The following Chapters, 5, 6 and 7, discuss the use and possible applications of the land use model and look at the information obtainable from the model in more detail. Further details of the land use model are given in Appendix 4.

Chapter 5

LAND ALLOCATION IN THE SEDBERGH DISTRICT - POTENTIAL USE OF THE LAND USE MODEL

5.1 INTRODUCTION

The land use model is capable of exploring a vast number of problems and adjustments to the format or variable coefficients can easily be made. It has a wide range of potential uses and could be used to discuss policy proposals and their effect on the area, or the impact of a particular form of action looking at likely changes in the district.

The first land use model proposed by Bishop, was used to look at the effect of limiting the land area available for change and the effect of certain management policy proposals, favouring for example, low density forestry or low energy agriculture (Bishop, 1978). The County Council study similarly looked at the effect of adopting a particular strategy, which was derived from a series of strategies suggested by organisations concerned with the study, which they would like to see implemented in the Sedbergh district. The model considered this strategy under different situations in which restrictions were placed on the land area available for change (Cumbria County Council, 1980).

The current land use model has been used to look at suggested allocations of land use in the Sedbergh district under similar conditions, to assess the usefulness and ability of this modelling approach. The model has been used to explore many situations which take the objectives of the various organisations concerned with land use, including the objectives of the local plan (Chapter 3), into consideration where possible. This chapter looks at the influence of limiting the land area on which land use changes would be accepted and the influence of adjusting constraint specifications on land allocation. The following chapters examine the effect on land allocation of adopting different objective functions and discount rates in the model and looks at the suggested use of common land and land regarded as being of high ecological, archaeological and landscape value.

5.2 THE INFLUENCE OF RESTRICTING THE LAND AREA AVAILABLE FOR CHANGE ON LAND ALLOCATION

It is highly likely that there will be restrictions on land use in certain areas of the district. Areas at present designated as common land or regarded as being important for their ecological, historical or amenity value are unlikely to change from their current land use of sheep grazing in the near future, but with changes in government legislation or public attitude, such areas may be "available" for different land use activities. The degree of change in land use may also be limited by the land users who might not be willing to change the use of their land whatever the financial incentives or additional benefits offered.

The influence of potential restrictions on land use allocation such as those mentioned above, has been examined by the model assuming a discount rate of 3%. A low discount rate was chosen as it was regarded as most realistic in the current economic climate. Private woodland is more likely to be favoured at this rate, and using 3% would allow a comparison to be made between the land allocations suggested by the current land use model and the earlier model which devoted a high proportion of the land area to forestry (Chapter 3). The objective function was taken as maximising the total economic value (TNPV) and the allocation of land was considered when the production constraint specifications were set at both zero ie no predetermined level of production output is desired and at current production levels ie minimum production levels must be achieved equivalent to that produced at present. The actual situations examined are shown below:

Maximise: Total economic value (TNPV)

Discount rate (r) = 3%

Constraint limitations:

(a) Production limitations:

- (i) CST.ZERO - no predetermined levels of output
- or (ii) CST.CRT. - minimum level of production must be achieved equal to current estimated levels.

(b) Land availability restrictions:

- (i) No restrictions on land availability: all land in the district available for allocation. (Indicates the maximum value of the objective function possible).

(ii) Conservation areas are restricted to their current form of land use.

(iii) Common land and conservation areas are restricted to their current form of land use.

(iv) Only a limited area, taken as an arbitrary 10% of the total land area, is 'willing' to change land use activities, ie only 10% of the total land area is available for allocation.

(v) Conservation areas are restricted to their current land use activities and of the remaining land area, only 10% is 'willing' to change land use activities.

(vi) Common land and conservation areas are restricted to their current form of land use and of the remaining land area, only 10% is 'willing' to change land use activities. Highly restricted situation.

5.2.1 Results arising from the model given no predetermined production specifications

Considerable information is generated by the land use model (Section 4.5). Each problem explored by the model leads to a suggested optimal land use pattern and gives details of the associated production from and input levels to the district. To illustrate the information directly obtainable from the model, Table 5.1 shows the suggested land allocation, ie the number of ¼ square kilometres of land allocated to each land use, when the total economic value of production in the district is maximised at 3%, with no predetermined levels of production output or labour requirements, and there are:

(i) no restrictions on land use

(ii) common land and conservation areas restricted to their current form of land use

(iii) common land and conservation areas restricted to their current form of land use and only 10% of the remaining land area is 'willing' to change land use activities.

The land use pattern gives the number of squares allocated to each land use in each of the seven land classes. For example, with no restrictions on land use it is suggested that all of the squares in land class 1 are allocated to private woodland, and that three

Table 5.1 Land use allocation to land classes (number of squares) for alternative land availability restrictions, given no predetermined production and labour input limits

Problem: Max. TNPV, r = 3%, CST. ZERO, Land availability as indicated.

(i) No restriction on land use

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	333						333
2	3					191	194
3	168						168
4	4		69				73
5	1		47				48
6			21				21
7	1		66				67
Total	510	0	203	0	0	191	904

Key:

PW Private Woodland

SD Specialist Dairying

MD Mainly Dairying

Livestock rearing:

C Mostly Cattle

CS Sheep and Cattle

S Mostly Sheep

KS Sheep farming on common land

PS Sheep farming on conservation land areas.

NOTE: The above key is used in Tables throughout this thesis as indicated.

Table 5.1 (continued)

(ii) Common land and conservation areas restricted to their current form of land use

Land Class	Land Use								Total
	PW	SD	MD	C	CS	S	KS	PS	
1	185						123	25	333
2	3					69	104	18	194
3	117						41	10	168
4	4			69					73
5	1			46				1	48
6				15			6		21
7	1			33			31	2	67
Total	311	0	0	163	0	69	305	56	904

(iii) Common land and conservation areas restricted to their current form of land use, and only 10% of the remaining land area is 'willing' to change land use activities

Land Class	Land Use								Total
	PW	SD	MD	C	CS	S	KS	PS	
1	28		16		38	103	123	25	333
2	3				9	60	104	18	194
3	17		15		33	52	41	10	168
4	4	13	37	6	9	4			73
5	1		28	5	6	7		1	48
6		1	6	1	5	2	6		21
7	1	4	10	3	16		31	2	67
Total	54	18	112	15	116	228	305	56	904

of the available squares in land class 2 are allocated to private woodland and the remaining 191 squares are devoted to sheep farming. The model gives no spatial location of these squares but suggests that one must look at all of those squares classified as land class 2, for three suitable for timber production and devote the rest to sheep farming.

It is extremely difficult to present all of the land use patterns suggested by the model. No one pattern may be regarded as the best, and one can only attempt to look at general trends and identify the common elements in the patterns as these may be of use in planning. The general land use pattern reflected by examining restrictions on the land available for change and given the production constraint specifications are set at zero, is as follows:

Land Class	Land Use
1	Private Woodland
2	Sheep farming
3	Private Woodland
4	Cattle farming
5	Cattle farming
6	Cattle farming
7	Cattle farming

Common land if available in the upper and middle land classes (land classes 1 - 3) is likely to be used for private woodland or sheep farming. Relaxation of the restriction on common land and conservation areas leads to a greater area in the upland land classes being allocated to private woodland. This suggests that areas at present designated as common land and conservation areas are of potential value as forestry land. All of the problems explored showed a large degree of similarity in land use allocation.

The associated production levels are given in Table 5.2. The output/input levels are expressed as a percentage change from current levels. For example, the model suggested that with no restrictions on land use, the level of use of production from the whole district would increase 443% over current estimated levels

Table 5.2 Production and input levels associated with alternative land availability restrictions, given no predetermined production and labour input limits (expressed as a percentage change from current levels)

Problem: Max TNPV, r = 3%, CST. ZERO, Land availability as indicated.

Criterion	Primary Output Variables						
	Beef	Sheep	Milk	Timber	Total NPV	Agri. NPV	For. NPV
(i)	+443	-49	-88	+2294	+54	+ 9	+1697
(ii)	+438	-47	-89	+2131	+52	+11	+1578
(iii)	+383	-41	-90	+1378	+39	+12	+1031
(iv)	+ 95	-12	- 6	+1057	+18	- 2	+ 772
(v)	+ 89	-10	- 7	+ 894	+16	- 1	+ 653
(vi)	+ 35	- 4	- 8	+ 141	+ 4	+ 1	+ 106

Key:

(i) No restrictions on land availability

(ii) Conservation areas restricted

(iii) Common land and conservation areas restricted

(iv) Only 10% 'willing' to change land use activities

(v) Conservation areas restricted and only 10% of the remaining land area is 'willing' to change land use activities

(vi) Common land and conservation areas restricted and only 10% of the remaining land area is 'willing' to change land use activities.

NPV represents net present value

Agri. represents agricultural

For. represents forestry.

NOTE: The above key is used in Tables throughout this thesis as indicated.

Table 5.2 (continued)

Criterion	Other Output Variables		
	Wool	Dairy Meat	Food Energy
(i)	-61	-88	-52
(ii)	-57	-89	-52
(iii)	-43	-90	-57
(iv)	-34	- 6	- 1
(v)	-30	- 6	- 1
(vi)	- 3	- 8	- 5

Criterion	Input Variables				
	Total Labour	Agri. Labour	For. Labour	Agri. Subsidies	For. Subsidies
(i)	+12	-44	+1890	- 1	+2173
(ii)	+ 9	-42	+1755	+ 3	+2016
(iii)	- 3	-36	+1131	+17	+1281
(iv)	+14	-11	+ 874	+16	+1021
(v)	+12	-10	+739	+13	+ 865
(vi)	=	- 3	+115	+ 1	+ 129

if land was reallocated to different uses, but if common land and conservation areas are restricted to their current form of land use, sheep grazing, the increase in beef production suggested is reduced to 383% above current levels.

The maximum increase in total economic value (TNPV) suggested given no restrictions on land use is 54%, but this is reduced to 39% by restricting land use activities on common land and conservation areas. If tighter restrictions are imposed on land use, for example where only 10% of the total area is available for change, the maximum increase in total NPV suggested is considerably reduced to below 20%. The increases in total NPV are related to increases in both Forestry NPV (a 1600% increase given no restrictions) which is directly related to an increase in timber production (2000% increase given no restrictions); and Agricultural NPV which is related to an increase in beef output (over 400% increase given no restrictions). Such increases occurred in all of the situations explored to differing degrees. The output of milk, sheep and 'secondary' outputs all decrease, particularly where there are few restrictions on land availability, suggesting that economically, the land would be better utilised by changing the current form of usage.

The estimated subsidy input to agriculture increases to 16/17% when limitations exist on common land, conservation areas and on the area likely to accept land use changes, which implies an increase of approximately £800,000. Forestry subsidies are suggested as increasing by 2000% above current levels if there are no restrictions on land use which implies a subsidy outlay of approximately £1,500,000.

The model suggests that by reallocating land use activities total labour requirements will increase in general by approximately 10% which is equivalent to about fifteen jobs. Agricultural labour decreases considerably due to the suggested decrease in the production of sheep and milk, but forestry labour is suggested as increasing 1000% above current levels. This level of increase in forestry labour requirements represents an increase of about 40 - 50 jobs which is high and leads one to question the validity of the coefficients, in which one has to overcome the problem of taking the variable labour input over the length of the forestry rotation cycle into consideration (Section 8.2.2).

5.2.2 Results arising from the model given the need to maintain current production and labour input levels

The land use model was also used to look at suggested land allocation under the land availability restrictions defined previously (Section 5.2.1), but where the constraint specifications were set to maintain current production and labour input levels, ie the model regarded that a minimum level of production and labour requirements must be achieved from the area, and this was defined as being equal to current estimated levels.

The land use allocations suggested by the model were examined and common elements identified. Full details of each land use pattern are not given but the general land use pattern suggested is as follows:

Land Class	Land Use
1	Private woodland/sheep farming
2	Sheep farming/private woodland (mostly sheep farming)
3	Sheep farming/private woodland (mostly sheep farming)
4	Cattle farming/specialist dairying
5	Cattle farming/specialist dairying/ sheep farming
6	Sheep farming
7	Sheep farming

The land use patterns suggested do not show any definite pattern, ie no single land use allocated to each land class, as indicated by the model when there were no constraint limitations on production levels, though trends are indicated (alternate solutions were shown to exist). The results suggested as in the previous investigations that common land and areas of conservation value have a high potential for timber production. Table 5.3 shows the suggested changes in the levels of the output and input variables considered in the model. The maximum increase in total NPV possible when maintaining current production levels, with no restrictions on land use is 32%, all of which is related to an

Table 5.3 Production and input levels associated with alternative land availability restrictions while maintaining current production and labour input levels (expressed as a percentage change from current levels)

Problem: Max TNPV, r = 3%, CST. CRT. Land availability as indicated.

Criterion	Primary Output Variables						
	Beef	Sheep	Milk	Timber	Total NPV	Agri. NPV	For. NPV
(i)	+238	=	=	=	+32	+32	=
(ii)	+208	=	=	=	+29	+30	=
(iii)	+122	=	=	=	+13	+13	=
(iv)	+ 86	+5	+ 4	+370	+13	+ 7	+252
(v)	+ 44	=	+12	+500	+13	+ 4	+340
(vi)	+ 2	=	=	=	+ 1	+ 1	=

Criterion	Other Output Variables		
	Wool	Dairy Meat	Food Energy
(i)	-29	+ 3	+14
(ii)	-24	+ 2	+13
(iii)	=	+ 1	- 1
(iv)	-23	+ 5	+ 9
(v)	+22	+13	+13
(vi)	=	=	=

Criterion	Input Variables				
	Total Labour	Agri. Labour	For. Labour	Agri. Subsidies	For. Subsidies
(i)	+ 4	+ 4	=	+ 4	=
(ii)	+ 3	+ 3	=	=	=
(iii)	=	=	=	+ 1	=
(iv)	+ 9	=	+312	- 6	+394
(v)	+12	=	+412	-14	+533
(vi)	=	=	=	=	=

Key: As given in Table 5.2

increase in the production level of beef (over 200%). Restricting land use on common land and conservation areas and only allowing a small area to change ie only 10% 'willing' to change land use activities, reduces this potential increase to 13%.

In all of the situations explored an increase in the production of beef was suggested and only where the area 'willing to change' is limited, with or without restrictions on conservation areas, is there an increase in timber production suggested (350% increase). The major agricultural change suggested by the model is an increase in the output of beef, though minor changes are also suggested. The estimated input of subsidies associated with the land use patterns is considerably less compared to the suggestions by the model when there were no production constraint specifications, and the results suggest that the level of agricultural subsidies may even be reduced. Taking all of the problems explored into consideration, the level of subsidy input is equivalent to that at present but there is a substantial increase in the level of forestry subsidies (400%) where afforestation is proposed.

Only minor changes in total labour requirements are suggested on average. If there are few restrictions on land availability, agricultural labour input may increase slightly by 4% (equivalent to about six jobs), and where afforestation is suggested, the associated increases in forestry labour input is of the order of 300% (twelve to fifteen jobs). Total labour changes suggested are increases of approximately 10% (fifteen jobs).

5.2.3 Discussion of the model results exploring the influence of restricting the land area available for change on land allocation

Using the land use model to explore a wide range of problems looking at the effect of different restrictions on total production and input levels and land use patterns in the district, offers some suggestions on land allocation which the planners can consider. No single run is the 'correct' answer to the planning problems of the area, in fact the model only considers a limited aspect of the total planning problem. One can only hope to identify the common elements suggested in all of the model runs. These suggestions may be regarded as being the preferred land use activities which the planners should discuss and, if agreed in the light of other considerations, aim to achieve through the planning procedures available.

The overall land use pattern suggested by looking at the problem outlined in Section 5.2.1, to offer the greatest economic advantage to the district is given below:

Land Class	Land Use
1	Private woodland/sheep farming
2	Sheep farming
3	Private woodland/sheep farming
4	Cattle farming/specialist dairying
5	Cattle farming/specialist dairying/ sheep farming
6	Cattle farming/sheep farming
7	Sheep farming

The model gives a strong indication of allocating certain land use activities to particular land classes. For example the upper and middle slope land classes (land classes 1 - 3) are used for either private woodland or sheep farming, but the current land use pattern, Tables 5.4 and 5.5, shows no visible trend. The current pattern shows no distinct use of any one type of land for any one activity, whereas the land use model suggests more specialised land uses and less diversity of activities within each land class.

Optimisation in the land use model appears to suggest allocating particular land use activities to different land areas. Each farming activity considered in the model is concerned with a major farming enterprise but also includes other minor enterprises. This diversity of enterprises reduces the risks associated with the farming industry, such as depressed markets, high interest rates and severe weather. The current pattern of land use has evolved slowly and is the result of a combination of market and administrative forces, most of which are not directly linked to the land resources. Historical circumstances associated for example with land ownership and previous management practises play an important role, together with the personal preferences, the attitude and ability of every owner or tenant, the market situation, government policy and political pressures. Many of these factors are not, and cannot feasibly be included in the

Table 5.4 The current land use pattern in the Sedbergh district

Land Class	Land Use								Total
	PW	SD	MD	C	CS	S	KS	PS	
1	11		18		42	114	123	25	333
2	3				10	59	104	18	194
3	5		17		37	58	41	10	168
4	4	14	41		10	4			73
5	1		31		7	8		1	48
6		1	7		5	2	6		21
7	1	4	11		18		31	2	67
Total	25	19	125	0	129	245	305	56	904

(Taken from the Sedbergh Rural Land Use Study, Cumbria County Council, 1980).

Key: As given in Table 5.1.

Table 5.5 Current input and putput levels in the Sedbergh district (Estimates based on the model input coefficients)

Area	Primary Output Variables						
	Beef kg/pa	Sheep kg/pa	Milk 000 kg/pa	Timber m^3/pa	Total NPV @ 3% (£000s)	Agri. NPV @ 3% (£000s)	For. NPV @ 3% (£000s)
Sedbergh District - Total land area	157,280	230,940	7,843	4,141	21,050	20,470	552
Common land[1]	-	40,022	-	-	2,919	2,919	-
Conservation areas[2]	-	6,745	-	-	492	492	-
Common land and Conservation areas	-	46,767	-	-	3,411	3,411	-

Area	Other Output Variables		
	Wool kg/pa	Dairy Meat kg/pa	Food Energy GS/pa
Sedbergh district - Total land area	65,389	100,129	26,868
Common land[1]	22,546	-	469
Conservation areas[2]	3,796	-	78
Common land and Conservation areas	26,342	-	547

Area	Input Variables				
	Total Labour SMD/pa	Agri. Labour SMD/pa	For. Labour SMD/pa	Agri. Subsidies NPV @ 3% (£000s)	For. Subsidies NPV @ 3% (£000s)
Sedbergh district - Total land area	45,998	44,661	1,327	5,126	83
Common land[1]	7,033	7,033	-	1,148	-
Conservation areas[2]	1,185	1,185	-	264	-
Common land and Conservation areas	8,218	8,218	-	1,412	-

1 Common land represents 34% total land area.
2 Conservation areas represent 6% total land area.

land use model which basically includes factors relating to the production capability of the land itself and the market circumstances. The model suggests that if more consideration is given to these factors than the other factors affecting land use, different land types would be used for particular land uses.

The increases in total NPV suggested are mostly related to increases in the production levels of beef and timber. Private woodland ie increased timber production, is only suggested as a form of land use in the upland areas when there are few restrictions on land use. Maintaining current production levels leads to binding constraints in the model, restricting that area which could possibly be devoted to private woodland. Similarly, it appears that maintaining common land areas, ie restricting land use on common land, reduces the potential forestry increase, in both areal extent and production output.

The model suggests a considerable increase in the required level of forestry labour if areas are afforested, but care is necessary when interpreting the results. Given the current low level of employment in forestry, a 500% increase in labour input (SMD) is equivalent to approximately 22 jobs and therefore the actual increase suggested is reduced. Agricultural labour input levels decrease with no predetermined level of production because the model suggests less labour intensive uses, ie cattle farming as opposed to dairying, and show little change when current production levels are maintained. Overall, the total labour input shows a slight increase. The estimated level of subsidy input is similar to that estimated at present, the only change being an increase in the level of forestry subsidies where planting is suggested.

The model demonstrates that if current production levels are to be maintained then there is a rapid reduction in the level of potential economic value of production in the district (total net present value) which also occurs when land use is highly restricted in one way or another. This suggests that some reallocation of land use activities would be economically advantageous to the district.

5.3 AN INVESTIGATION INTO THE EFFECT OF RESTRICTING FORESTRY PLANTINGS ON LAND ALLOCATION

There is considerable argument over the use of uplands for forestry, and it is highly likely that in the Sedbergh district the area actually planted will be restricted for landscape or conservation reasons, particularly as it lies within the Yorkshire Dales National Park. The model is able to look at such a limitation by adjusting the constraint specifications. To illustrate this, the model was used to look at the effect of limiting the area which may be used for forestry to an arbitrary 10% of the total land area available in the district.

In the previous investigations (Section 5.2.1), it was observed that in several cases large areas, exceeding 10% of the total land available, were suggested as being allocated to private woodland. These situations are identified below:

Max. TNPV, r = 3%, CST. ZERO:

(iii) Common land and conservation areas restricted

(ii) Conservation areas restricted

(iv) Only 10% of total land area 'willing' to change land use activities

(v) Conservation areas restricted and only 10% of remaining land area 'willing' to change land use activities.

Max. TNPV, r = 3%, CST. CRT:

(iv) Only 10% of total land area 'willing' to change land use activities

(v) Conservation areas restricted and only 10% of remaining land area 'willing' to change land use activities.

In all of the other situations explored, the area suggested for planting did not exceed the selected 10% limitation, and therefore would not be altered by such a constraint.

Some of the results of limiting the area planted to 10% over the time period considered are shown in Tables 5.6 and 5.7. The land use model suggested that with no restrictions on the area actually planted and on production or labour input levels, the upper and lower middle slopes (land classes 1 and 3), should be allocated to private woodland. However, if current levels of production and labour input are to be maintained, private woodland is only suggested on the upper slopes (land class 1). The model looking at land allocation given a planting restriction with no predetermined limits on production or labour input, indicates that private woodland is favoured on the lower middle slopes (land class 3) as opposed to the upper middle slopes (land class 1) which is reallocated to sheep farming (Table 5.6). If current production and labour input levels are to be maintained, the area allocated to private woodland on the upper middle slopes (land class 1) is reduced, and the area devoted to sheep farming increased (Table 5.7). These results indicate a close relationship between the use of upper and middle land class areas for private woodland and sheep farming.

Reductions in the area available for planting decreases the potential timber production considerably and leads to minor adjustments in the production levels of other forms of output, most of which are related to the increased area given to sheep farming activities. Total labour requirements and economic value (TNPV) are reduced by up to 30% according to the land restrictions defined.

Table 5.6 The effect of restricting forestry planting in the district on land allocation, production and labour input levels, given no predetermined production and labour input limits

Problem: Max. TNPV, r = 3%, CST. ZERO. Common land and conservation areas restricted to their current form of land use. Afforestation restricted as indicated.

A. Land Use Allocation

(i) Common land and conservation areas restricted to their current form and land use; no restriction on afforestation.

Land Class	Land Use								Total
	PW	SD	MD	C	CS	S	KS	PS	
1	185						123	25	333
2	3					69	104	18	194
3	117						41	10	168
4	4			69					73
5	1			46				1	48
6				15			6		21
7	1			33			31	2	67
Total	311	0	0	163	0	69	305	56	904

(ii) Common land and conservation areas restricted; afforestation restricted to 10% of the available land area.

Land Class	Land Use								Total
	PW	SD	MD	C	CS	S	KS	PS	
1	11					174	123	25	333
2	3					69	104	18	194
3	93					24	41	10	168
4	4			69					73
5	1			46				1	48
6				15			6		21
7	1			33			31	2	67
Total	113	0	0	163	0	267	305	56	904

Key: As given in Table 5.1

Table 5.6 (continued)

B. Production and labour input levels
(expressed as a percentage change from current levels)

Restriction	Primary Output Variables						
	Beef	Sheep	Milk	Timber	Total NPV	Agri. NPV	For. NPV
(i)	+383	-41	-90	+1378	+39	+12	+1031
(ii)	+393	-21	-86	+ 508	+31	+21	+ 419

Restriction	Other Output Variables		
	Wool	Dairy Meat	Food Energy
(i)	-30	-90	-57
(ii)	-16	-86	-51

Restriction	Input Variables				
	Total Labour	Agri. Labour	For. Labour	Agri. Subsidies	For. Subsidies
(i)	- 3	-36	+1131	+17	+1281
(ii)	-13	-25	+ 405	+34	+ 394

(i) Common land and conservation areas restricted to their current form and land use; no restriction on afforestation.

(ii) Common land and conservation areas restricted; afforestation restricted to 10% of the available land area.

Table 5.7 The effect of restricting forestry planting in the district on land allocation, production and labour input levels, whilst maintaining current production and labour input levels

Problem: Max. TNPV, r = 3%, CST. CRT. Restricted area 'willing' to change land use activities. Afforestation restricted as indicated.

A. Land Use Allocation

(i) Only 10% of total land area 'willing' to change land use activities; no restriction on afforestation.

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	152		16		38	127	333
2	3				9	182	194
3	5		15		33	115	168
4	4	13	37	6	9	4	73
5	1	6	28		6	7	48
6		1	6	7	5	2	21
7	1	27	10		16	13	67
Total	166	47	112	13	116	450	904

(ii) Only 10% of total land area 'willing' to change land use activities; afforestation restricted to 10% of the available land area.

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	99		16		38	180	333
2	3				9	182	194
3	5		15		33	115	168
4	4	13	37	6	9	4	73
5	1	6	28		6	7	48
6		1	6	7	5	2	21
7	1	6	10	34	16		67
Total	113	26	112	47	116	490	904

Key: As given in Table 5.1

Table 5.7 (continued)

B. Production and labour input levels
(expressed as a percentage change from current levels)

Restriction	Primary Output Variables						
	Beef	Sheep	Milk	Timber	Total NPV	Agri. NPV	For. NPV
(i)	+45	=	+15	+593	+14	+4	+404
(ii)	+86	+5	+ 4	+370	+13	+7	+252

Restriction	Other Output Variables		
	Wool	Dairy Meat	Food Energy
(i)	+26	+16	+16
(ii)	-23	+ 5	+ 9

Restriction	Input Variables				
	Total Labour	Agri. Labour	For. Labour	Agri. Subsidies	For. Subsidies
(i)	+14	=	+500	-17	+633
(ii)	+ 9	=	+312	- 6	+394

(i) Only 10% of total land area 'willing' to change land use activities; no restriction on afforestation.

(ii) Only 10% of total land area 'willing' to change land use activities; afforestation restricted to 10% of the available land area.

Chapter 6

THE INFLUENCE OF OBJECTIVE FUNCTIONS AND DISCOUNT RATES ON LAND ALLOCATION

6.1 CHOICE OF AN APPROPRIATE OBJECTIVE FUNCTION

The land use model is only concerned with the optimisation of single objective functions and avoids the difficulties associated with defining a multiple objective function (Section 4.3). By investigating a wide range of objective functions one can obtain a broad picture of suggested land use patterns. Different planning organisations may regard the maximisation of one objective as the most appropriate to the problem in hand, but this 'chosen' objective will vary between organisations. The Forestry Commission for example, may be interested in the suggested land allocation associated with optimising timber production, whereas the Ministry of Agriculture (MAFF) may be more interested in optimising beef, sheep or milk production, and the individual land user the maximisation of profit. The land use model will be of most value if a range of single objective functions are optimised, and the suggested allocations examined for common elements which could be used as a basis for discussion and decision making.

The land use model was used to look at suggested land allocations according to different objective functions. Each of the 'primary' forms of output (Section 4.2) were optimised in turn and the constraints adjusted accordingly.

Given no restrictions on land availability or the desired level of production of any of the outputs or the input level of labour, optimising the different objective functions devoted all of the land available to that use with the highest output/value which was being optimised as expected. These allocations gave the optimal value of the objective concerned if one was only concerned with maximising that primary output with no restrictions on land use. Alternate solutions were shown to exist in some of the problems. These were not investigated but appeared to be mostly associated with the lowland land classes particularly the best lowland area, land class 4, to which the model allocated a range of land use activities. Table 6.1 shows the suggested land use allocations associated with optimising beef production given no predetermined limits on production output. The model assumes that each area of land (25 ha.) can be used for any land use activity.

Table 6.1 Suggested land allocation when optimising beef production, with no limits on production and labour input levels.

Problem: Max. Beef Production, r = 3%, CST. ZERO, Land availability as below.

(i) No restrictions on land availability

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	11			322			333
2	3			191			194
3	5			163			168
4	4			69			73
5	1			47			48
6				21			21
7	1			66			67
Total	25	0	0	879	0	0	904

Maximum value of the objective function: 1,025,900 kg, an increase of +552% over current levels.

(ii) Common land and conservation areas restricted to their current form of land use

Land Class	Land Use								Total
	PW	SD	MD	C	CS	S	KS	PS	
1	11			174			123	25	333
2	3			69			104	18	194
3	5			112			41	10	168
4	4			69					73
5	1			46				1	48
6				15			6		21
7	1			33			31	2	67
Total	25	0	0	518	0	0	305	56	904

Maximum value of the objective function: 865,580 kg, an increase of +350% over current levels.

Key: As given in Table 5.1

This leads to an error in some of the situations examined as it is unlikely that certain activities such as cattle rearing and dairying could be feasible from a practical point of view in the upper land classes, ie land classes 1 and 2. Nevertheless, in the more realistic problems explored where there are restrictions on land use this error does not arise, and if it did the model could be easily adjusted to restrict certain activities from particular land classes.

Restricting land use on common land and conservation areas, but having no restrictions on the desired level of production output or labour input led to few changes in the suggested land allocations. A smaller land area is available for change and the allocations suggested merely reduce the area allocated to each use and the associated production output and input levels, as shown in the optimisation of beef production in Table 6.1.

Restricting the desired level of production and labour input to estimated current levels suggested slightly different land use patterns, most changes occurring in the lowland land classes (land classes 4 to 7). The land use allocations suggested when maximising beef production are illustrated in Table 6.2. These results might be regarded as more realistic as planners are unlikely to consider suggesting any revolutionary land use changes which considerably alter the type and quantity of output currently produced within the district, as a significant change in the balance might have greater repercussions on a wider scale. Restricting land use on common land and conservation areas causes slight changes in the land allocations diversifying the suggested land use activities in each land class, mostly in the lowland classes, to maintain current levels of production and labour input as defined in the model.

It is interesting to observe that in many of the optimisations especially when maximising the economic value (TNPV) of the district, that cattle rearing is often suggested in lowland land classes. At present there is no area in the district defined as being used for cattle rearing, though a large proportion of the district is used for mixed cattle and sheep rearing. The land use category adopted, livestock rearing - mostly cattle, has not been

Table 6.2 Suggested land allocation when optimising beef production and maintaining current production and labour input levels

Problem: Max. Beef Production, r = 3%, CST. CRT., Land availability as below.

(i) No restrictions on land availability

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	11					322	333
2	3					191	194
3	5					163	168
4	4			69			73
5	1	47					48
6		7		14			21
7	1	32	34				67
Total	25	86	34	83	0	676	904

Maximum value of the objective function: 536,510 kg
an increase of +241% over current levels.

(ii) Common land and conservation areas restricted to their current form of land use

Land Class	Land Use								Total
	PW	SD	MD	C	CS	S	KS	PS	
1	11					174	123	25	333
2	3					69	104	18	194
3	5					112	41	10	168
4	4	34		3	32				73
5	1		46					1	48
6						15	6		21
7	1		33				31	2	67
Total	25	34	79	3	32	370	305	56	904

Maximum value of the objective function: 197,230 kg,
an increase of +25% over current levels.

Key: As given in Table 5.1.

used in current publications (since 1977/78) and is now combined with the category livestock rearing - cattle and sheep, to ensure an adequate sample of holdings and to bring the classification used in line with that adopted in the European Community. There is little distinction between mostly cattle and mixed cattle and sheep rearing, the difference being related to the proportion of each enterprise in the farming activity. Where the model suggests mostly cattle rearing one must look for land to be used for livestock rearing with both beef and sheep enterprises, the greatest emphasis being on beef enterprises though the ratio between beef and sheep enterprises will vary according to local circumstances.

Despite the wide ranging objective functions examined the model does suggest similarities between each optimisation, and one can begin to build up a crude picture of the suggested land allocation. Table 6.3 shows the actual land allocation suggested when different objective functions were optimised in the land use model using a discount rate of 3%. There were no restrictions on land availability defined, but the production and labour input constraints were adjusted to maintain current levels. The associated production and input values are shown in Table 6.4. Maximising the total NPV of all the land uses considered and the agricultural NPV in the model led to the same land use pattern, output and input levels irrespective of whether current production and labour input levels were maintained or not.

Looking at all of the land allocations suggested one can see that it would be advantageous according to the model, to increase the number of beef enterprises in the area as significant increases in beef production levels are suggested, which leads to increases in the total economic value. Expansion of milk, sheep, and timber enterprises lead to lower economic increases. If some areas could be afforested without affecting agricultural enterprises, this would be advantageous in terms of production but would result in increases in the input of forestry grants and the economic advantage would be reduced. The estimated input of agricultural subsidies associated with the land allocations show only minor changes. The model gives no suggestion of significant increases in meat production from the sheep flock. The output of wool is shown to decrease suggesting a considerable change in the allocation of sheep rearing activities to that at present. Labour changes suggested with each allocation are only small, the greatest increase being associated with increased afforestation.

From the land use allocations suggested for each optimisation it would appear that certain land classes are more suitable for particular land uses. The upper land classes are suggested as being devoted to sheep farming mostly but on the middle slopes private woodland is suggested. The remaining land area is allocated a wide range of land uses, suggesting that no one land use activity is dominant in any land class. This is especially true of the best land, ie land classes 4 and 5, which is given to dairying and livestock rearing, greater emphasis being on sheep rearing than cattle rearing in land class 5. The other lowland classes which are poorer in quality are suggested as being devoted to a combination of both dairying and sheep rearing activities.

The objective function clearly has an important effect on land allocation. Afforestation for example, is only suggested as a form of land use in the situations explored when timber production, the economic value of forestry activities or total labour input is optimised. (Optimising total labour input leads to the same results as that suggested when maximising forestry labour input). Any user of the land use model must be aware of the importance of selecting an appropriate objective function(s) as well as considering a wide range of likely constraint specifications as discussed in Chapter 5. Table 6.5 shows the range in the maximum value of each objective function possible under different constraint limitations. For example, the total economic value of production in the district (TNPV) can be seen to increase anything from 13% to 54% over current levels and timber production, 99% to 3356% over current levels according to the restrictions defined in the model.

Table 6.3 Land use allocation to land classes when optimising different objective functions

Problem: Max. Objective Function as given below, r = 3%, CST. CRT., No restrictions on land availability.

(i) Maximise Total NPV

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	11					322	333
2	3					191	194
3	5					163	168
4	4	7		62			73
5	1	47					48
6				21			21
7	1	49				17	67
Total	25	103	0	83	0	693	904

(ii) Maximise Forestry NPV

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	11					322	333
2	3					191	194
3	84					84	168
4	4		44		25		73
5	10		38				48
6		7				14	21
7	1	66					67
Total	113	68	89	0	25	607	904

Table 6.3 (continued)

(iii) Maximise Timber Production

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	11					322	333
2	3					191	194
3	81					87	168
4	4		42	27			73
5	1		47				48
6	12	2				7	21
7	1	66					67
Total	113	68	89	27	0	607	904

(iv) Maximise Beef Production

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	11					322	333
2	3					191	194
3	5					163	168
4	4			69			73
5	1	47					48
6		7		14			21
7	1	32	34				67
Total	25	86	34	83	0	676	904

Table 6.3 (continued)

(v) Maximise Sheep Production

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	11					322	333
2	3					191	194
3	5					163	168
4	4		69				73
5	1		10			37	48
6						21	21
7	1					66	67
Total	25	0	79	0	0	800	904

(vi) Maximise Milk Production

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	11					322	333
2	3					191	194
3	5					163	168
4	4	55		14			73
5	1	47					48
6			3			18	21
7	1		66				67
Total	25	102	69	14	0	694	904

Table 6.3 (continued)

(vii) Maximise Total Labour input*

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	202					131	333
2	3					191	194
3	5					163	168
4	4		38		16	15	73
5	1		47				48
6						21	21
7	1	66					67
Total	216	66	85	0	16	521	904

* Same land use allocation suggested if forestry labour input is maximised.

Key: As given in Table 5.1.

Table 6.4 Production and input levels suggested when optimising different objective functions (expressed as a percentage change from current levels)

Problem: Max. Objective Function as given below, r = 3%, CST. CRT., No Restrictions on land availability.

Objective	Primary Output Variables						
	Beef	Sheep	Milk	Timber	Total NPV	Agri. NPV	For. NPV
Total NPV	+238	=	=	=	+32	+32	=
Forestry NPV	=	=	+21	+486	+10	- 1	+445
Timber Production	=	=	+21	+527	+10	- 2	+436
Beef Production	+241	=	=	=	+30	+31	=
Sheep Production	+ 4	+35	=	=	+ 9	+ 9	=
Milk Production	=	=	+57	=	+17	+17	=
Total Labour Input	=	=	+21	+801	+16	+ 2	+545

Objective	Other Output Variables		
	Wool	Dairy Meat	Food Energy
Total NPV	-29	+ 3	+14
Forestry NPV	-28	+23	+18
Timber Production	-28	+24	+18
Beef Production	-29	+ 4	+15
Sheep Production	- 1	=	+ 4
Milk Production	-29	+58	+47
Total Labour Input	-26	+24	+18

Objective	Input Variables				
	Total Labour	Agri. Labour	For. Labour	Agri. Subsidies	For. Subsidies
Total NPV	+ 4	+ 4	=	+ 4	=
Forestry NPV	+12	=	+421	-25	+394
Timber Production	+12	=	+5118	-25	+394
Beef Production	+ 4	+ 4	=	+ 4	=
Sheep Production	+ 4	+ 4	=	- 1	=
Milk Production	+15	+15	=	-23	=
Total Labour Input	+19	=	+675	-26	+854

Table 6.5 Maximum value of objective functions under different constraint specifications

1. Actual value of the objective function

(i) No restrictions on land availability

Production constraint specification	Objective Function						
	TNPV[1] @ 3% £000	FNPV[2] @ 3% £000	Timber m^3/pa	Beef kg/pa	Sheep kg/pa	Milk 000kg/pa	Total Labour Input SMD/annum
CST. ZERO.	32323	17969	143120	1025900	352130	18976	67105
CST. CRT.	27535	3010	25956	536510	311530	12285	54944

(ii) Common land and conservation areas restricted to their current form of land use

Production constraint specification	Objective Function						
	TNPV[1] @ 3% £000	FNPV[2] @ 3% £000	Timber m^3/pa	Beef kg/pa	Sheep kg/pa	Milk 000kg/pa	Total Labour Input SMD/annum
CST. ZERO.	29223	12768	92191	865580	303110	15234	58242
CST. CRT.	23590	993	8221	197230	239330	8299	47090

2. Percentage change from current estimated levels

(i) No restrictions on land availability

Production constraint specification	Objective Function						
	TNPV[1]	FNPV[2]	Timber	Beef	Sheep	Milk	Total Labour Input
CST. ZERO.	+54	+3153	+3356	+552	+52	+142	+46
CST. CRT.	+32	+ 445	+ 527	+241	+35	+ 57	+19

(ii) Common land and conservation areas restricted to their current form of land use

Production constraint specification	Objective Function						
	TNPV[1]	FNPV[2]	Timber	Beef	Sheep	Milk	Total Labour Input
CST. ZERO.	+39	+2212	+2126	+450	+31	+94	+27
CST. CRT.	+13	+ 80	+ 99	+ 25	+ 4	+ 6	+ 2

1 TNPV represents Total Net Present Value.
2 FNPV represents Forestry Net Present Value.

6.2 THE IMPORTANCE OF DISCOUNTING AND ITS EFFECT ON LAND ALLOCATION IN THE SEDBERGH DISTRICT

6.2.1 The use of discounting in land use investment appraisal

Investment appraisal includes comparing returns from different activities. When comparing the economic return from forestry and agricultural activities, one must overcome the problem that each land use activity offers different returns and the money invested is tied up for different lengths of time. The cost and revenue streams from each activity must be reduced to comparable terms by discounting over the investment period. This means that in each land class, the potential forestry "discounted margin" can be related to the potential margin arising from agricultural activities which is also discounted over the same time period. In essence, discounting is the reverse of compounding. By discounting, the returns on an investment which yields £100 at the end of say twenty years, can be compared with one which yields £30 after three years.

The problem of discounting is that a discount rate must be chosen together with the length of the investment period considered, both of which will affect the apparent desirability of the investment. A fifty year time period is used in order to compare a fifty year forestry rotation with other land use activities. As discussed previously (Section 4.4.2), the higher the discount rate used, the less incentive there is to invest in a long-term project.

The private individual and the State will approach the choice of discount rate (calculated on current values) in different ways, owing to their different characteristics and requirements as investors.

The private investor will set a rate in accordance with his 'time preference rate' which reflects the rate of return which would be sufficient to encourage him to invest rather than to consume immediately. If one assumes that individuals investing in forestry have a similar outlook to those who invest in land, the long-term investment in land provides an indication of what this time preference rate might be. Real returns on land investment have been steady over a long time period at 1 - 2%, and one may regard this as representing the minimum return for a private investor. Investment in alternative long-term securities have not been much higher than this, and therefore a discount rate of approximately 2 - 3% would be appropriate. A lower rate may be acceptable to those making investment on behalf of heirs as a long turn-around time is desired, or to those providing amenities and game cover.

Private organisations or financial institutions have slightly different investment criteria and would be looking for a return equivalent to alternative low-risk investments. For any investment in forestry for example, such institutions would require a return equivalent to an investment in another sector "rolled over" for the length of the forestry rotation.

State investment in land is mostly concerned with forestry investment which is the responsibility of the Forestry Commission. The selection of an appropriate discount rate by the State is a complex matter as it is impossible to estimate the return from all State projects. The State has laid down a minimum rate of return that must be earned by public investments. The test discount rate accepted by the Treasury for public investments is currently 5% (H M Treasury, 1978) but this figure has been considerably reduced over the past few years. In the Treasury's cost/benefit appraisal of forestry (H M Treasury, 1972) an annual real return of 10% was expected. Forestry investments in the UK are only likely to yield an internal rate of return of 5% on very good sites within easy reach of good communication networks. A lower discount rate is used to test public investment in forestry. The Forestry Commission must achieve a return in real terms of 3% on investments, and it may invest in areas giving a lower return (1%) if additional benefits such as the support of local rural economies or the provision of recreational facilities, are favourable. Arguments for adopting a rate of return lower than the Treasury's test discount rate are partly related to the State's duty to provide for present and future generations and so to encourage investment at the cost of present consumption. One must also remember the strategic roles of the State, anticipating future trends in both supply and demand of all commodities and investing in those fields such as forestry, which at present give low economic returns and attract insufficient private investment.

Land allocation using the land use model has been investigated under a range of discount rates, 3 - 15%, to illustrate the implication of the rate chosen, although a low rate of 3% is that most likely to be regarded as acceptable to private investors at present. Looking at a range of discount rates also enables one to look at the effect of possible changes in the money market.

The importance of an appropriate discount rate is shown in Figure 4.1, where the Net Present Values (NPVs) of both farming and forestry are brought together. The validity of the economic data on which the NPV calculations are based is uncertain (Section 8.2.1), and it is highly likely that the forestry costs are too low considering the small block of land considered (25 hectares). Fencing and general maintenance costs may be higher than given. Assuming a 20% increase in total forestry costs, private woodland appears less favourable economically at high discount rates and is only likely to conflict with sheep farming activities at low discount rates (Figure 4.1).

The degree of error associated with the agricultural economic figures is unknown and adopting different data sources leads to slightly different relationships between the expected NPVs in each land class (Figures 8.1 and 8.2), although it is likely that the relationship between the NPV of dairying and livestock rearing is realistic. All of the NPV estimates, ie associated with both forestry and agricultural activities, are liable to errors as no consideration is given to unpredictable variables such as climatic conditions and market fluctuations which will influence land use activities. Nevertheless, in general the growing conditions which favour livestock production also favour tree growth and economic assessments will tend to move together under a wide range of conditions.

Changes in the relative economics of forestry and agricultural activities have been excluded as they are highly speculative, but one expects a future reduction in unit costs and improved yields as both activities are supported by considerable research programmes. It is anticipated that future relative financial returns from hill farming and forestry are unlikely to differ substantially from the present. For example, it is expected that timber prices will rise by 20 - 30% in real terms over the next 25 - 30 years. The price of sheep meat is also expected to rise sharply by say 50%, but this is likely to lead to a reduction in sheep subsidies as they would not be necessary, and the Government may seek to reduce support payments which overall could reduce the anticipated increase in gross receipts from sheep rearing to perhaps 25%. Therefore, movements in returns from sheep farming may be very comparable to movements in timber prices (ie 20 - 30%) over the next 10 - 15 years in real terms (Centre for Agricultural Strategy, 1980).

The comparison of the NPVs of farming and forestry ignores the wider consequences of changing land use activities in the uplands. Secondary effects may be important especially in the sheep sector. Increasing the area for afforestation may for example reduce the hill sheep flock which would have a serious effect on lowland sheep production and in turn on the relative economics of each land use activity. Consideration to secondary effects must be given when discussing and determining any land use policy for the district. Integration of forestry/farming activities may reduce the possible loss in breeding stock but more research is necessary into the management of such land use systems.

6.2.2 Suggested land allocation in the Sedbergh district using different discount rates

Using the land use model applied to the Sedbergh district, the allocation of land to different activities was examined under a range of discount rates. Production and labour input levels were specified to ensure that a minimum level of production and labour requirements was achieved, equal to that at present. A series of objective functions were adopted (maximise total NPV, beef, sheep, milk or timber production) and changes in the area of land available explored.

Despite the difficulties of collating the results, for each discount rate general land use patterns were identified.
Table 6.6 shows the suggested allocation of land use activities to each land class, from which one can see that the choice of discount rate does influence land allocation in the model, and that these are different to the current land use pattern and the suggested allocation from the earlier model used in the Sedbergh Rural Land Use Study by Cumbria County Council.

Table 6.6 Land Use allocation trends

(i) Current Land Use Allocation

Class	Land Use
1	S/CS/MD/PW
2	S/CS/PW
3	S/CS/MD/PW
4	MD/SD/CS/PW
5	MD/S/CS
6	MD/S/CS
7	S/CS/MD/SD

(ii) SRLUS* suggested allocation

Class	Land Use
1	S/F
2	F
3	F/S
4	MD' mostly/S/CS
5	MD'/S
6	S
7	F/S

(iii) Allocation using a discount rate of 3%

Class	Land Use
1	PW/S
2	S
3	S/PW
4	SD/MD/C/CS
5	C/SD/MD/S
6	S/C
7	S/C/SD/MD

(iv) Allocating using a discount rate of 5%

Class	Land Use
1	S/PW rare
2	S
3	S
4	SD/MD/C/CS/S
5	SD/MD mostly
6	MD/S/C
7	MD mostly/SD/S

(v) Allocation using discount rates of 7 - 15%

Class	Land Use
1	S
2	S
3	S
4	MD/SD/C/CS
5	MD mostly
6	S/C/MD/SD
7	MD mostly/SD/S

Key:

Land use activities:
- F Forestry as defined in SRLUS Ch. 3
- PW Private woodland
- SD Specialist dairy
- MD Mainly dairy
- MD' Forestry as defined in SRLUS Ch. 3 but only MD activities in Land Classes 4 and 5.

Livestock Rearing:
- C Mostly cattle
- CS Cattle and sheep
- S Mostly sheep.

* SRLUS represents the Sedbergh rural land use study undertaken by Cumbria County Council (1980).

The hill tops in the district, ie land class 2, are devoted to sheep farming activities irrespective of the discount rate adopted. One might expect forestry to be allocated to this area when low discount rates are used, but one must remember that forestry planting is limited to 1500 ft and only an estimated 10% of the area in this land class lies below this height. This restriction 'built into' the model coefficients considerably reduces the potential for forestry. The upper and lower middle slopes is the only land area on which forestry is suggested. This area is partly allocated to private woodland at low discount rates (3%), the remaining land area being devoted to sheep farming. At high discount rates all of this area is allocated to sheep farming. In the optimisations explored using a discount rate of 3%, less private woodland is allocated to land class 3 than land class 1 and when using a 5% discount rate, private woodland if suggested at all, is allocated to land class 1. This suggests that land class 1 ie the upper middle slopes, is more suitable for forestry.

The lowland land classes show more variation in terms of suggested land use activities than the upper land areas, each land class being suggested for several uses. Land class 4 shows no definite land use pattern, being used for both dairying and livestock rearing activities (mostly cattle, cattle and sheep), and there is no visible trend at different discount rates. Land class 5 is devoted to similar land use activities but at high discount rates there is a trend towards increased dairying activities particularly mainly dairying. This bias towards mainly dairying, is also shown in land class 7 where the proportion of the land class allocated to sheep farming declines with increases in the level of the discount rate. The remaining land class, land class 6 is also suggested as being of most value if used for both livestock rearing and dairying activities. No definite trend is suggested when using different discount rates, and it is likely that changes are suggested in the poorer lowland classes, 6 and 7, to maintain current production and labour input levels in the whole district.

Any decision between land use alternatives is greatly influenced by the discount rate chosen. At discount rates up to 3% the advantage lies with private woodland whereas at a rate of 5% or more, the advantage lies with agricultural activities or more specifically with livestock rearing (mostly sheep) activities. This trend is shown by the land use allocations suggested by the model, which ensure that total production levels and labour input are at least equal to that achieved at present if not higher.

Chapter 7

THE PROBLEMS AND POTENTIAL USE OF UPLAND COMMON LAND - ONE APPLICATION OF THE LAND USE MODEL

7.1 COMMON LAND AND CONSERVATION AREAS IN THE SEDBERGH DISTRICT

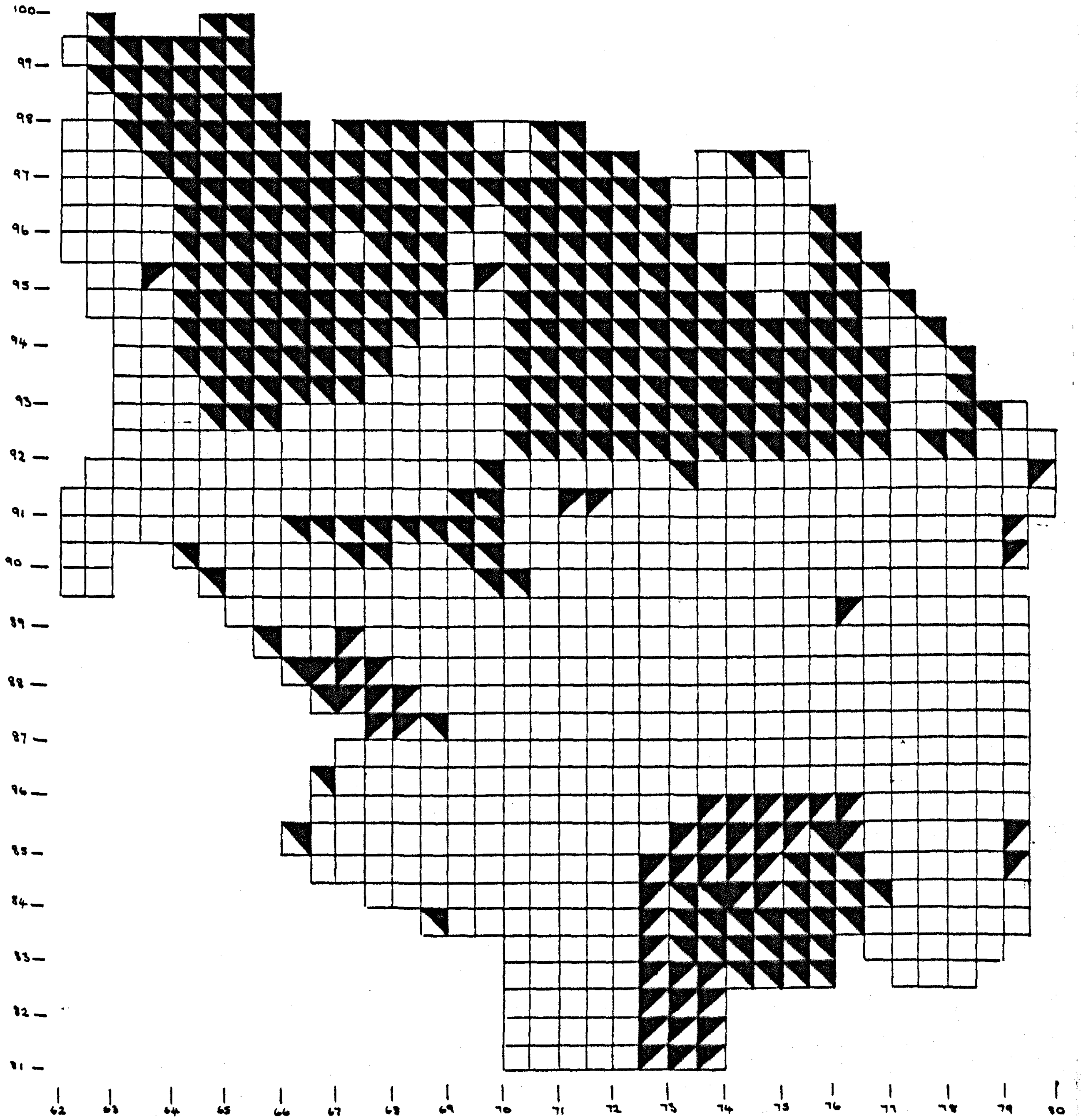
Common land is important to the viability of the hill farming communities in the Sedbergh district, as it offers the small farm holdings considerable areas of rough grazing land. 34% of the total land area of the Sedbergh district is designated as common land and a further 6% is recognised as land which is important for its ecological, archaeological and landscape value, referred to as conservation areas. This land area has a variety of potential uses such as agriculture, forestry, water catchment and recreation, but there is considerable conflict between each land use and this is increased on common land due to the sense of heritage rights which such areas suggest. Land use activities on common land are governed by legislation and as long as the current legislation prevails, this land area is likely to remain under its current form of usage which is mostly sheep grazing though there may be some cattle grazing. Land use activities are also restricted, usually to sheep grazing, on conservation areas, in order to maintain the character of the area. The use of these areas may be restricted through management agreements.

The distribution of common land and conservation areas in the Sedbergh district (Figure 7.1 and Table 7.1) shows that most of this land area is upland in nature lying within land classes 1, 2 and 3. From this area, it is estimated that 20% of the total production of sheep meat in the district is obtained (Table 7.2). Areas recognised as being important for their ecological, archaeological or landscape value are similar in nature to common land, and many of the problems associated with upland common land which are discussed in this chapter, also arise in these land areas. (All common land discussed in this chapter refers to upland common land only).

7.2 THE UNDERUTILISATION OF COMMON LAND

Upland common land is often regarded as being under-used and forming vast areas of lost potential to both agricultural and forestry, and other land use activities. In many cases the

Figure 7.1 The distribution of common land and areas recognised as being important for their ecological, archaeological and landscape value in the Sedbergh district



Key:

Common land

Land recognised as being important for its ecological, archaeological or landscape value (conservation areas).

Table 7.1 The distribution of common land and conservation areas in the Sedbergh district

Land Class	Common Land	Conservation areas	Conservation Areas: Archaeo-logical Sites	Conservation Areas: Coombe Scar	Conservation Areas: Whernside SSSI
1	123	25	6	3	16
2	104	18	3	5	9
3	41	10			10
4					
5		1	1		
6	6				
7	31	2	1	1	
Total number of squares	305	56			
Percentage total area	34%	6%			

Table 7.2 Estimated current production and input levels from common land and conservation areas in the Sedbergh district

Criterion	Primary Output Variables: Sheep meat kg/annum	Food energy GJ/annum	Wool kg/annum	Agricultural NPV @ 3%, £000
Common land	40022	469	22546	2919
Conservation areas	6745	78	3796	492
Common land and Conservation areas	46767	547	26342	3411
% of total production in district	20%	2%	40%	16%

Criterion	Input Variables: Labour SMD/annum	Agricultural Subsidies NPV @ 3% £000
Common land	7033	1564
Conservation areas	1185	264
Common land and Conservation areas	8218	1828
% of total production in district	18%	35%

productivity of common land falls short of its potential output. Common rights may exceed the carrying capacity of the land but often these rights are disused, particularly if the terrain is difficult for any activity through poor drainage, bracken infestation or rocky outcrops; most common land is only good for rough grazing. Lack of management and use can turn commons into areas of idle wasteland, which become increasingly more bracken and heather infested. Similarly, overstocking can easily lead to deterioration of the land (Young, 1979). Efficient management of common land areas is essential not only to maintain the viability of hill farms where often farming is the only means of livelihood, but also to maintain the "quality of life" in rural areas and the land heritage for the general public.

Common land is regarded as vital to the viability of hill farmers, offering rough grazing land for a greater part of the year. Sheep can be overwintered on the lower inbye land and then turned out onto the hill, allowing the inbye land to be allocated to different enterprises. Without rights to common land many farms concerned with livestock rearing who do not own any rough grazing land, would have to consider agistment on other farms or in other valleys (which is costly), and if this was not feasible would have to consider the best use of their available land. This may involve a change in the farm enterprises and management systems adopted, with possible adjustments in livestock characteristics and stocking rates to 'optimise' on the available land, finding the necessary balance between the farms' capacity in summer and winter. In such a situation any sheep enterprise for example, may be regarded as uneconomic compared to alternative uses of the available land because of increased forage costs, but numerous other factors will be considered especially the prevailing market situation and anticipated trends.

The influence of common land on farm economics has been given little attention and no study appears to have been undertaken. The economic data from which the input coefficients to the model were estimated was taken from the Farm Management Survey, which gives the average situation in each type of farming category. The farm types defined in the published data include a certain proportion of common land, and this leads to an error in estimating the economics associated with each land use activity in each land class. Interdependencies such as the significance of a certain proportion of common land to each type of farming and the complementary role played by hill farming through providing stock to lowland farms, is neglected in the land use model. Adjustments may be made to available statistics to isolate those costs associated with common land, but when considering the question of land allocation given no restrictions on the available land area, ie no common land designation or recognition of areas of high ecological, archaeological or landscape value, some error is likely in the economic coefficients. This illustrates one of the limitations of the land use model, neglecting land class interdependency and economies of scale, treating each parcel of land as an isolated entity.

7.3 CONFLICTS OVER THE USE OF COMMON LAND

Conflicts arise in the use of common land, between landowners, commoners and the general public. Landowners of common land have the right to plant timber, fence areas, work mineral rights, shoot and take game, subject to not exceeding the rights of the commoners. In many cases such usage can lead to conflict but no one land use has precedence and the argument over land use is often surrounded by political arguments.

The main use of upland common land is grazing which conflicts in particular with sporting rights. Public access to common land is also a problem as many members of the public regard such areas as being a common resource and having public rights of access which is rarely true (Wager, 1967). Access leads to a depletion in the quality of the grazing, and this access problem is likely to increase in the future rather than decrease. Many common land areas are of high ecological value and organisations such as the Nature Conservancy Council play an important role in supporting and aiding land management. Such organisations are opposed to the improvement and changes in land usage of common land in many areas, and this leads to increased conflict when commoners attempt to obtain permission for improved management schemes.

Management rights and access on common land are governed by legislation (Campbell, 1976) which has not been reviewed for some time, and this increases the difficulties associated with attempts to realise the full potential of common land. There is very little written information regarding common land and what is available generally dates back to the period of the Royal Commission Report on Common Land, 1955 - 1958 (1958). The actual law relating to common land is not clear and often forms a legal barrier to attempts by commoners themselves to change or improve the management of their common; it is difficult at times to ascertain what is actually common land. A land register does exist but it has been shown that often land is registered in error. In many situations common rights exceed the potential carrying capacity of the land, and if all rights were exercised the potential of the land would diminish rapidly unless positive steps were taken to change the management system. The actual ownership of common land is rarely known and this must be ascertained if land improvement is to be undertaken. It is hoped that more accurate information on common land will become available in the 1980s when the Commons Commissioners complete their examination of contested cases under the Commons Registration Act 1965.

The Department of the Environment set up an inter-departmental working party (1975 - 1977) to review the nature and extent of further legislation needed to implement the recommendations of the Royal Commission. The Working Party looked at a wide range of issues including public access, management, regulation and improvement (including financial aid), and mistaken registration of common land (Department of the Environment, 1978). The findings are being used for consultations with various organisations interested in common land, and this hopefully will act as a basis for new comprehensive legislation.

7.4 INCREASING THE AGRICULTURAL POTENTIAL OF COMMON LAND

Land improvement is regarded as the first step to increasing the utilisation of upland areas but this is very difficult to achieve on common land and occasionally is not possible, merely due to terrain limitations. Work by the Hill Farming Research Organisation (HFRO) on Experimental Husbandry Farms (EHF) shows that without land improvement output from the hills is limited. At Pwllpeiran EHF in Wales and at Redesdale EHF in Northumberland, following a programme of land improvement on only 10 - 15% of the total hill area with integration into the farming system, it was found that the output of weaned lamb could be increased from 28 kg to over 65 kg per ha (J R Thompson, 1978).

No individual commoner has the right to improve common land and any form of land improvement needs the approval of all the commoners concerned and the Agricultural Minister. Commoners' attitudes clearly vary and often there is little agreement over the actual use of the land. Individuals will have differing opinions as to the actual increase in stocking ratio which will arise from any improvement, and therefore the expected economic return. Pasture enclosure - fencing - is the prerequisite for any form of land improvement, but even this leads to numerous problems including sources of funds, location of boundaries which may be opposed on aesthetic lines and by public opinion, and allocation of responsibilities for fence erection and maintenance. Some individuals, academic experts and commoners, have suggested that it is more advantageous to improve the existing inbye land rather than the open common land but this has gained little support and is clearly related to the management system adopted.

The process of actually seeking permission to improve common land areas is surrounded in 'red tape', discouraging most commoners to even consider land improvement. There are no incentives to improve common land and a high level of capital is necessary. For example, in 1977 it was estimated that upland pasture improvement would cost a minimum of £370 per ha, (£150 per acre) for fencing, drainage, reseeding, road construction, ploughing, fertilising etc (McConnell-Wood and Foxall, 1977), and it is questionable as to whether this outlay would lead to a substantial improvement in the quality of grazing. Financial considerations are not necessarily the most important factor to consider as one must also remember the social consequences of improving or changing the usage of common land; without any change in land use hill farming communities may decline.

To avoid commons becoming vast areas of wasteland, and to increase the utilisation of common land, cooperative land management has been proposed and is practised in some upland areas (Foxall, 1979). Cooperative management is difficult to achieve owing to the large number of individuals concerned in most situations, all of whom have an independent attitude and are suspicious of any form of organisation. To be a success each commoner must be willing to enter agreements and possibly compromise on certain issues, sharing the associated risks, costs and benefits. Cooperative management of land offers considerable benefits particularly to the small hill farmer, both in terms of production and marketing. One of the main advantages is that organised management schemes controlling livestock ratios will lead to the production of better quality and a higher level of output of sheep, which in turn leads to an economic advantage arising from less effort and worry on the part of the individual farmer. Such management also offers advantages in terms of convenience to the individual through for example, depot location, delivery services and economies of scale through bulk purchase of supplies. Nevertheless, any form of land management and improvement is impossible to achieve without a knowledge of the existing common rights and land ownership. This in turn hinges on government legislation and the government's attitude to the problems surrounding land use on common land and in rural areas in general. Extensive land improvement or even changes in land use activities on common land is unlikely prior to the anticipated change in common land legislation in the near future.

7.5 SUGGESTED LAND USE ACTIVITIES ON COMMON LAND AND CONSERVATION AREAS IN THE SEDBERGH DISTRICT

The use of common land and conservation areas in the Sedbergh district can be explored in the land use model by looking at suggested land allocations when there are no constraints on land availability, and when these areas are restricted to their current form of land use. The model is capable of suggesting the optimal land allocation in the district necessary to achieve a defined objective and the associated total production and input requirements, if changes in the land use activities of these areas are acceptable or vice-versa.

The current land use of common land and conservation areas in the Sedbergh district is assumed to be sheep grazing. There is little information on the current land use pattern which makes it extremely difficult to allocate any particular type of farming category defined in the model to common land, as common grazing rights could belong to any of the activities defined. It is assumed that common land and conservation areas are at present devoted to livestock rearing - mostly sheep. The production estimates relating to these land areas are based on grazing livestock unit (GLU) estimates per land class for hill sheep (see Appendix 2, 2.1.1). Estimates of the current production and production value from these land areas have been made, but one must remember the degree of error likely in these estimates related to both the uncertainty of the data source, and the relationship between common land and each farm holding (Section 7.2). Different data sources can lead to different economic estimations of the value of production from common land and conservation areas. Different economic input coefficients were used in the model and these led to different indications of the suggested lost/gained production achieved through maintaining common land and restricting land use on areas of high ecological, historical or amenity value (Table 7.3), indicating a need to closely scrutinise the coefficients and their associated assumptions.

The land use model was used to explore the use of common land and conservation areas according to two data sources:

A. "Financial Returns and Measures of Efficiency - the Northern Region, 1977/1978", MAFF (Farm Management Department), and Newcastle University, 1979.

B. "Farm Incomes in England and Wales, 1977/1978", No. 31, MAFF, 1979. Data taken related to the Northern Region of England.

The problem was defined as:

Max. Total NPV @ r = 3%,

(1)	CST. ZERO	(i)	No restrictions on land availability
		or (ii)	Common land and conservation areas restricted to their current form of land use
(2)	CST.CRT.	(i)	No restrictions on land availability
		or (ii)	Common land and conservation areas restricted to their current form of land use.

Table 7.3 Estimated potential lost/gained by maintaining common land and conservation areas[1]

Derived from the problem:

Max. TNPV, r = 3%
Data source A. Financial Returns and Measures of Efficiency
or B. Farm Incomes in England and Wales - Northern Region.

(1) CST. ZERO (i) No restrictions
or (ii) Common land and conservation areas restricted.

(2) CST. CRT. (i) No restrictions
or (ii) Common land and conservation areas restricted.

Constraint Specification		Primary Output Variables						
		Beef	Sheep	Milk	Timber	Total NPV	Agri. NPV	For. NPV
A.	CST.ZERO	- 60	+ 8	- 2	- 916	- 16	+ 4	-666
	CST.CRT.	-215	=	=	=	- 21	-22	=
B.	CST.ZERO	- 23	- 7	-19	- 622	- 25	-10	-427
	CST.CRT.	- 25	-19	=	- 347	- 32	-25	-239

Constraint Specification		Other Output Variables		
		Wool	Dairy Meat	Food Energy
A.	CST.ZERO	+ 31	- 2	- 5
	CST.CRT.	+ 29	- 3	-13
B.	CST.ZERO	+ 20	- 8	- 8
	CST.CRT.	+ 12	- 1	- 4

Constraint Specification		Input Variables				
		Total Labour	Agri. Labour	For. Labour	Agri. Subsidies	For. Subsidies
A.	CST.ZERO	- 15	+ 8	-759	+ 18	- 892
	CST.CRT.	- 4	- 4	=	- 2	=
B.	CST.ZERO	- 13	+ 2	-524	+ 15	- 603
	CST.CRT.	- 8	=	-293	+ 7	- 370

1. Potential loss (-) / gain (+) is the estimated increase (decrease) given restricted land use on common land and conservation areas minus the estimated increase (decrease) given no restrictions on land availability, expressed as the percentage change from current estimated levels.

Using data from the MAFF publication "Financial Returns and Measures of Efficiency" (A), restricting land use activities on common land and conservation areas and maintaining current production and labour input levels is suggested by the model as significantly reducing the potential for beef production (-215%). This in turn leads to a loss in the potential economic value of production from the district (-21% of current value). The other data source investigated, the publication "Farm Incomes in England and Wales - The Northern Region" (B), suggests that restricting the land use of these areas as defined above leads to a greater loss in the potential economic value of production, -32%. This loss is related to lost potential in beef (-25%), sheep (-19%), and timber production (-374%), which differs considerably from that suggested by the previous data source.

The most noticeable changes in the district suggested by the model when land use on common land and conservation areas is restricted, are the reduction in the potential total NPV of production in the district by approximately 30%, and the change in the levels of timber and beef production (Table 7.3). This would appear to suggest that some common land and conservation areas are suitable for beef enterprises (most likely associated with the land use category, livestock rearing - mostly sheep) and forestry. No distinct trend can be seen in sheep meat production; different data sources led to different suggestions. Using input coefficients based on data source A (Table 7.3), the land use model suggested that when aiming to maximise the economic value of production for all land use activities in the district defined in the model, maintaining common land and conservation areas caused an increase in the production of sheep meat compared to current production levels. However, adopting coefficients based on data source B suggested the opposite trend, that maintaining common land and conservation areas would lead to a decrease in the current level of sheep meat production. The only significant gain indicated by the model through restricting land use on common land and conservation areas, irrespective of which data source was used, was associated with wool production. The validity of the model input coefficients is vitally important as it can considerably influence the suggested production levels and land allocation.

Given the crude coefficient estimations, one can only consider the general trends suggested by the land use model.

It is often argued that upland common land would be suitable for afforestation if legislation concerning the use of common land and attitudes towards afforestation were changed. The results from the land use model which has been used to investigate many problems, suggests that both common land and land recognised as being valuable for its wildlife and historical resources are potentially suitable for forestry; restricting these land areas to their current form of land use reduces the total land area allocated to private woodland and total timber production. If the total potential economic value (TNPV) of production from the district for example, is optimised with no restrictions on desired production or labour input levels, the upper land classes particularly at low rates of discount, are allocated to private woodland. However, when land usage on common land and conservation areas is restricted and current production and labour input levels set, the area allocated to forestry is reduced, and there are some changes indicated with regard to the actual distribution of this area between land classes (see Tables 8.1 and 8.3).

There appears to be a close relationship between allocating forestry to the upper and lower middle slopes (land classes 1 and 3 respectively). In most situations it appears that forestry is preferred on the upper middle slopes (land class 1). Afforestation is only favoured at low discount rates giving way to sheep farming at high rates whether common land and conservation areas are restricted or not. Using a 3% discount rate leads to the suggestion that land classified as land class 1 and 3 be allocated to private woodland if the constraint specifications are set to zero, ie no predetermined limits on production, and there are no restrictions on land availability. However, if the production constraints are set to minimum production levels or restrictions are set on the use of common land and conservation areas, then sheep farming is favoured in land class 3 and any private woodland suggested is allocated to land class 1. However, in other problems explored land class 3 is preferred by the land use model for afforestation. In chapter 5 (section 5.3), it was shown that if afforestation is only acceptable in 10% of the total land area available given no predetermined agricultural output or labour input levels, then the model suggests only land class 3 for afforestation. This close association between land class 1 and 3 is also suggested by the sensitivity analysis (section 8.3.2) which indicated that only slight changes in the economic return of timber in land class 3 will "shift" afforestation to land class 1. A close association is also indicated between private woodland in these two land classes and sheep farming, only minor changes in the economic coefficients resulting in changes in the optimal basis.

The land area in the Sedbergh district designated as common land or recognised as being of a high ecological, archaeological or landscape value, was suggested by the land use model as offering the greatest production value (economically) to the district if it was allocated to private woodland and/or sheep farming activities. Part of the land area was suggested as being appropriate to beef enterprises. Most common land and conservation areas in the district lie on the hill tops and the upper and lower middle slopes, land classes 1, 2 and 3. A planting height limitation restricts the use of land class 2 (the hill tops) for forestry which means that any common land or conservation areas in this land class are allocated to the land use category, livestock rearing - mostly sheep. A proportion of the lower middle slopes, land class 3 (30%), and the upper middle slopes, land class 1 (44%), is designated as common land and recognised as being of high conservation value and these areas, particularly that on the upper middle slopes are likely to be of potential use as forestry land. However, all of these suggestions are dependent on the validity of the input coefficients and the land use model itself which is discussed in the following chapter.

Chapter 8

LIMITATIONS OF THE LAND USE MODEL

8.1 VALIDITY OF THE MODEL STRUCTURE AND DATA INPUT

The ability of the land use model, like any other model, is dependent on the quality of the data input and the validity of the assumptions made. Throughout the model framework numerous assumptions are made, many of which are surrounded by a large degree of uncertainty as is much of the data input. It is essential that any planner or user of the method is aware of the limitations of the land use model, both in terms of the structure and technique of linear programming adopted, and with regard to the data input to the model. The introduction of any new method is difficult especially when different disciplines are involved and strangers may obtain the wrong impression of the model and its use, and this can lead to considerable misapplication.

8.1.1 The model structure

The model structure follows a standard linear programming format in which a defined objective is optimised (in the mathematical sense) subject to a series of constraints. It requires that both the objective function and the constraints are well defined and linear. Planners are not single minded and different planners have different views on the objectives one is trying to achieve, and it is unlikely that all those concerned, from all of the planning organisations, could agree on a well-defined and linear objective function. It is for this reason that the land use model examines single objective functions and avoids the complexities of defining multiple objectives, but this does make interpretation of the results difficult (Section 4.3). The constraints are similarly surrounded with a large degree of uncertainty due to the difficulties of obtaining representative relationships and adequate data input.

The main limitation of using linear programming is that all of the relationships defined must be linear which is a gross oversimplification of the real world but adopting such an approach, does allow one to look at a large range of variables and constraints which previously one could not consider in one framework. One could regard the use of simulation techniques as overcoming this problem. However, using such an approach leads to highly complex models which would require a high level of data input and, given the accuracy of available data (and its limited availability) it is unlikely that adopting such an approach would offer any great advantage to planning.

The model is concerned with looking at future land use patterns within a defined area, the Sedbergh district, and is based on a consideration of a single fifty year period. It is aimed towards use in a regional/district planning context where one is attempting to define alternative strategies and is not concerned with the problem of individual farm planning or social consequences of land use change, for which other methods are more appropriate (Maxwell et al, 1979; MAFF/ADAS, 1979).

Any model involving such a long time period raises questions on the accuracy of the model. Over a fifty year time scale land use activities could alter considerably through changes for example, in technology resulting in increased productivity, in the price relationship between each form of output which is influenced by changes in both supply and demand for goods, and in environmental conditions which are virtually unpredictable. It is extremely difficult to incorporate such variables in any model, and in this model one must assume the continuation of current circumstances throughout the whole time period considered. One could argue that a multi-period model looking at land use on an annual basis would be more advantageous to planning as such elements could be incorporated into the framework; but this implies the development of a full scale simulation model (eg Dye, 1973), with a greater complexity in terms of both the model structure and data input and would involve defining land use decisions at each stage in the model. Planning objectives are at present vague and 'woolly', and to define criteria for a range of land use decisions would be virtually impossible and involve considerable uncertainty. This, together with the current limitations on data availability, restricts the feasibility of developing such a model. Linear programming is a relatively simple technique and more realistic from the practical point of view of planning given an awareness of its limitations.

One must remember that the model is only a means of exploring and suggesting possible land uses in the district concerned, experimenting with likely management schemes and policies. The use of such a model can only play a low role in the actual planning process, its main advantage being to aid decision-making by exploring suggestions on land use, looking at the likely effect of certain events. It is a crude model due to its simplification of the real world situation and an awareness of the model's limitations is critical to its successful application and use in planning.

8.1.2 The exclusion of recreation and nature conservation from the land use model

The land use model does not consider intangible variables (Section 4.2) though these were considered in the original model. In the land use model proposed by Bishop (1978) the recreation potential and ecological value associated with the land use activities defined in the model were included, as they were regarded as being of significant importance to planning in Cumbria. Cumbria County Council had carried out a recreational potential surface analysis in 1975, and this was used as a basis to a scoring system used to value recreation potential. Land use independent and dependent scores were determined and later combined. It was recognised that the method involved considerable subjectivity, the degree of variation in the recreational score being considered the most important factor. A similar scoring system was used to evaluate the ecological value associated with each land use after the factors regarded as indicators of nature conservation and the vegetation groups in each class were defined. The procedure adopted did not include all or sufficient factors which define recreational potential and ecological value, and Bishop recognised the error associated with these values but believed them to be reasonable and of use to the model. No attempt was made to estimate or incorporate monetary values into the model.

Attempts were made to incorporate recreation and nature conservation values in the model used in the Sedbergh study undertaken by Cumbria County Council, but it was discovered that these confused the results and their interpretation, as the coefficients had no real value, not being assessed in common units of measurement. The variables considered within the model were assessed using different criteria, and there was no standard unit of measurement such as a monetary value, to make a realistic comparison between the different land uses. For this reason recreation and nature conservation were omitted from the actual model, leaving the decision maker to judge the desirability of the suggested alternative land use patterns from the recreation and nature conservation viewpoints. The estimated values of recreation potential and nature conservation per land class were used as guidelines in the post-optimal analysis (Cumbria County Council, 1980). The land use model was used to examine land allocation under different situations where certain land areas were restricted to their current land use activities for recreation, landscape and nature conservation reasons (Chapter 3). In other words, recreation and nature conservation were being treated as constraints in the model, limiting the land areas available for change. In many models non-monetary objectives (if included at all) are relegated to the set of constraints as target specifications as this avoids the problem of valuing non-monetary objectives.

One of the main problems in attempting to include recreation and nature conservation in the model is that such factors are not single forms of land use but depend on the land use activities of the area concerned. Any value defined will be highly dependent not only on the activity of the area defined but also on the activity of the adjacent land and changes in that land use activity (ie the value will be dependent on both the internal and external landscape of an area). The scale of each land use activity which will vary according to the land characteristics, may also considerably influence the recreation or nature conservation value of any area. Assessing the value of recreation and nature conservation is a highly subjective process, landscape preception being a personal opinion in which there are an infinite number of choices. The model is not able to explain interdependencies such as these and must assume that each area of land is independent.

Quantification of recreation and nature conservation values is extremely difficult and no one method has been devised which is widely accepted (Whitby and Willis, 1978). Many scoring methods have been suggested but the greatest controversy exists over attempts to value recreation and conservation in monetary terms. The best known model used to establish recreational demand for particular sites was developed by Clawson (1959) and has since been used in several studies in Great Britain (see for example H. M. Treasury, 1972; Smith, 1971). Clawson-type models provide a basis for ranking alternatives but it is not a perfect tool and research is continuing into new approaches. Sinden (1974) has suggested one possible model which has still to be widely tested. All of the proposed models have severe practical and theoretical limitations, many being only concerned with measuring selected aspects of recreational benefits which does not give an adequate or complete measure of the benefits. Little attention has been given to the immense problem of valuing nature conservation which is highly site specific and cannot be defined in terms of general values.

To attempt to define the value of recreation in the Sedbergh district which is mostly concerned with informal recreation, ie pleasure driving, walking and picknicking, and nature conservation is extremely difficult and would be surrounded with considerable suspicion. Owing to the difficulties associated with quantifying these elements and incorporating them into the model framework, they are omitted from the current land use model though some consideration is given to these factors when defining the management of each land use activity considered in the model. For example, forestry as a form of land use is regarded as following management guidelines used by the Forestry Commission who take recreation and environmental factors into consideration when planning and developing forest areas. The land uses considered in the model are not aiming at maximum production irrespective of everything else, but adopt realistic management regimes which are regarded as being acceptable today. As in the previous model (Cumbria County Council, 1980) recreation and nature conservation are only considered through limiting land use changes in certain land areas.

One attempt to incorporate non-income earning forms of land use into a model framework was suggested by Hitchens, Thampapillai and Sinden (1978), and it is possible that the current land use model as applied to the Sedbergh district could be developed in a similar manner. Hitchens et al (1978) while looking at land allocation using opportunity cost criteria in a linear programming model, also looked at the possibility of extending the model, using a single set of prices, to generate a schedule of possible plans meeting both income earning and environmental preservation objectives in a specific way. The objective function of the model was separated into those activities contributing to the monetary income objective and those to the environmental preservation objective. To derive the trade-off values between each objective a weighting procedure was adopted. A range of weightings was defined such that at one extreme only the income objective is maximised, while at the other the environmental objective is maximised. This accounted for all attainable levels of combination of the two objectives and formed the basis for the parametric variation of the objective function, but implies nothing about society's weight for one objective or another. Such an approach led to a trade-off function between the two objectives representing an infinite set of efficient management strategies.

Estimating the monetary value of the income earning activities was possible from published data but difficulties arose with respect to the measurement of environmental preservation benefits. Thampapillai and Sinden (1979) suggested several procedures for valuing environment quality based on society's willingness to pay for the preservation of natural environments, all of which rest on the concept of a social demand curve, and limited funds. The different procedures suggested modify the social willingness to pay for irreversibility and quality characteristics of natural environments. One procedure equates the preservation benefits to the social willingness to pay and environmental quality characteristics. The benefits were estimated through a land value method (Reynolds, 1978) in which it is assumed there is a competitive land market, a government agency purchasing land for preservation purposes and social institutions encouraging agencies to follow social preferences. While imperfect, such a method was regarded as feasible because recent purchases of land for preservation purposes in Australia had several bidders for each block. Each market value for each land type was examined and adjusted by government agencies where it was believed that the price was not normal and represented a temporary fluctuation in the market. In this way a politically established value was defined for each land type which was combined with a score related to the preservation benefits of the area. No one valuation procedure is acceptable and different methods need to be examined. Thampapillai and Sinden (1979) found that using different environmental quality valuation procedures led to different trade-off suggestions, although similarities did exist between each valuation method.

Using the information from the trade-off functions, the decision maker could examine the consequences of particular plans, looking at the direction in which management could be improved, the relationship and degree of conflict between the two objectives. Such an approach separates the task of analysing alternative management strategies from the task of selecting socially desirable weights for each objective. Extension of the land use model as applied to the Sedbergh district to include nature conservation and recreation along similar lines would be of immense value, though the model would increase in complexity due to the number of runs necessary to adequately define the trade-off function for each problem considered. However, the usefulness of such an approach will depend on "the adequacy of the procedure to value the non-monetary objective" (Thampapillai and Sinden, 1979).

8.1.3 Model Assumptions

In all modelling procedures assumptions are made, simplifying the situation being investigated and the significance of these assumptions must be recognised. Particular assumptions will have a greater influence on land use allocation than others, as these may have an influence on the meaning of the whole model such as the economic assumption of constant real prices over the time period examined, whereas other assumptions will only affect a particular set of coefficients such as those relating to farm management details in the area. If one data source eg all of the agricultural economic information, is liable to error or say higher than in reality, then this is likely to have less effect on the land use allocations than an error associated with only one variable, which may be overestimated, which could lead to a different optimal solution. The model may be easily rerun if particular assumptions or data input are in doubt, but there is a limitation to this, and the use of ranging facilities associated with all linear programmes is essential to determine the sensitivity of the variables in the model and those which need careful validation and estimating. The use of ranging enables one to identify risky variables to be avoided if possible, and therefore could result in the saving of resources if planners concentrated on adopting insensitive variables in the first instance. For example, if there are several land classes in which one land use such as forestry was suggested, but only one of these allocations showed little sensitivity to changes, then it would be advantageous to consider afforestation in this land class initially, and then go on to examine the reasons for the other land classes showing a higher sensitivity. Sensitivity analysis can provide valuable information on the robustness of the actual model and the likely changes in the optimal basis if certain factors ie data input, exceed a given degree of error, and this will be discussed later (Section 8.3).

The validity of the assumptions made in the model is largely related to the quality of the information on which the model is based. Numerous organisations have contributed to the data and information used in the land use model, much of which was collected during the study undertaken by Cumbria County Council. This collection of data is in itself useful as one becomes increasingly aware of the situation being examined and better informed. The land use model has been modified since the initial work (Chapter 9), particularly with respect to agricultural details which are believed to be more realistic. Further modifications would appear to be desirable looking at the actual form of agricultural output ie hill lamb, fat sheep, and different agricultural management systems, and this suggests the use of more details on the actual farm management practises adopted in the district.

Considerable effort is needed to obtain information for the model as it covers a wide range of disciplines and involves a large number of government agencies, all of whom have certain information available within their departments. There is no information record as to whom holds what type of information and much of what is required is confidential, although average estimates do exist if their locations are known. The problem of information retrieval in Scotland is being examined by a Working Party set up to look at rural land use information systems (Lyall, 1980). The Working Party chaired by the Department of Agriculture for Scotland (DAFS), includes all of the agencies concerned with land use planning in Scotland. They have been looking at available information sources, their collection, storage and dissemination, information gaps and the possibility of a long term information system for use by government and local authorities. It is recognised that coordination of widely held varied information is necessary with the development of current planning processes, and the increased number of planning organisations concerned with rural land use.

8.2 ESTIMATION OF THE INPUT COEFFICIENTS AND THEIR VALIDITY

It is difficult to obtain statistics which are directly applicable to the area being investigated. The data actually used in the model is either based on the Sedbergh district itself through surveys carried out by the County Council or is related to the Northern Region of England, though each organisation providing information has a different administrative boundary. Using the data available and estimating the input coefficients involves a series of assumptions (Appendix 2), and it is essential to ensure that all of the figures related to each land use are compatible. The validity of the model input coefficients is difficult to assess through a lack of published statistics, and if such information is available it is difficult to ascertain whether the errors observed between the various data sources are due to errors in the use of the input data, in the accuracy of the assumptions or in the degree of compatability of the two sources of information. The degree of error and the level of uncertainty associated with all of the estimations are difficult to assess (if not impossible) and without any sources of statistics for validation sensitivity analysis plays a critical role in the model. Sensitivity analysis (Section 8.3) enables one to determine the sensitivity of the optimal solution to changes in crudely estimated coefficients. One can identify the coefficients which need refining and subsequently refined coefficients can be used in the model.

The model is based on tangible elements of land use avoiding intangibles such as recreation and nature conservation which are extremely difficult to quantify in both monetary and non-monetary terms (Section 8.1.2). All of the assessments are based on market values (1977 - 1978 prices) or expected productivities, and there are no subjective measurements in the model. This is advantageous from the point of the validity of the data as a greater degree of suspicion is associated with subjective criteria. However, this leads to problems with regard to an assessment of the model results, as these intangible elements of land use must be considered in any rural planning process and this must be left to the planner to consider.

8.2.1 Economic Input Coefficients

Economic assessment of each land use activity may appear relatively simple but it is difficult to obtain figures representative of land use in the Sedbergh district. All of the economics are expressed in current market prices (1977 - 1978) and the model assumes constant real prices throughout the time period examined. The Ministry of Agriculture (MAFF) produces statistics on the financial return to different types of farming and farm enterprises but relating these to the Sedbergh district is extremely difficult. It was felt preferable to estimate farm revenue from the production estimates specific to the district (Cumbria County Council, 1980) and current market prices, but to use cost data from one of the many MAFF statistical publications. Defining market prices and cost data is beset with problems, as often different sources lead to different estimations. The model was run with what were regarded as the most appropriate figures available at the time, but attempts were made to also look at the use of different sources of statistics and different means of assessment.

The model explored several problems using economic coefficients based on a number of sources:

A. "Financial results and measures of efficiency - the Northern Region 1977/78", MAFF (Farm Management Department) and Newcastle University, 1979.

B. "Farm Management Handbook - Northern Region, 1977/78", MAFF (Farm Management Department), 1979.

C. "Farm Incomes in England and Wales 1977/78", No. 31, MAFF, 1979. Data relating to the Northern Region of England.

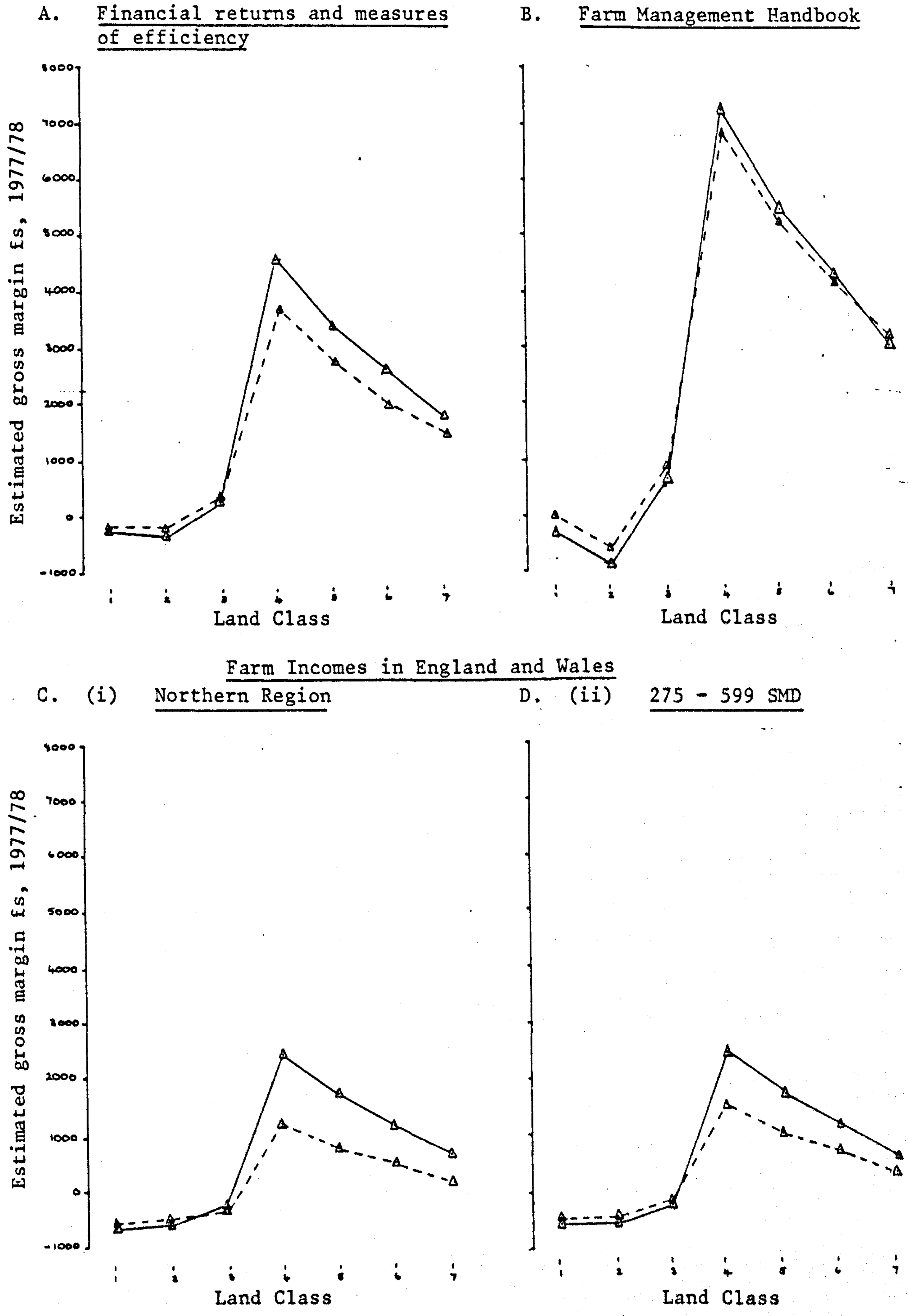
D. "Farm Incomes in England and Wales 1977/78", No. 31, MAFF, 1979. Data relating to farms with low labour input, 275 - 599 smd.

All of the data are derived from information from the Farm Management Survey but collated and presented in different forms. The main difficulty with using this data was relating the types of farming categories defined in the Sedbergh study to the tabulation of the published statistics, the best correlation being based on livestock criteria. Tbe economic coefficients based on these different sources of information displayed a different relationship between the land classes (Figures 8.1 and 8.2), and when used in the model led to a change in the suggested land allocations as anticipated from the observed relationships.

Land use allocation was explored using each set of coefficients based on a different data source, optimising the total economic value (TNPV) using a discount rate of 3% under limited constraint specifications defined below.

(1)	CST.ZERO	(i)	No restrictions on land availability
		or (ii)	Common land and conservation areas restricted to their current form of land use
(2)	CST.CRT.	(i)	No restrictions on land availability
		or (ii)	Common land and conservation areas restricted to their current form of land use.

Figure 8.1 Potential gross margins (£, 1977/78) associated with dairying per land class according to different data sources (expressed per 25 ha)



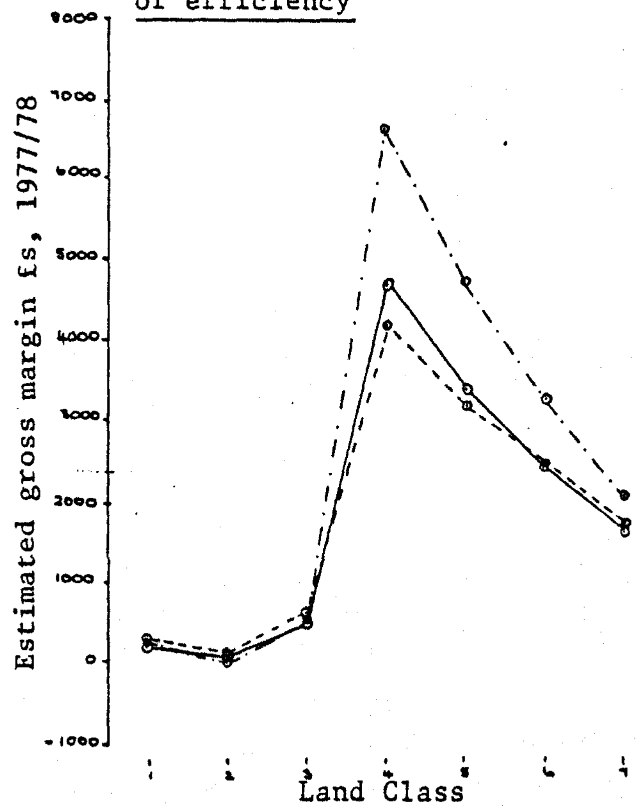
Key:

——— Specialist dairying (SD)

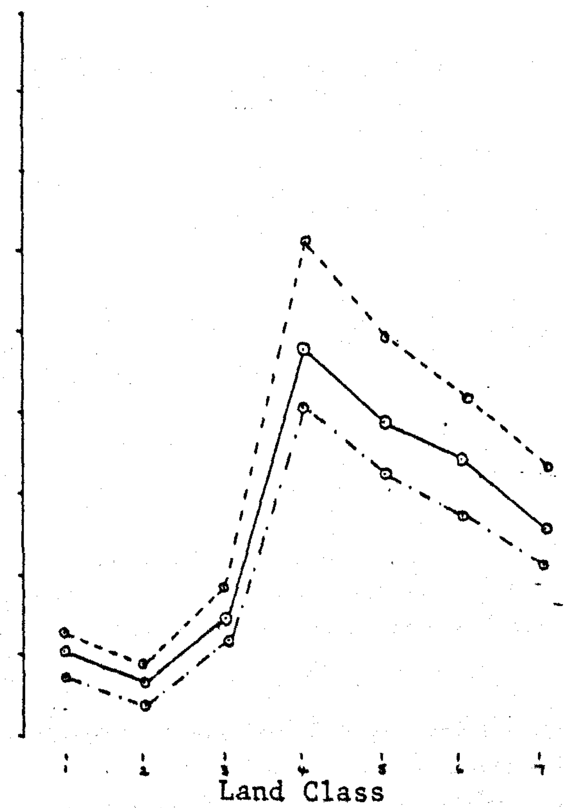
- - - - - Mainly dairying (MD)

Figure 8.2 Potential gross margins (£, 1977/78) associated with livestock rearing per land class, according to different data sources (expressed per 25 ha)

A. Financial returns and measures of efficiency

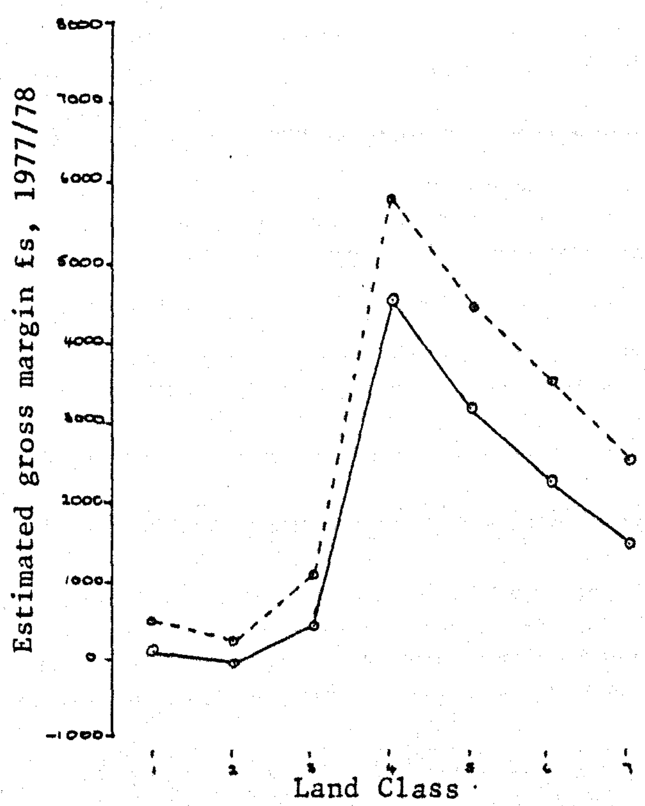


B. Farm Management Handbook

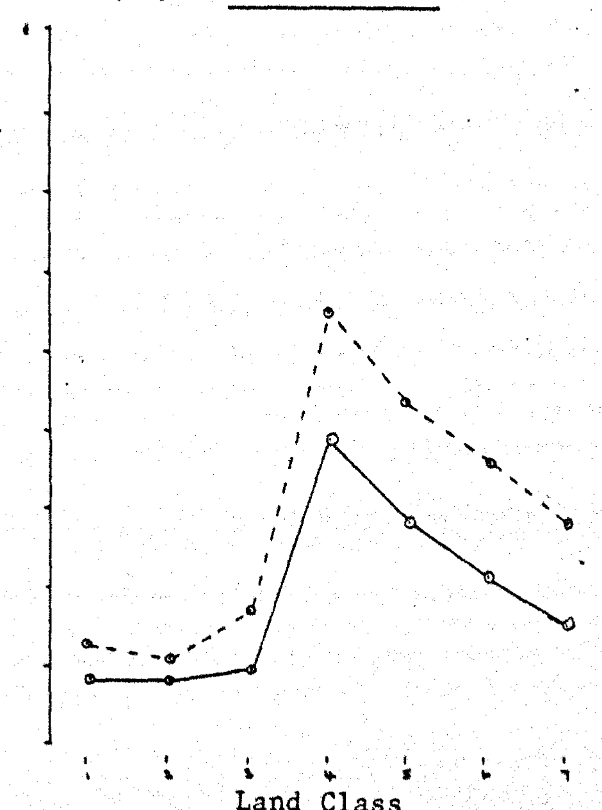


Farm Incomes in England and Wales

C. (i) Northern Region



D. (ii) 275 - 599 SMD



Key:
-·-·- Mostly cattle ——— Cattle and sheep ----- Mostly sheep

Table 8.1 Suggested land allocations according to different data sources, given no predetermined production and labour input levels

Problem: Max. TNPV, r = 3%, CST.ZERO, Land Availability and data source as defined.

A. Financial returns and measures of efficiency

(i) No restrictions on land availability

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	333						333
2	3					191	194
3	168						168
4	4			69			73
5	1			47			48
6				21			21
7	1			66			67
Total	510	0	0	203	0	191	904

(ii) Common land and conservation areas restricted to their current form of land use

Land Class	Land Use								Total
	PW	SD	MD	C	CS	S	KS	PS	
1	185						123	25	333
2	3					69	104	18	194
3	117						41	10	168
4	4			69					73
5	1			46				1	48
6				15			6		21
7	1			33			31	2	67
Total	311	0	0	163	0	69	305	56	904

Table 8.1 (continued)

B. Farm Management Handbook

(i) No restrictions on land availability

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	333						333
2	194						194
3	168						168
4	4	69					73
5	1	47					48
6		21					21
7	1		66				67
Total	701	137	66	0	0	0	904

(ii) Common land and conservation areas restricted to their current form of land use

Land Class	Land Use								Total
	PW	SD	MD	C	CS	S	KS	PS	
1	185						123	25	333
2	72						104	18	194
3	117						41	10	168
4	4	69							73
5	1	46						1	48
6		15					6		21
7	1		33				31	2	67
Total	380	130	33	0	0	0	305	56	904

Table 8.1 (continued)

C. Farm Incomes in England and Wales - Northern Region

(i) No restrictions on land availability

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	333						333
2	3					191	194
3	5					163	168
4	4					69	73
5	1					47	48
6						21	21
7	1					66	67
Total	347	0	0	0	0	557	904

(ii) Common land and conservation areas restricted to their current form of land use

Land Class	Land Use								Total
	PW	SD	MD	C	CS	S	KS	PS	
1	185						123	25	333
2	3					69	104	18	194
3	5					112	41	10	168
4	4					69			73
5	1					46		1	48
6						15	6		21
7	1					33	31	2	67
Total	199	0	0	0	0	344	305	56	904

Table 8.1 (continued)

D. Farm Incomes in England and Wales - 275 - 599 SMD

(i) No restrictions on land availability

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	333						333
2	3					191	194
3	168						168
4	4					69	73
5	1					47	48
6						21	21
7	1					66	67
Total	510	0	0	0	0	394	904

(ii) Common land and conservation areas restricted to their current form of land use

Land Class	Land Use								Total
	PW	SD	MD	C	CS	S	KS	PS	
1	185						123	25	333
2	3					69	104	18	194
3	117						41	10	168
4	4					69			73
5	1					46		1	48
6						15	6		21
7	1					33	31	2	67
Total	311	0	0	0	0	232	305	56	904

Key: As given in Table 5.1

Table 8.2 Production and input levels suggested by different data sources, given no predetermined production and labour input levels (expressed as a percentage change from current levels).

Problem: Max. TNPV, r = 3%, CST.ZERO, Data source and land availability as defined.

Data source/ land availability		Primary Output Variables						
		Beef	Sheep	Milk	Timber	Total NPV	Agri. NPV	For. NPV
(i)	A.	+443	-49	-88	+2294	+ 74	+25	+1697
	B.	-100	-75	+70	+2372	+ 38	+ 1	+1753
	C.	+ 75	+21	-42	+1353	+118	+88	+ 931
	D.	+ 58	- 4	-61	+2294	+139	+58	+1711
(ii)	A.	+383	-41	-90	+1378	+ 58	+29	+1031
	B.	-100	-61	+52	+1406	+ 24	+ 2	+1051
	C.	+ 52	+14	-61	+ 731	+ 93	+78	+ 503
	D.	+ 40	- 3	-66	+1378	+110	+63	+1039

Data source/ land availability		Other Output Variables		
		Wool	Dairy Meat	Food Energy
(i)	A.	-61	-88	-52
	B.	-80	+70	+45
	C.	- 7	-53	-38
	D.	-25	-61	-47
(ii)	A.	-30	-90	-57
	B.	-44	+50	+30
	C.	+13	-61	-46
	D.	+ 1	-67	-53

Table 8.2 (continued)

Data source/ land availability		Input Variables				
		Total Labour	Agri. Labour	For. Labour	Agri. Subsidies	For. Subsidies
(i)	A.	+12	-44	+1890	- 1	+2173
	B.	+40	-17	+1962	-86	+2265
	C.	+12	-22	+1140	- 5	+1382
	D.	+18	-37	+1890	-24	+2172
(ii)	A.	- 3	-36	+1131	+17	+1281
	B.	+24	- 9	+1157	-53	+1315
	C.	- 1	-20	+ 616	+10	+ 779
	D.	+ 3	-30	+1131	- 3	+1281

Key:

(i) No restrictions on land availability

(ii) Common land and conservation areas restricted to their current form of land use.

A. Financial Returns and Measures of Efficiency

B. Farm Management Handbook

C. Farm Incomes in England and Wales - Northern Region

D. Farm Incomes in England and Wales - 275 - 599 SMD

Table 8.3 Suggested land allocations according to different sources while maintaining current production and labour input levels

Problem: Max. TNPV, r = 3%, CST.CRT, Land availability and data source as defined.

A. Financial Returns and Measures of Efficiency

(i) No restrictions on land availability

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	11					322	333
2	3					191	194
3	5					163	168
4	4			69			73
5	1	39		8			48
6		21					21
7	1	48				18	67
Total	25	108	0	77	0	694	904

(ii) Common land and conservation areas restricted to their current form of land use

Land Class	Land Use								Total
	PW	SD	MD	C	CS	S	KS	PS	
1	11					174	123	25	333
2	3					69	104	18	194
3	5					112	41	10	168
4	4	56		13					73
5	1	10				36		1	48
6						15	6		21
7	1					33	31	2	67
Total	25	66	0	13	0	439	305	56	904

Table 8.3 (continued)

B. Farm Management Handbook

(i) No restrictions on land availability

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	194					139	333
2	3					191	194
3	5					163	168
4	4	6	48	15			73
5	1		47				48
6						21	21
7	1		66				67
Total	208	6	161	15	0	514	904

(ii) Common land and conservation areas restricted to their current form of land use

Land Class	Land Use								Total
	PW	SD	MD	C	CS	S	KS	PS	
1	31					154	123	25	333
2	3					69	104	18	194
3	5					112	41	10	168
4	4		51	18					73
5	1		46					1	48
6						15	6		21
7	1		33				31	2	67
Total	45	0	130	18	0	350	305	56	904

Table 8.3 (continued)

C. Farm Incomes in England and Wales - Northern Region

(i) No restrictions on land availability

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	94					239	333
2	3					191	194
3	5					163	168
4	4	52				17	73
5	1					47	48
6						21	21
7	1					66	67
Total	108	52	0	0	0	744	904

(ii) Common land and conservation areas restricted to their current form of land use

Land Class	Land Use								Total
	PW	SD	MD	C	CS	S	KS	PS	
1	11					174	123	25	333
2	3					69	104	18	194
3	5					112	41	10	168
4	4	60			9				73
5	1	4				42		1	48
6						15	6		21
7	1					33	31	2	67
Total	25	64	0	0	9	445	305	56	904

Table 8.3 (continued)

D. Farm Incomes in England and Wales - 275 - 599 SMD

(i) No restrictions on land availability

Land Class	Land Use						Total
	PW	SD	MD	C	CS	S	
1	94					239	333
2	3					191	194
3	5					163	168
4	4	52				17	73
5	1					47	48
6						21	21
7	1					66	67
Total	108	52	0	0	0	744	904

(ii) Common land and conservation areas restricted to their current form of land use

Land Class	Land Use								Total
	PW	SD	MD	C	CS	S	KS	PS	
1	31					154	123	25	333
2	3					69	104	18	194
3	5					112	41	10	168
4	4	12			3	54			73
5	1	46						1	48
6						15	6		21
7	1	33					31	2	67
Total	45	91	0	0	3	404	305	56	904

Key: As given in Table 5.1

Table 8.4 Production and input levels suggested by different data sources, while maintaining current production and labour input sources (expressed as a percentage change from current levels)

Problem: Max. TNPV, r = 3%, CST.CRT., Data source and land availability as defined.

Data source/ land availability		Primary Output Variables						
		Beef	Sheep	Milk	Timber	Total NPV	Agri. NPV	For. NPV
(i)	A.	+237	=	=	=	+35	+35	=
	B.	=	=	+24	+771	+17	+ 7	+525
	C.	+ 25	+22	=	+347	+85	+79	+239
	D.	+ 25	+22	=	+347	+84	+76	+239
(ii)	A.	+ 22	=	=	=	+14	+14	=
	B.	=	=	+ 2	+325	+ 5	+ 4	+ 57
	C.	=	+ 3	=	=	+53	+54	=
	D.	=	+ 1	=	+ 83	+57	+57	+ 57

Data source/ land availability		Other Output Variables		
		Wool	Dairy Meat	Food Energy
(i)	A.	-29	+ 4	+14
	B.	-26	+25	+20
	C.	-10	=	+ 4
	D.	-10	=	+ 4
(ii)	A.	=	+ 1	+ 1
	B.	=	+ 3	+ 2
	C.	+ 2	- 1	=
	D.	=	+ 2	=

Table 8.4 (continued)

Data source/ land availability		Input Variables				
		Total Labour	Agri. Labour	For. Labour	Agri. Subsidies	For. Subsidies
(i)	A.	+ 4	+ 4	-	+ 3	-
	B.	+19	-	+650	-26	+822
	C.	+ 8	-	+293	- 7	+370
	D.	+ 8	-	+293	- 7	+370
(ii)	A.	-	-	-	+ 1	-
	B.	+ 2	-	+ 70	- 3	+ 89
	C.	-	-	-	-	-
	D.	+ 2	-	+ 70	- 3	+ 89

Key: As given in Table 8.2

The resulting land use patterns, output and input estimates suggested varied considerably between data sources as shown in Tables 8.1 - 8.4. For example, when maintaining current production levels and restricting land use activities on common land other areas for landscape and nature conservation reasons, afforestation is only suggested (land class 1) if the coefficients are based on information from data sources B and D. The importance of the need to validate the input coefficients is illustrated in Table 8.5 which shows the variation in suggested potential increases in Total NPV according to the input coefficients adopted.

Table 8.5 Potential increase in the total net present value of production in the district according to different data sources

Data source	Constraint Specification			
	CST.ZERO		CST.CRT.	
	Land Availability Constraint			
	No R	K, P	No R	K, P
A.	74	58	35	14
B.	38	24	17	5
C.	118	93	85	53
D.	139	110	84	57

(Increase expressed as the percentage increase over the current estimated value)

Key:

No R — No restrictions on land availability
K, P — Common land and conservation areas restricted to their current form of land use
A. — Financial returns and measures of efficiency
B. — Farm Management Handbook
C. — Farm Incomes in England and Wales - Northern Region
D. — Farm Incomes in England and Wales - 275 - 599 SMD

Each land allocation suggested by the model showed similarities in the upland land classes but considerable differences in the lowland areas (Tables 8.1 and 8.3). The upland area (land classes 1 - 3) was allocated to private woodland and/or sheep rearing. When there were no target constraint specifications (CST.ZERO), the upper middle slopes (land class 1) were allocated to private woodland, whichever data source was adopted, and most suggested using the hill tops (land class 2) for sheep farming and the lower middle slopes (land class 3) for forestry (Table 8.1). However, the allocations suggested when maintaining current agricultural production and labour input levels, devoted most of the upland area to sheep farming, private woodland only being suggested if at all, on the upper middle slopes (land class 1) (Table 8.3). When using coefficients based on information from the Farm Management Handbook (data source B), 194 squares are devoted to private woodland in land class 1 but under the same circumstances only 94 are allocated to private woodland according to those coefficients based on the publication Farm Incomes in England and Wales (data sources C and D), which is a considerable difference. However, restricting common land and conservation areas to their current form of land use led to the suggestion of planting just 31 squares of land class 1 (data source B and D only).

The land use activities allocated to the lowlands (land classes 4 - 7) showed considerable variation, each data source favouring particular land use activities. Sheep farming was favoured by the data based on the publication Farm Incomes in England and Wales, cattle rearing by that based on Financial Returns and Measures of Efficiency, and the coefficients based on information from the Farm Management Handbook favoured dairying activities. This emphasis was also indicated in the production levels associated with each allocation (Tables 8.2 and 8.4) which suggested increases of particular outputs according to the data source used, ie sheep, beef and milk respectively. The allocations suggested while maintaining current agricultural production and labour input levels, devoted most of the better lowland area, land classes 4 and 5, to dairying activities, the remaining area being given to cattle or sheep rearing in different proportions according to the data source adopted. The remaining lowland area, land classes 6 and 7, is devoted to sheep and dairying activities. In general, the coefficients based on data from the Farm Management Handbook favour specialist dairying activities whereas that based on the publication Farm Incomes in England and Wales specific to small farms (275 - 599 SMD) show a bias to mainly dairying activities.

Using input coefficients based on each data source in the land use model suggested a substantial increase in timber production ranging from an increase of 1000% to 2300% given no restrictions on production levels or land availability. However, specifying current production levels reduces this potential increase to the order of 300 - 700% over current levels (Tables 8.2 and 8.4). Associated with the increase in the area allocated to private woodland is an increase in the suggested level of forestry labour requirements. The level of agricultural labour requirements is suggested as decreasing, any change in the total level of labour input being related to forestry activities. The coefficients based on information from the Farm Management Handbook appear to be extreme, as an increase in the total labour input of 40% over current levels is suggested as opposed to 12 - 18% using other data sources (CST.ZERO, no restrictions on land availability - Table 8.2 (i)). Similar differences in the increase in total labour levels are suggested when current agricultural production and labour input levels are maintained (Table 8.4). Subsidy levels in general, are suggested as decreasing with respect to agricultural activities but increasing with respect to forestry subsidies as expected from the suggested land allocations.

The estimated potential increase in the economic value of production (TNPV) varies considerably according to the data source chosen (Tables 8.2 and 8.4). Given no restrictions on land availability and no restrictions on production levels leads to suggested increases of between 38% and 139% over the current estimated value. In all of the situations explored, the coefficients based on information from the Farm Management Handbook and the publication, Farm Incomes in England and Wales suggested the most extreme estimates, low and high increases in TNPV levels respectively. Clearly, the accuracy of the economic data is questioned and the validity of accepting such information as being representative of the Sedbergh district. Sensitivity analysis may indicate those variables which are most sensitive but the estimated coefficients show large variances, and it is clearly necessary to find out which data is appropriate to the farming situation in this district.

8.2.2 Forestry labour input coefficients

As indicated in previous chapters the land use allocations suggested by the model led to questions on the validity of the estimation of the forestry labour input figures. These estimates appeared to be rather on the high side, and this was felt to be due to the difficulty of considering the complete rotation cycle and expressing labour input on an annual basis. Labour input to forestry operations is variable; demand for forest workers increases slowly during the establishment period, stabilises between years five and twenty, then increases more rapidly through the thinning period and at final felling. This means that labour input figures are dependent on both the size of the area planted and the age structure of the plantation, and this makes estimation of an annual input value highly difficult. If a forestry area is well established consisting of different aged plantations, each will be at a different stage of production and this will result in a relatively steady input of labour per annum over the whole area. On the other hand, afforesting an area which previously has been little used for forestry will lead to a highly variable input of labour per year until some of the plantations reach the production stage which may be twenty years or more after planting.

A crude estimation of forestry labour requirements based on information provided by the Forestry Commission (Edinburgh) was used in which a simple average labour input value was estimated. This was used in preference to forestry input estimates adopted in the Sedbergh Rural Land Use Study (Cumbria County Council) which were based on Bishop's method of estimation (who attributed labour to both forestry yield and area) and used data collected from the Forestry Commission (Kendal). The latter (Table 8.6 A) are higher than the crude average estimations (Table 8.6 B) and show a slightly different relationship between land classes. As all of

Table 8.6 Labour input associated with forestry activities (SMD/annum/25 ha)

Land Class	Different estimations, SMD per annum per 25 ha.		
	A	B	C
1	85.1	47.3	103.5
2	8.1	4.7	10.4
3	101.5	60.8	107.5
4	96.1	84.8	121.8
5	112.0	84.8	121.8
6	113.4	79.5	119.3
7	117.5	65.3	108.8

Estimation based on A. Sedbergh rural land use study, Bishop estimates - FC (Kendal)
B. FC (Edinburgh) information specific to NW Conservancy
C. FC (Edinburgh) weighted, 5% factor.

Table 8.7 Timber production assessments (m^3/annum/25 ha)

(i) SRLUS[1] coefficients based on survey information from FC (Kendal)

Land Class	Land Use					
	F	SD	MD	C	CS	S
1	154	1	1	1	1	1
2	15					
3	186	2	2	2	2	2
4	173	2	2	2	2	2
5	206	3	3	3	3	3
6	208	4	4	4	4	4
7	218	5	5	5	5	5

(ii) Coefficients based on information from FC (Edinburgh)

Land Class	Land Use
	PW
1	174
2	17
3	239
4	142
5	142
6	304
7	271

1 SRLUS represents the Sedbergh Rural Land Use Study undertaken by Cumbria County Council (1980).

Key: F Forestry as defined in the SRLUS (Chapter 3).
Then as used in Table 5.1

the forestry economic data were obtained from the Edinburgh office of the Forestry Commission, it was regarded as preferable to adopt the associated labour estimations. These data are readily available within the Forestry Commission on a Conservancy basis and would be available for similar studies in different areas.

On exploring land allocation in the district with the aid of the land use model, the forestry labour input was criticised as being unrealistic and suspiciously on the high side, and therefore alternate methods of estimations were sought. An attempt was made to weight the labour input figures in a similar manner to that adopted by the Forestry Commission in connection with the Cost Benefit analysis of Forestry in 1972 (H M Treasury, 1972). The labour estimations were weighted using a 5% discount factor (the accepted Treasury test rate of return) which implies that forestry labour input is favoured in the early period of the rotation as opposed to the final stages of the cycle, ie looking for employment now as opposed to in future years. These figures (Table 8.6 C) are considerably higher than those used in the land use model and show a greater resemblance (though at a higher level) to the estimates used in the study undertaken by Cumbria County Council. Different means of estimating forestry labour requirements have an important effect on both the input level and the relationship between each land class, and therefore must be given due consideration when interpreting the results.

Estimation of the labour requirements associated with any land use on an annual basis is exceedingly difficult. Agricultural enterprises have periods of high and low activity throughout the year, such as at lambing and hay time, similar to that associated with forestry activities throughout the rotation cycle. The different methods of estimating the annual labour input to forestry all led to higher figures compared to those actually used in the land use model, suggesting that the latter were reasonable and that forestry does offer a means of maintaining and/or increasing rural employment.

However, employment in forestry operations at a local scale is only likely to be part-time as for many of the operations labour is usually imported from outside the district, from the surrounding areas. It is becoming increasingly common for forestry workers to live considerable distances away from forested areas, and often gangs of workers move from area to area without generally contributing to the stability or wealth of any one district. Forestry workers themselves are highly skilled to carry out productive tasks throughout the year but many of these skills are, or could be, applied in other industries. To avoid single industry specialisation in the district and to avoid too much reliance on migratory workers, it may be necessary to stimulate local contractors and farmers into carrying out forestry operations. Integrating farming and forestry activities may offer increased benefits to both the local district and region, leading to stable employment prospects.

The kind of community supported in the district is as important as the number of jobs created, both in the district and the region. The land use model suggests that allocating different land use activities to different land classes offers the greatest benefit to the district. Forestry offers the greatest employment capacity per unit area of land and if forestry activities were introduced into particular land classes, the district would be capable of maintaining current agricultural production levels and a higher level of rural employment. Estimates of the labour requirement ratio between forestry and hill farming have been suggested as 12 : 1 by Newton (1977), though the figures are not truly comparable as the farm and forest sample were not directly compatible. A similar ratio was suggested in the Interdepartment Cost/Benefit Survey (H M Treasury, 1972) of 12.2 : 1 for the North of Scotland, but for the South of Scotland the estimate was reduced to 2 : 1. There is probably no direct competition for labour between farming and forestry activities, but since forestry in general employs more men per managed hectare, it would seem to give a greater social benefit, and therefore some degree of afforestation would appear to be beneficial to the district.

When considering district development, one must not only look at the level of employment within the local district but also at the wider implications of any planning suggestions on a regional scale. One must consider for example, the multiplier effect of how many jobs would be created elsewhere in the region as a result of any change in land use activities in the Sedbergh district. The Treasury in their much criticised report (H M Treasury, 1972) (Rankin, 1973), suggested that the main effect of the introduction of forestry on the structure of employment of a region will be to provide jobs for the unemployed. The report postulates that every 100 jobs created in forestry will:

1. Reduce local registered unemployment by 30
2. Reduce local unregistered unemployment by 20
3. Reduce local 'concealed' unemployment by 5
   (employees being 'carried' by the alternative employer)
4. Reduce local productive employment by 15
   (ie cause 15 workers to change their jobs)
5. Reduce migration to more prosperous areas by 30.

It appears that theoretically forestry has a greater employment capacity per unit area of land than hill farming, and therefore the estimates suggested by the land use model are likely to be valid, but one must remember that stable employment levels will not arise until the forestry areas are well established.

8.2.3 Forestry production input coefficients

The coefficients relating to potential forestry production per land class were also scrutinised, as coefficients based on information from different branches of the Forestry Commission showed some variation (Table 8.7). This variation is largely related to an awareness of the situation in the Sedbergh district. The coefficients based on information from the local conservancy of the Forestry Commission (Kendal) are more likely to be the most representative as they were based on field samples and local knowledge. The other coefficients are based on information obtained through the Forestry Commission (Edinburgh) which is specific to the North West Conservancy. The latter data is more generalised being based mainly on soil and altitude details, but as it is collected on a Conservancy basis this would be easily available for future use in other similar studies. It is unlikely that more specific data would be available in most situations as surveys and field sampling is both time consuming and costly, and for this reason the production coefficients based on the more generalised data were used in the model. Some difficulties arose in relating information on forestry potential productivity collected by the Forestry Commission, to each land class defined, which leads one to look closely at the land classification system.

8.2.4 Classification of the land types

To investigate land use activities in different areas, it is necessary to classify the land types into convenient recognisable groups. Several land classification systems exist but each has its own disadvantages being for example either inconsistent or incomplete in coverage, based on only a single group of characteristics, too wide a range of properties considered within any one land type, or highly dependent on short term changes.

The MAFF agricultural classification which is used throughout England and Wales is not appropriate for examining a range of land uses, being based on agricultural land ignoring other land use activities such as forestry, urban and non-urban activities, which are only defined as a cumulative value (MAFF, 1974). This classification centres on the flexibility of land in agricultural use and not on the productivity of the land which is important when considering land use changes and so is not an effective tool in land use decisions. According to this land classification, the land in the Sedbergh district, like most upland areas, falls into two grades (4 and 5), which gives little discrimination between different types of land. For example, a brief description of these two grades is as follows:

Grade 4: 'Land with severe limitations due to adverse soil, relief or climate or a combination of these. Land in this grade is generally only suitable for low output enterprises.'

Grade 5: 'Land with very severe limitations due to adverse soil, relief or climate or a combination of these. This land is generally under grass or rough grazing, except for the occasional pioneer forage crop.'

Overall, this classification gives little indication of the relationships between the various land gradings, the maps are too broad to be of use at the local planning level, and it is a system which is not readily understood. Like most classifications including that actually used as a basis for the land use model, it is extremely difficult to recognise the land classes in the field. At present work is being carried out on a national survey using a more detailed classification of hills and uplands. The classification is geared to agricultural potential and aims to define four categories of improvability in 'hill' areas (unimproved land) and four of flexibility of use in 'upland' areas (enclosed land under relatively intensive use). This information will be more useful, but it remains to be seen whether this classification will act as a suitable basis for investigating a range of land use activities.

Land characteristics are displayed on soil maps but these are only available at a detailed level for a small part of the uplands, and by themselves are of limited value for examining land use. There is also only limited coverage of land capability maps, which grade land using a combination of soil, landform and climatic factors according to the flexibility of land for agricultural use. This information is valuable although usually less than three classes apply to upland areas. The soils and land capability of the Sedbergh district were assessed within the land class system adopted (Appendix 1) by the Soil Survey of England and Wales (Bendelow and Carroll, 1980) for the study undertaken by Cumbria County Council (1980). Three capability classes were identified as applying to the district, and it is this assessment of land capability which forms the basis on which the potential production in each land class was assessed.

The classification system used (Appendix 1) is derived from existing maps (which is useful as field sampling is often not possible) from which the land characteristics can be determined objectively, and this means that the determined land classes are directly related to the distribution of many biological and land use features. One advantage of such a classification is that it can readily be used in different areas allowing comparisons to be made and can also be applied in different scales. The classification system has been used in different studies on a national

(Institute of Terrestrial Ecology, 1978), regional (Bishop, 1978), and local (Cumbria County Council, 1980) level, the size of the grid square being adjusted accordingly.

Defining land classes in terms of grid squares has been criticised as being artificial. The land area in each land class is heterogenous, ie contains many different types of land of different capability class, some land classes being more heterogenous than others, However, the model treats each land class as being homogenous on the basis that squares belonging to one land class are more like each other than squares in different land classes. This is a simplification of reality as is the artificial definition of land class boundaries on a grid square basis, which can lead to strange combinations of attributes in each land class. Such simplifications could be regarded as rendering the model useless but this is not true as in each land class there is land which has the characteristics suggested by the land class, and given the model results one must look in the specified land class for land appropriate to the suggested activity.

Each land class brings together a range of soil types and elevation zones and for such variable conditions it is difficult to define economic cash flows and production estimates especially with respect to forestry activities, and those used in the model tend to be overgeneralised. Adopting a classification of sixteen land classes would be more specific, reducing the error in the production and economic estimates, but as observed in the Cumbria County Council study, using a greater number of land classes led to difficulties when interpreting the results as many land classes were highly similar in terms of production. The agricultural production coefficients were based on details of the land capability in each land class, which was assessed by sampling using the grid square basis together with soil information, and other attributes defined in each land class were not considered. The land use model only considers agricultural and forestry activities, giving no consideration to the spatial distribution of land use, and in this situation the classification was only required to define the suitability of land for agriculture and forestry. To be of widespread use the characteristics of each land class need to be defined and expressed in terms which can easily be interpreted by different organisations, and to which available statistics can be related.

8.2.5 Constraint specifications (R H S assessment)

When defining the constraints in the model it is necessary to specify the right-hand-side value (R H S), ie indicate that the value of the linear expression must not fall below, or must be above, or must exactly equal a specified value. The land use model has been used to explore optimal land use patterns which maintain current agricultural and forestry production and labour input levels. This means that one must assess the current levels for the whole of the Sedbergh district of each agricultural and forestry output (and input) considered in the model, in order to define the R H S values of the constraints, ie the target specifications. Estimations may be made using the model input coefficients and the current land use pattern defined earlier (Table 5.4). The accuracy of the current land use pattern is questionable as it is difficult to define current usage in terms of type of farming categories, but it is more representative than most surveys/maps available. Current production estimates based on the estimated current land use pattern and model input coefficients, are dependent on the estimated potential production (and input) levels, and therefore include the errors believed to be associated with the model coefficients. Alternate estimates were made where possible, using a diverse range of sources and methods (Table 8.8). Considerable uncertainty exists over a number of estimates particularly the current level of employment in agricultural and forestry activities in the district. Estimates based on agricultural return data imply much higher levels than those estimated according to the model coefficients, although these may vary significantly according to the number of standard man days assumed to be provided per worker per annum. It is very difficult to define the average number of standard man days worked per year, as many of the farm holdings are small part time enterprises, offering less than 275 smd/annum. Also, labour requirements vary according to seasonality and the special circumstances of each individual farm such as soil type, the level of mechanisation and conditions, and the layout of buildings. Usually it is assumed that stockmen provide 300 smd/annum and other agricultural workers 250 smd/annum, but it is possible that on small holdings only 200 smd are worked per annum. Estimations of the current levels of production and value from and inputs to the district based on the model input coefficients were adopted, as these appear to be conservative estimates in most situations.

Table 8.8 Estimated levels of current production and value from, and inputs to, the Sedbergh district

	Information Source			
	Model Coeff-icients	Agricultural Returns 1977/78		Other sources
Production output				
Beef kg/annum	157,280		231,837	
Sheep, kg/annum	230,940		292,744	297,727[1]
Milk, 000kg/annum	7,842		7,499	
Timber, m^3/annum	4,141			
Wool, kg/annum	65,389		67,416	65,806[1]
Dairy meat, kg/annum	100,129		102,285	
Food energy, GJ/annum	26,868			
Inputs (smd/annum)				
Agricultural labour	44,661	A	71,707	
		B(i)	49,700	55,200[2]
		B(ii)	61,995	69,000[3]
		B(iii)	74,410	
Forestry labour	1,327			
Total labour	45,988			

1. Assumptions based on estimates from the Centre for Agricultural Strategy, Report No. 6, 1980 (CAS).
2. Sedbergh district draft local plan survey, assume 200 smd/annum.
3. Sedbergh district draft local plan survey, assume 250 smd/annum.
A. Based on holding size.
B. Based on numbers employed. (i) Assume 200 smd/annum
(ii) Assume 250 smd/annum
(iii) Assume 300 smd/annum.

8.3 SENSITIVITY ANALYSIS

8.3.1 The use of sensitivity analysis

The importance and accuracy of the model input coefficients can be investigated in the model by both re-running the problem with different coefficients and by looking at the sensitivity of the coefficients. Sensitivity analysis of the model results is vitally important, as when the optimal solution of a model is obtained, one is often interested in looking at the effects of changes in the objective and right-hand-side coefficients on this solution. One is interested in knowing in what way, if any, the optimal solution and the original problem is altered if a particular coefficient is altered. Often the data used has been crudely estimated as the actual values are unknown, and it is useful to know how sensitive the optimal solution is to changes in the input data. Most commercial linear programming packages have a RANGE facility which enables one to look at the limits (ranges) within which one of these coefficients can be changed to have a predicted effect on the solution.

Ranging is the name of the method to determine the limits. One usually looks at the ranges for the coefficients in the objective function or the right-hand-side (ie constraint specification), though it is possible to obtain ranges for other coefficients but usually such information is far less useful. Whatever range one is looking at, the principle is the same. For each of the variables in the final solution relating to the objective function for example, the original value defined is taken and then increased until there is a change of basis if any, and then starting from the original value decreased until a change of basis occurs again. This leads to information about the upper and lower limit on that variable examined, between which the optimal basis defined is true. At each limit the value of the objective function is given and details of the variable which enters the basis at that limit.

For example, in one situation explored, Max. TNPV, r = 3%, CST.ZERO, Common land and conservation areas restricted to their current form of land use, the variable livestock rearing - mostly sheep in land class 2 (hill tops) has an original estimated net present value of

£2.8 000s. Sensitivity analysis implies that if this return drops to £1.6 000s then land class 2 should be allocated to livestock rearing - cattle and sheep, as it would not be favourable to continue using this land class for sheep farming, and the optimal value of potential total NPV would decrease by only 0.3%. Ranging also gives extra information about the robustness of the solution as it suggests that the return can drop by approximately £1,000 before considering mixed cattle and sheep rearing as worthwhile in this particular land class. The accuracy of the coefficients may be questionable, and one must assess whether a drop of 44% in this example, is within the error limit expected. The upper limit of this variable is infinity and therefore increasing the return will not alter the optimal land use pattern suggested. One important difference between ranging an objective and right-hand-side coefficient (R H S) is that if one alters the R H S of a binding constraint within the defined limits, then all of the variables in the optimal solution and the objective value will change, whereas if a single objective coefficient is changed within the permitted range, then the optimal solution values of the variables will not change, although the optimal value of the objective may.

One limitation of this ranging process is that the interpretation of the effect on the objective of decreasing, or increasing any coefficient is only valid if one coefficient is changed at a time within the permitted ranges. Procedures do exist for examining more radical changes such as the situation when several variables are allowed to vary in different proportions at once, ie by parametric programming, but not all packages available (including that used in this study) possess such facilities. Discussion of each run is time consuming and a great deal of information is available. Many constraints are interlinked and when one tries to reason out the pattern of events, the situation becomes highly complex. This emphasises that linear programming problems are usually complex, and that is why a procedure is necessary to find the optimal solution though this is "optimal" in a restricted sense; "the optimum" of the model is the best only relative to that model.

8.3.2 Sensitivity of the land use model

Every problem explored by the land use model possesses its own conditions in which the optimal solution is true. Each problem involves a different set of constraints and variables, all of which are interlinked, which means that each variable will show a different degree of sensitivity according to the defined problem. Irrespective of the objective function, it appears that increasing the constraint specifications, making them tighter through requiring a minimum level of each production output considered in the model and labour input requirements, or restricting the land area available for change, causes the variables to exhibit a greater degree of sensitivity; the limits within which the coefficients must lie to achieve the defined optimal solution being small. In one situation, Max. TNPV, r = 3%, CST.CRT., Common land and conservation areas restricted to their current form of land use, the land classification system ie the number of squares available in each land class, was shown to be highly sensitive. Changes in any one of these R H S estimates of 1 - 5% was suggested as leading to a different optimal solution and land use pattern. This suggests that an error in overestimating the number of squares in any one land class by over 5% will lead to a different solution. Such an error is highly likely using the classification method in situations where there is a complex mixture of very different land classes, and one could not regard the suggested solution as being feasible. However, this result is one of a few isolated cases as in most of the other problems explored in the model, any change in the R H S coefficients of the land classification does not suggest changes in the optimal land use pattern, input and output values.

On investigating a wide range of problems looking at different constraint specifications and objectives, it was observed that each set of input coefficients has its own degree of sensitivity. There are extreme situations as shown above where one case explored suggests particular variables as being highly sensitive to changes, but in general each set of coefficients was shown to lie within similar ranges. The observed degree of sensitivity associated with each set of input coefficients is discussed below.

1. Economic coefficients

A high degree of uncertainty surrounds the agricultural economic variables as an error of over (+/-) 4% in the estimation of the coefficients is likely to lead to a change in the suggested land use allocations. This will cause a change in total production (input) levels and in the value of the optimal solution, though it was observed that the optimal solution only changes slightly.

The economic variables associated with forestry activities show a lower degree of uncertainty as the results from the model suggest that a high degree of variability is allowed in the co-efficients prior to any change in the suggested model solution. There appears to be a close relationship between the upper and lower middle slopes (land classes 1 and 3), as far as their use for private woodland is concerned. In many of the situations explored, if the economic value of private woodland on the lower middle slopes (P W 3) decreases by a small amount, only 1 or 2%, then there is a change in the optimal basis which brings private woodland on the upper middle slopes into the basis. This supports earlier observations of a linkage between these two land classes for afforestation, suggesting that on the whole the upper middle slopes are favoured for afforestation. From the results, it would be preferable to consider planting on the upper middle slopes (land class 1) initially, and look in further detail at the consequences and the associated risks of using the lower middle slopes for planting. The sensitivity analysis also suggests a close relationship between forestry and sheep farming activities in the upper land classes, particularly on the lower middle slopes (land class 3).

2. Timber production coefficients

The model coefficients defining potential timber production in each land class appear to be relatively insensitive. A 20% error in the estimation of the coefficients is suggested prior to any change in the optimal basis, though tightening the constraints by limiting land use on common land and in areas of ecological, historicaland amenity value has the effect of decreasing this error to +15%, suggesting a higher likelihood of a change in the basis. This suggests that using the timber production estimates based on more generalised information from the Forestry Commission (Edinburgh) (Section 8.2.3) as opposed to those based on field sampling (Forestry Commission (Kendal)), does not have an important effect on land allocation.

3. Beef production coefficients

The optimal solutions show a low degree of sensitivity to changes in the beef production coefficients. The results suggest that an error of 15 - 30% could be associated with the estimation of these coefficients before a change is likely in the optimal solution.

4. Sheep production coefficients

The coefficients relating to sheep meat production are important to the optimal solutions. The sensitivity analysis suggested that the optimal solutions are highly sensitive to only small changes in any one of these coefficients. Any one variable ie sheep meat production in any one land class, in any one category of land use, may change by only 2 - 7%, and this will lead to a change in the optimal solution. The lowland land classes, land classes 5 - 7, showed the highest degree of sensitivity to these coefficients.

5. Milk production coefficients

The optimal solutions are highly sensitive to changes in the estimation of potential milk production from each land class. Changes of less than 3% in the estimations will influence the results and the optimal solution defined will not be valid.

6. Labour requirements coefficients

Labour requirements to dairying activities was shown to be critical to the validity of the optimal solution. If the estimates are overestimated by anything from 1 - 8% according to the variable concerned, the optimal solution will not be valid. The change in the optimal solution indicated if the estimated requirement fell to the lower limit defined, is suggested as being a change from the allocation of specialist dairying activities to mainly dairying activities, mostly within the same land class concerned. The lowland land classes show the highest degree of sensitivity to changes.

Changes in the labour requirements to forestry up to a +25 - 30% error, has no influence on the optimal land allocation suggested. Defining labour requirements in land class 3, the lower middle slopes, is the most important. If this value is overestimated by approximately 25% then the model suggests that the area afforested in this land class will be limited to the area constrained, ie the existing forestry area, and it is likely that this land class will be suggested for sheep farming.

The ranging information supports the earlier observation that the actual method of estimating the input coefficients and the choice of data source needs careful consideration, and validating the coefficients is vitally important. The agricultural economic coefficients used in the land use model are extremely sensitive, together with the production estimations of both sheep and milk production. The accuracy of these coefficients needs to be scrutinised as a relatively low degree of error in estimating the coefficients could considerably influence the results.

Despite the high degree of sensitivity exhibited by most of the agricultural details in the model, there is the suggestion that the changes in the optimal basis at the upper and lower limit, ie which variable enters (or leaves) the basis at this limit, appear in general to be within those land use activities believed appropriate to that land class. In other words, the changes in the optimal basis at each limit fall in line with the general trends in land allocation identified from exploring a range of problems. The land use model is not able to provide the planners with the best land allocation and can only suggest general trends. This reduces slightly the influence of highly sensitive data as the land allocation trends suggested by the model are in line with the changes implied by the sensitivity analysis at the limits of each coefficient.

Chapter 9

THE DEVELOPMENT OF THE LAND USE MODELLING APPROACH

9.1 COMPARISON OF THE LAND USE MODELS DEFINED FOR THE SEDBERGH DISTRICT

The land use modelling approach has developed gradually, each successive model which has been defined exhibiting a greater degree of complexity and more accurate representation of reality. The land use model initially proposed (Bishop, 1978) illustrated the approach in a regional context and indicated the type of criteria which could be included in the model framework (Table 9.1). Subsequent models specific to the Sedbergh district were applied in a local planning context and the criteria investigated were believed to be more realistic to the situation being explored. The land use models applied to the Sedbergh district, ie that adopted in the study undertaken by Cumbria County Council and the current land use model described in this thesis, illustrate the development of the approach. The criteria included in each model framework differs (Table 9.1), the current model being more detailed, and this influences the suggested land use patterns. Both models have been used to explore the influence of similar restrictions ie total production requirements and land availability, on land allocation in the Sedbergh district.

The land use trends suggested by exploring a wide range of situations with the current land use model show slight differences to that suggested by the earlier model used in the Sedbergh Rural Land Use Study (SRLUS). To ensure that the optimisation programs were comparable, the model defined in the study by Cumbria County Council was taken (SRLUS) and the strategies explored were rerun at the University of Manchester Regional Computer Centre using the MPOS package. The results were the same as that suggested in the study undertaken by Cumbria County Council and the general land use allocation trend identified is shown in Table 6.6 (ii). The land allocations suggested by each model however, are not directly comparable. The current land use model is more complex, includes a wider range of constraints and the detail provided is more specific. Nevertheless, many of the factors considered in the first land use model (SRLUS) are included in the current land use model in one form or another.

Table 9.1 The development of the land use model

Criteria considered in each model	A. Initial land use model proposed in a regional context to Cumbria (Bishop, 1978)	B. Model defined in a local context to the Sedbergh district (Study undertaken by Cumbria County Council, R S Smith, 1980)	C. Current land use model defined in a local context to the Sedbergh district (R E Budd)
Number of land classes	16	7	7
Land use activities considered	1. Coniferous forest 2. Broadleaved forest 3. Dairy cattle and beef on improved pastures 4. Beef cattle 5. Sheep on improved pastures and crops 6. Sheep	1. Forestry, dairying, hill sheep. 2. Specialist dairying 3. Mainly dairying Livestock rearing: 4. Mostly cattle 5. Cattle and sheep 6. Mostly sheep	1. Private woodland 2. Specialist dairying 3. Mainly dairying Livestock rearing: 4. Mostly cattle 5. Cattle and sheep 6. Mostly sheep 7. Sheep on common land 8. Sheep on conservation areas

Table 9.1 continued

Criteria considered in each model	A. Initial land use model proposed in a regional context to Cumbria (Bishop, 1978)	B. Model defined in a local context to the Sedbergh district (Study undertaken by Cumbria County Council, R S Smith, 1980)	C. Current land use model defined in a local context to the Sedbergh district (R E Budd)
Outputs considered	1. Timber 2. Meat 3. Milk 4. Wool 5. Food energy 6. Recreational potential 7. Ecological value	1. Timber 2. Meat 3. Milk 4. Wool 5. Food energy	Primary outputs: 1. Timber 2. Beef meat 3. Sheep meat 4. Milk 5. Total net present value (TNPV) 6. Agricultural NPV 7. Forestry NPV Secondary outputs: 8. Wool 9. Food energy 10. Meat from dairy cattle
Inputs considered	1. Labour requirements 2. Energy consumption	1. Labour requirements	1. Total labour requirements 2. Agricultural labour requirements 3. Forestry labour requirements 4. Agricultural subsidies 5. Forestry subsidies

The first land use model used in the Sedbergh Rural Land Use Study, explored land allocation in the district associated with a defined strategy. It looked at the land use patterns, production and labour input levels suggested if this defined strategy was implemented. The strategy was derived from a series of strategies proposed by members of the Working Party Group associated with the study, which they would like to see implemented in this district. Common elements from each of the suggested strategies were combined into one strategy (Chapter 3). The current land use model has not been used to consider the effect of any one strategy on land allocation in the district, but considers land allocation in a broader sense looking at numerous situations and likely constraints.

The first land use model was adapted to consider the chosen strategy by changing various input coefficients and constraint specifications. The strategy was concerned with four main elements and the effect of these on the coefficients and constraints was defined and the input values adjusted accordingly. The basic elements incorporated in this strategy are:

1. The preservation of broadleaved tree species
2. The preservation of inbye land ie capability class 4 and 5, for agricultural activities
3. Common land and areas of value to nature conservation and the maintenance of the landscape were restricted to their current land use activities (this actual land area was excluded from the model ie the model is looking at the allocation of the remaining land area to different land uses)
4. To maintain current agricultural production from, and labour input to the Sedbergh district.

Each of these elements are to some extent expressed in the current land use model and in the problems which have been explored as shown below.

1. The current land use model does not consider any production from broadleaved woodland as this is seen as being of value to only general amenity, ie maintenance of the landscape and nature conservation.

2. One important difference between the coefficients used in the two land use models is that those used in the first land use model (SRLUS) defined as forestry are based on a mixed form of land use. The production coefficients were adjusted and inbye land which is regarded as belonging to capability class 4 and 5, was given to mainly dairying activities, and any unplanted areas of capability class 6 was given to hill sheep. In a limited sense this may be regarded as a mixed, integrated form of land use including forestry, mainly dairying and hill sheep (see Chapter 3 for full details).

   The current land use model takes no consideration of this assumption and each land class is devoted to one or more land uses, each of which is a series of different enterprises in different proportions as defined in the basic model. Any land use activity may be allocated to any land class (the model could be constrained to limit the use of particular land classes if required). Land classes 4 and 5 have the highest proportion of inbye land, and it is interesting to note that in all of the optimisations considered private woodland is not suggested in these land classes at all. Whatever the suggested land allocation, one must look in each land class for land which would be suitable for the suggested activities. Not every piece of land in each land class will be appropriate to the suggested land use. For example, inbye land will not be regarded as suitable for private woodland, and one must look at the remaining land in the given land class for areas where planting might be acceptable if forestry is suggested by the model.

3. Constraints restricting land use activities on common land and conservation areas may be included or excluded in the optimisations according to the situation being explored.

4. As associated with the third element, a constraint defining the minimum level of agricultural production and labour input may be included or excluded as required.

All of the above elements are expressed to some extent in both land use models, and each model has been used to look at suggested land allocations according to a range of objective functions. The current land use model is capable of considering a wider range of optimisations as the production details are expressed in greater detail, eg the model used in the County Council study looked at the optimisation of meat production, whereas the current land use model can look at the optimisation of beef or sheep meat production (Table 9.1).

The current land use model also differs from the early model because economic factors are taken into consideration and a crude time element is used. A greater number of constraints may be defined and adjusted in this model and a wider investigation of likely land use allocations is possible. For example, one constraint in the current model not considered in the previous model, states that the land which at present is under private woodland, will continue to be used for forestry during the time period considered by the model and can therefore, not be re-allocated to an alternative land use activity.

The land use allocations suggested by each land use model do show some similarities. Both models suggest that some degree of afforestation would be advantageous on the upper slopes, and it is likely that forestry activities will compete with sheep farming. It is also indicated that the best lowland areas ie land classes 4 and 5, are allocated to several land uses namely dairying and livestock rearing, as opposed to any one activity.

The earlier model (SRLUS) examining fewer variables suggests a far greater emphasis on afforestation in the district. The general trend in land use allocation according to this model (Table 6.6 (ii)) suggests using the upland areas (land class 1, 2 and 3) and the poorer lowland area (land class 7) for forestry, any inbye land being devoted to dairying. In most optimisations, a greater proportion of the total land area on the lower middle slopes (land class 3) is suggested as being used for forestry than on the upper middle slopes (land class 1), and all of the hill top area ie all of land class 2, is given to forestry. The suggested allocations indicate that forestry and sheep farming activities are appropriate on the same land classes.

This contrasts markedly with the current land use model where forestry is suggested on the upper slopes mostly (land class 1) and occasionally on the lower middle slopes (land class 3). No forestry is suggested on the hill tops due to the restriction on planting at a height of 1500 ft. This contrasts with the previous model which also limited planting in terms of altitude, which suggested using all of the hill top land for forestry. However, one must remember that forestry as a form of land use in the early model implied combined forestry, mainly dairying and hill sheep activities, and it is likely that only a small proportion of the hill tops would actually be planted.

Clearly all upland areas (land classes 1, 2 and 3) in the Sedbergh district offer potential land for forestry but great consideration must be given to the effect of these activities on other land uses in the district. Many factors such as limiting planting to below 1500 ft and restricting certain areas for landscape and nature conservation reasons will confine planting, but one must look at the remaining land in these land classes for areas that would be suitable for forestry. Where forestry is restricted, sheep farming is suggested by each model as being the 'best' use of these land classes.

The better lowland area (land classes 4 and 5) according to the first model (SRLUS) is given to both dairying and livestock rearing activities but land class 6 is suggested as being used solely for sheep farming. This pattern does bear similarities to suggested allocations according to the current land use model, but shows less diversity of land use activities in each land class.

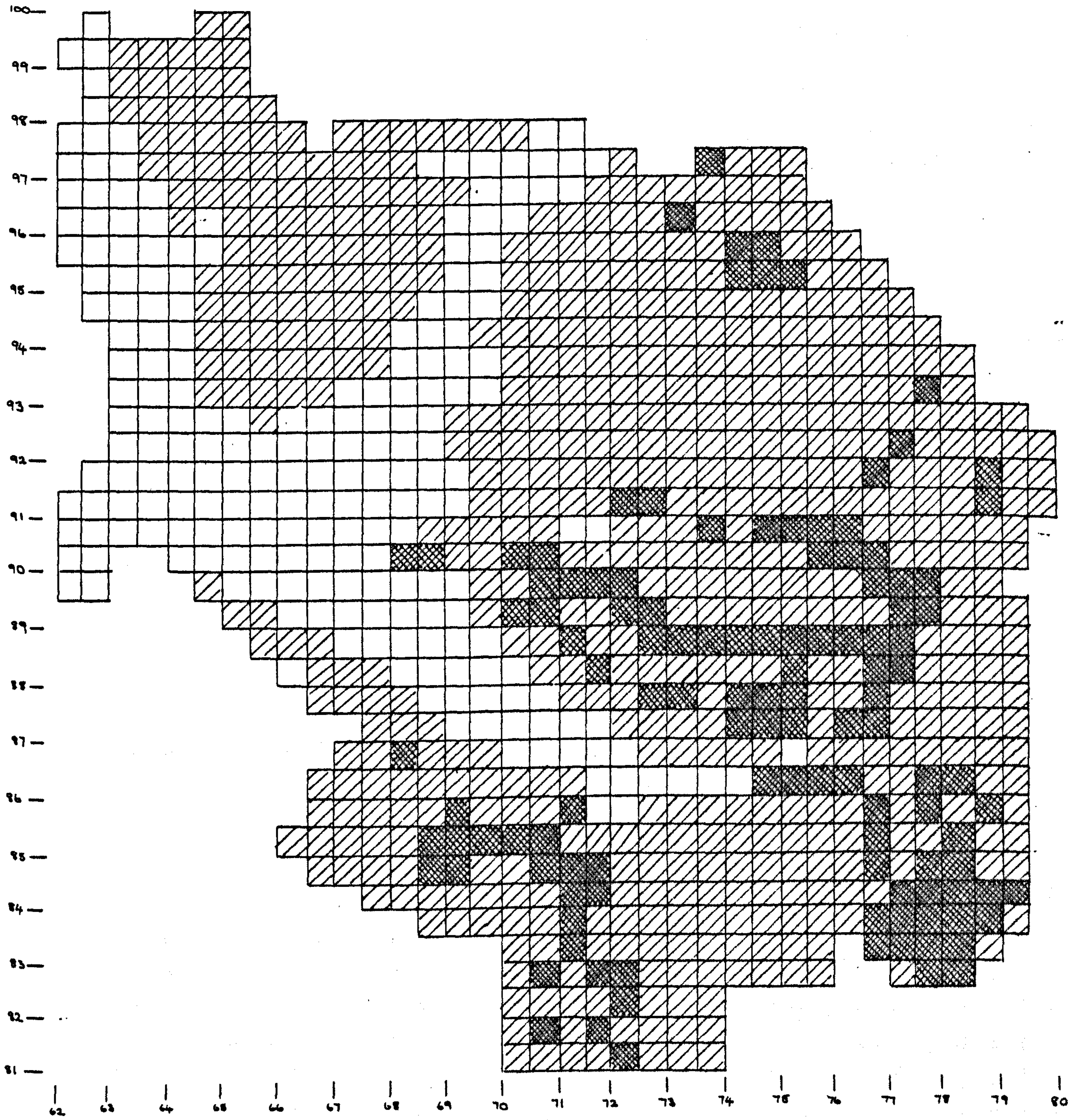
The emphasis of the previous land use model (SRLUS) to forestry is indicated in the suggested changes in total production levels. The most significant increase is shown in timber production where increases of approximately 20,000% are suggested. This increase is so high because it is assumed that there is little timber production from the district at present and an arbitrary value of 100 m^3/annum is taken. Many of the existing forestry areas are young in age and not contributing to timber production output, but the model assumes that one realises a certain level of timber production output per annum. If consideration is given to the current theoretical production level from existing forestry areas (ie estimated using the forestry production input coefficients) which is higher than 100 m^3, the percentage increase is reduced to levels suggested by the current land use model adopting a 3% discount rate. The production levels of the other forms of output considered in the first model (SRLUS) show no significant increase. Meat production is suggested as being approximately at the estimated level of current production apart from when optimising meat production when an increase of approximately 15% is suggested. According to the current land use model beef production shows a significant increase yet sheep meat production shows little change from current levels. If meat production was combined the increase suggested by the current model would be reduced but would probably be higher than that suggested in the first model.

A significant increase in total labour requirements is suggested by the original model (SRLUS), which is directly related to the suggested increase in timber production and the area planted. The levels are reduced slightly if some consideration is given to the theoretical level of labour required at present in existing forestry operations. However, the suggested levels are far higher than those suggested according to the current land use model. Nevertheless the suggested forestry labour input in the current land use model is high, and if the labour requirements in the previous model (SRLUS) were subdivided into that associated with agricultural activities or forestry, then it is highly likely that the increase suggested would virtually all be attributed to forestry, and that agricultural labour levels would show little change from current levels. Both land use models suggest a high level of labour input (indirectly an increase in the number employed in the district) associated with any land area used for forestry, and this leads one to question the validity of the input coefficients (Section 8.2.2).

The suggested land allocations, production and input levels from each land use model defined for the Sedbergh district do show similarities, though the current land use model suggests less emphasis on forestry. The differences in the results from each model are due to the different criteria considered; the current land use model being more realistic. It was observed that by taking a greater number of variables into consideration (many are still neglected) and a crude time element ie using the current land use model, a greater diversity in land uses is suggested for each land class.

The general trend in land allocation suggested by both models for the Sedbergh district is shown in Figure 9.1. This allocation involves some subjective assessment as the land use model is not able to suggest any spatial location of land uses. The upland areas are devoted to a combination of forestry and sheep rearing. The actual allocation to each land class spatially was based on information collected in the Sedbergh Rural Land Use Study on likely recreation, landscape and nature conservation restrictions within the district (Cumbria County Council, 1980, p.57). It was assumed that forestry would not be accecptable on the hill tops because of a planting height restriction, on common land, recognised conservation areas or on any land where land use activities are likely to be limited for recreation, landscape and nature conservation reasons. Any land in land classes 1 and 3 not affected by these restrictions was allocated to forestry. The remaining upland area including hill tops, ie land classes 1, 2 and 3 including common land, recognised conservation areas and other areas limited for recreation, landscape and nature conservation reasons was allocated to sheep rearing. The lowland area was suggested as being used for both dairying and livestock. Figure 9.1 merely suggests the land areas in which one might consider planting trees or rearing sheep. It is quite likely that many of the squares chosen cannot be used for the suggested use due to other factors such as land ownership, individual preferences or economic feasibility. The model considered every grid square as a separate entity ignoring economies of scale (Sections 7.2 and 8.1.1) but to try and plant small areas of forestry **may be infeasible in both economic and** practical terms. One must look at the land use allocation suggested by the model and then consider land in each land class which might be suitable for the suggested land use.

Figure 9.1 Suggested land use allocation in the Sedbergh district



Key:

Likely forestry areas

Likely sheep rearing areas, ie combination of enterprises in which approximately 63% are sheep enterprises, 19% beef and 18% dairy.

Likely dairying (specialist and mainly dairying activities) and livestock rearing (mostly cattle, and cattle and sheep) areas.

From an operational point of view, the model framework could be improved further by using a matrix generator ie a computer program that carries out the repetitive part of the construction of the model. The land use model has a definite structure, many of the constraints and variables being of a similar type, and by automating the repetitive part of the model construction one can concentrate on structural aspects. The advantages of using a matrix generator would be as follows:

(i) Data for the matrix generator can be presented in a more realistic form bearing the practical application in mind.

(ii) Repetitive aspects of the formulation can be automated by the program.

(iii) Formulative errors are less likely.

(iv) Modifications to the model with new data are more straightforward.

Similarly, it would be advantageous to look at the possibility of developing a multi-period model using both simulation and linear programming techniques, which would look at land use activities in the district over a period of time on a regular five-yearly basis. At each time interval considered decisions, based on investment criteria and other constraints on the system, would need to be taken on the choice of land use activities. This approach would allow one to build a more dynamic model which could take future trends into consideration. This would be more realistic, but at the same time the degree of complexity involved would increase, and one must carefully consider the desired balance between model complexity and realism.

9.2 USE OF THE LAND USE MODEL

The modelling approach which has been developed attempts to look at the problem of using different land areas for agricultural activities or forestry. It does not provide the answer for solving the conflicts between different land uses but looks at possible alternatives for solving or at least reducing this conflict. The statutory planning approach does not give much consideration to such conflicts. The local plan for the Sedbergh district does not recognise agricultural and forestry planning as a major issue (Section 1.1), and therefore does not attempt to propose planning strategies related to these activities. This is the result of political wrangles between different planning bodies, over the question of who is responsible for the planning of these activities. Agricultural and forestry issues are included in the Yorkshire Dales National Park Plan, (work has begun on the afforestation plan for the National Park) and it is argued that such issues are not a function of the County Council.

One must remember that the model only aims to assist planners in formulating strategies and does not consider what may be regarded as the second stage of the planning process, implementation. The land use model explores alternative strategies and suggests the effects of these different strategies on land allocation in the district and is able to provide information on the associated benefits. The model does not give one answer but makes a series of suggestions which must then be considered in the light of different planning aspects not considered in the model. Successful rural planning calls for the involvement of all those concerned with the use of rural land. The model is one means of initiating discussion between the interested parties but its use leads to questions as to who should take responsibility for using this approach, which in turn leads to questions concerning the organisational structure of those interested in rural land use.

Many groups and individuals have suggested administrative ways in which rural planning could be better integrated. Some argue for 'super' ministeries which are concerned with all rural activities. It has been suggested that a ministry could be newly conceived and for example take responsibility for environmental management (Conacher, 1980) or be an extension to some existing organisation such as the Ministry of Agriculture (Wibberley, 1976) or the Forestry Commission (Davidson and Wibberley, 1976, Centre for Agricultural Strategy, 1980). A more acceptable suggestion is the setting up of temporary or permanent coordinating committees of rural interests, whose members include senior officials of all interested existing organisations (Select Committee on Scottish Affairs, 1972). Whatever organisational structure exists it is essential to have frequent discussions between all those concerned with planning so that decisions can be based on the best available expertise.

The decision makers responsible for selecting the preferred planning strategy for the area concerned should make the most of available aids and approaches including the land use model. Having chosen the preferred planning strategy the planners must then consider how to implement this decision. Initially the strategy must be expressed on a spatial basis, and then questions asked as to the best mechanism by which this can be achieved.

The land use model only suggests general trends in land use allocation, and it is the responsibility of the decision makers to decide where changes should be attempted. Determining which land areas ie which squares in a particular land class, could be transferred to an alternative use is very difficult as it is influenced by many factors. The changes in land use desired may be only slight, and this might be achieved easily by trying to alter the management scheme or land allocation on one particular holding through offering sound advice and support. In other situations however, the individual land user may not be willing to change the use of his land, and one will not be able to achieve the planned allocation. In this situation one could rerun the land use model adjusting the format to take further constraints on land availability into consideration, and look at the new land use allocation suggested. When considering in which land areas one might be able to change land use the following criteria are likely to be important:

- land ownership
- the attitude of the owner/occupier to planners
- the current land use practise (the management system and the efficiency of operations)
- adjacent land use activities
- alternative uses of the land area concerned
- the degree of change anticipated; changes in resource requirements including capital cost
- likely future trends of that land area

Once an agreement has been reached on the type of land use changes desirable and the ideal location, the decision makers must consider how to achieve this. The separate planning organisations that exist at present, have little direct control over rural land use and a wide range of tools are used to direct land use. These include:

- advice and information, which is freely accessible and based on current research programmes
- financial support, eg guaranteed prices, grants, subsidies, compensation
- planning control which is largely preventative action on specific areas eg restrictions on building development
- voluntary agreements such as management agreements which can only be achieved through cooperation between the land user and planner
- public ownership
- legal sanctions

Different mechanisms will be appropriate in different situations, and research needs to be undertaken to look at the effectiveness of the different implementation mechanisms. It is likely that certain mechanisms are not effective and there may be a need to call for changes in the methods available. For example, it has often been suggested that private individuals should be encouraged to plant trees by offering measures to overcome the cash-flow problems of small landowners (Centre for Agricultural Strategy, 1980); Cameron, 1979).

The land use model is merely an aid to part of the planning process and is one of many different approaches which could be adopted to assist planning decisions. It offers the planner the opportunity to examine possible alternative strategies and their effect on the area concerned; it enables planners to concentrate more on questions of planning strategy, its impact on the area concerned and implementation, rather than on the technicalities of planning such as information collecting. It appears that the land use model is at present the only attempt to consider alternative uses of the land in this area, and such information is of immense value, even though the land use model only considers a limited number of activities. However, the value of the land use model depends on the awareness of the model user to the limitations and potential applications of the modelling approach as discussed in Chapter 8.

Chapter 10

CONCLUSIONS AND DISCUSSION

10.1 THE POTENTIAL OF THE MODEL FRAMEWORK

The land use model is of potential value as an aid to planning, particularly rural planning. It offers a framework in which different factors influencing a range of land use activities can be incorporated and investigated; the current land use model examines both physical production and economic factors. The model looking at different objectives can help in revealing the implications of conflicts that exist between the different organisations concerned with the use of land and act as a basis for coordinating planning thought.

Modelling rural land use involves the orderly and logical organisation of available data and information. This leads to a greater understanding of the rural planning system and the attitude of different interests. The land use model has the ability of examining the widest possible range of feasible solutions to the defined planning problem. The model structure enables one to examine a wide range of situations easily, looking at the consequences of possible planning policies from different organisations. Once a model has been defined, it can easily be used to review and reformulate policies as the planning circumstances in the area change. If, for example, a decision was made to move towards a particular land use distribution but it was realised that only 50 or 75% of the reallocation could be achieved, the model could easily be used to explore the production and economic value associated with this reallocation and look at the optimal use of the remaining land area.

Like all quantitative methods, the land use optimisation model aims to develop and process information and is not a subsititute for decision making. The model would enable decision makers to look less at the technicalities of planning and concentrate more on the important question of objectives and goals, policies, constraints and risks, which to date have been little considered. A wider application and development of modelling and quantitative methods in planning has been limited partly because of the difficulty of defining planning goals. This is a process at present considerably influenced by the political strength of vested interests, by changing views about conservation and the development of political goals and philosophies, and by individual personalities and attitudes towards future trends. Planning objectives need to be defined clearly, stating goals and criteria by which one measures success in attaining that goal, and not merely vague statements relying on intuitive processes. Clearer identification of objectives would enable one with the aid of the land use model, to investigate how more acceptable objectives could be achieved. It may be more realistic to define a different model framework that could examine land use allocation at regular time intervals such as five years as suggested in Chapter 9. However, the current land use model may prove to be preferable for regular use in planning because of its simple approach. The current model through analysing alternative planning strategies may be used as a basis to planning discussions, but to be successfully used, all users must understand the model and its potential applications and must be aware of the limitations of the model.

10.2 PROBLEMS ASSOCIATED WITH DATA REQUIREMENTS

The model has been shown to be highly dependent on the quality and availability of data (Section 8.2). There is an important need to locate further sources of data, particularly that which has been shown to exhibit a high degree of sensitivity in the model (ie agricultural economic coefficients) in order to validate the input coefficients. Having identified all available data sources and looked at their use, it is likely that further data collection would be advantageous to land use planning, and that the means of collating the information available needs to be changed into a form which will be of more use to a wider range of interests. Despite all of the economic information which is currently collected by various organisations, there is still little information on the economics of alternative land uses under specified management practises, on different types of land in different locations. In association with the identification of the nature of available data, there is a need to look at the land classification to ensure that available data can be related to the land class details defined. This would allow the classification to be widely used by different organisations without any difficulty of interpreting the information provided.

The numerous organisations concerned with rural land use play an important part in providing input to the land use model and with careful coordination, each will be able to provide expert advice on particular aspects of the model. It is highly likely that from an agricultural point of view, it may be preferable to change the land use activities considered in the model to make them more representative of the current farming systems in the district. This might be for example by modifying the details relating to beef enterprises, or even adopting the Scottish farm classification which is more applicable to hill and upland regions. Considerable controversy exists over the quantification (economically) of intangible variables but if an acceptable method of quantifying such values was developed, such variables could possibly be incorporated into the land use model along the lines of that suggested by Thampapillai et al (1979) (Section 8.1.2).

An indication of the degree of error and uncertainty associated with all inputs to the land use model is necessary. The degree of error associated with the model input ie the series of coefficients defined must be examined, and the coefficients must be scrutinised to ensure that the assessments are the best to date and representative of the real situation. Only by rigorous testing and exploration of the model can it be validated and improved.

10.3 LAND USE ALLOCATION IN THE SEDBERGH DISTRICT SUGGESTED BY THE LAND USE MODEL

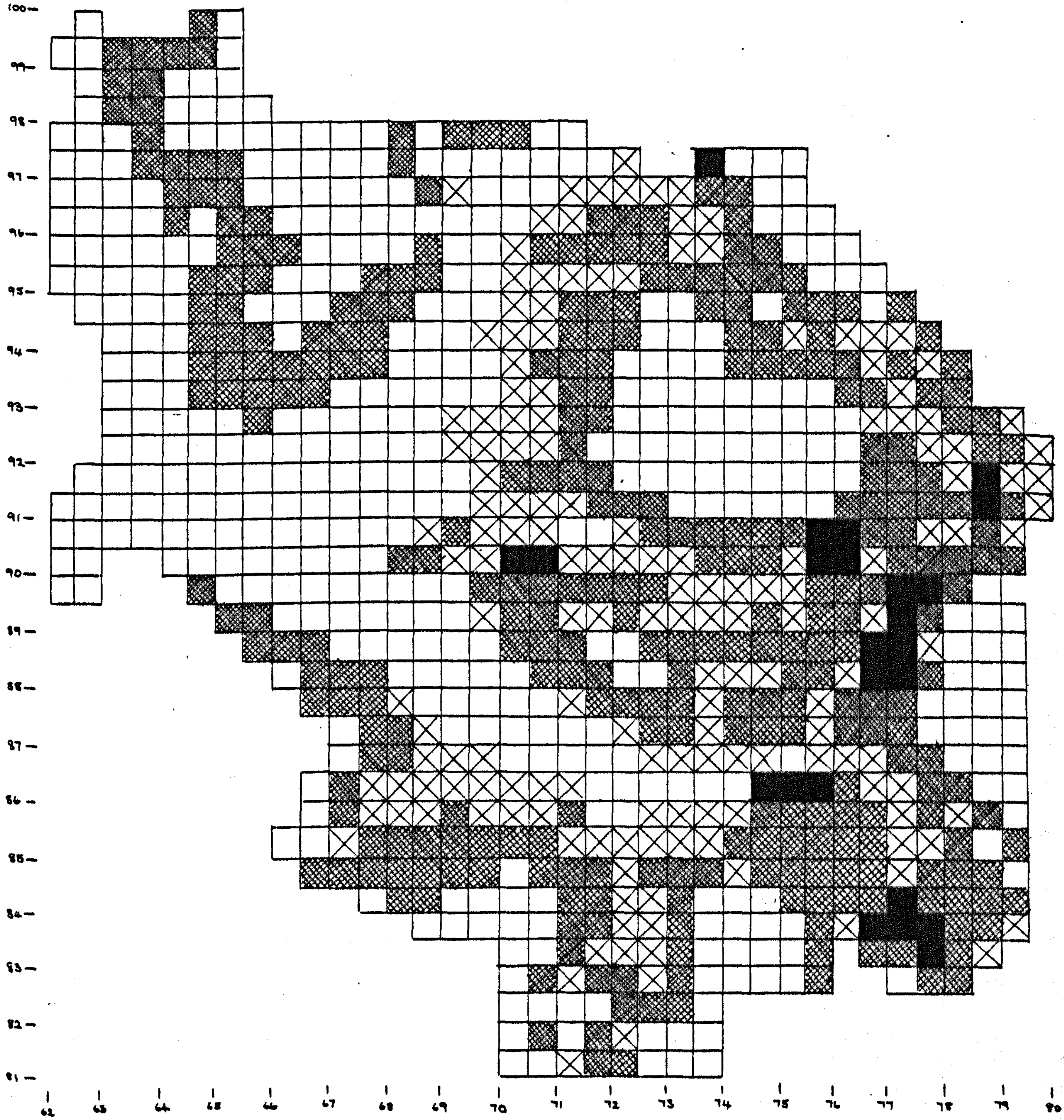
The model used to explore land allocation in the Sedbergh district (accepting the uncertainty surrounding the input data) suggested several common trends in land allocation. In all of the problems investigated it was observed that the model suggested less diversity in terms of land use activities within each land class compared to the current pattern of land use. The model suggested that the land area in the district could be more efficiently used by changing the current land use pattern so that beef production was increased, sheep production decreased and certain areas were used for afforestation. Maintaining current agricultural production, labour input levels, and common land, and recognising areas of high ecological, archaeological and landscape value reduces the potential increase in the economic value of production in the district. Therefore a high degree of change in land use would appear to be advantageous to the viability of the district (given the model assumptions).

Suggestions of changes in agricultural activities by the land use model are directly related to the economic data source and the nature of the problems investigated (Chapter 8), but they do indicate general trends and the type of results that the model can propose. Changing agricultural systems through the expansion of existing systems or changing the accepted management practise is limited and influenced by a considerable number of factors, such as technological changes, the transfer of knowledge, capital availability, and the motivation of individual farmers who are influenced by financial incentives and anticipated market trends. The model suggests expanding beef production in the district. This is technically possible but economic, structural and social problems are involved and could make this difficult to achieve. For example, the current instability of the cattle market and adverse cost/price relationships, has resulted in farmers losing confidence in cattle rearing and the number of cattle has declined over recent years. The future for cattle rearing is uncertain, particularly as the European Community is self-sufficient in beef and the sheep market, and therefore sheep rearing looks more attractive. The implication of any agricultural change must be considered from a wide point of view, both from the impact it could exert on other land use activities in the area, and the effect these changes could exert outside the district, such as on the livestock populations and farming systems in the lowlands.

Afforestation is suggested by the model only on the upper and lower middle slopes (land classes 1 and 3), much of which is currently designated as common land or recognised as being important for its ecological, historical or amenity value. The general trend indicated is to plant approximately 7% of the district if current agricultural production and labour input levels are to be maintained and 66% of the land area if there are no predetermined levels of agricultural production and labour input. The importance of forestry to Great Britain is recognised by many groups who are also aware of the many important issues associated with any afforestation scheme including for example, reduced dependence on imports, the relative profitability of wood growing, environmental aspects and the provision of rural employment. Increased timber production with due regard to non-market factors such as water gathering, wildlife and landscape conservation is suggested by the Centre for Agricultural Strategy in their report on forestry strategy in the United Kingdom (1980) and by the Forestry Commission. A group established by the Forestry Commission to explore wood production in Great Britain considered that "as long as the cost of land taken from agriculture does not rise markedly, the reasonable and prudent course ... is to maintain and increase the rate of planting." (Forestry Commission, 1977, p.64). Forestry is one alternative land use activity and some afforestation in the Sedbergh district, it is suggested, would lead to more efficient land use and would offer additional benefits to the area in terms of job opportunities and income, to Cumbria and to Britain.

Any forestry planting on the upper or lower middle slopes (Figure 10.1) needs to be carefully planned to occupy those areas which will have the least effect on the viability of farming units, and on the recreation and nature conservation potential of the district (Biggs, 1980). With careful siting, forestry may play a complementary role to farming by providing access roads, shelter belts and part-time employment for agricultural workers. If one accepts that the use of common land and conservation areas for forestry is unlikely in the foreseeable future, then the potential area where afforestation is likely is defined in Figure 10.2. All land which is classified as land class 1 and 3 is identified as being used for forestry, though the land use model suggested that only a small proportion of land class 3 be devoted to forestry, the majority of this land class being used for sheep rearing.

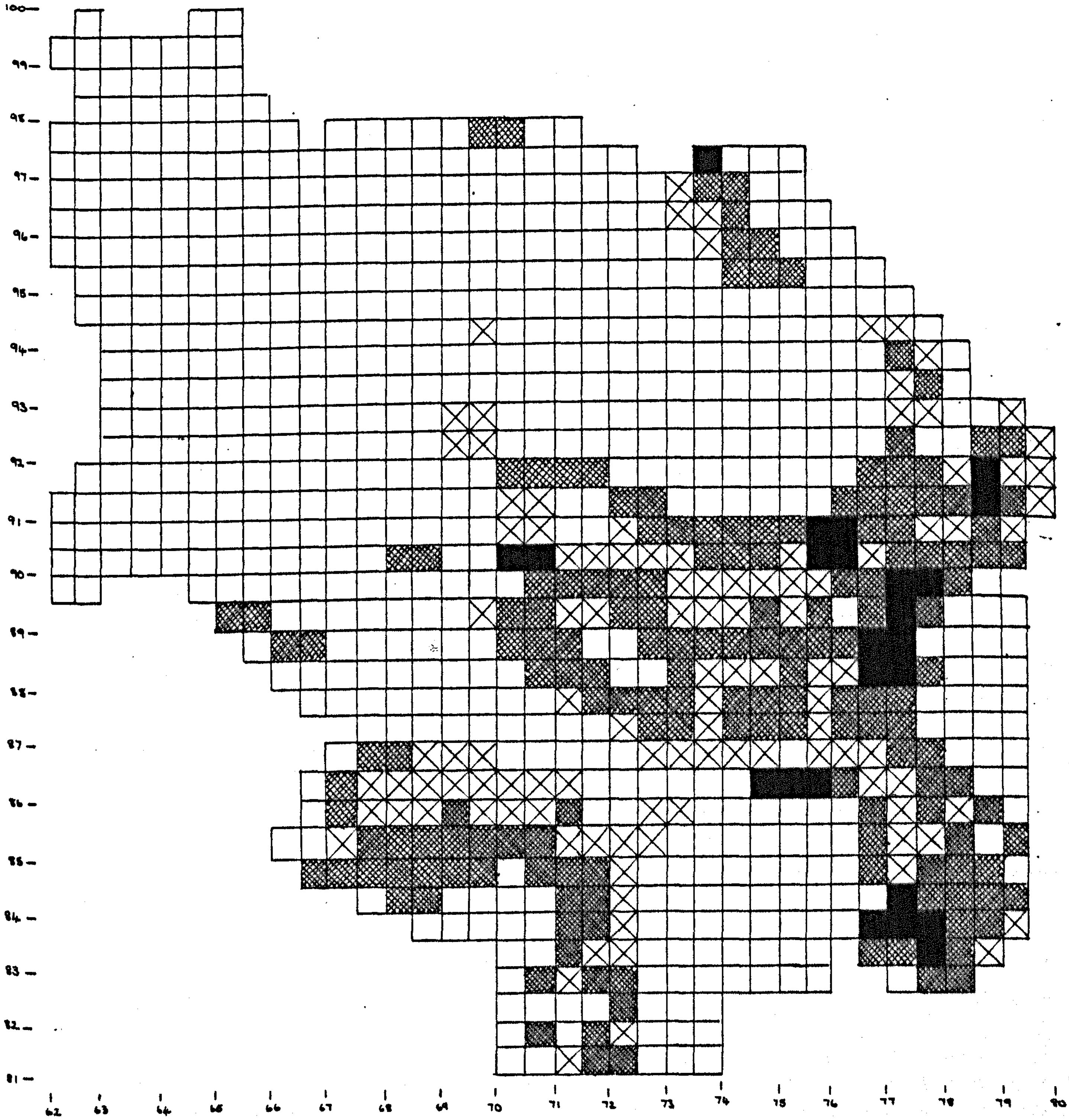
Figure 10.1 Potential forestry areas in the Sedbergh district assuming that all land is available for planting



Key:

- ■ Existing forestry areas
- ▒ Potential forestry area, land class 1
- ☒ Potential forestry area, land class 3.

Figure 10.2 Potential forestry areas in the Sedbergh district assuming no afforestation on common land or 'conservation' areas



Key:

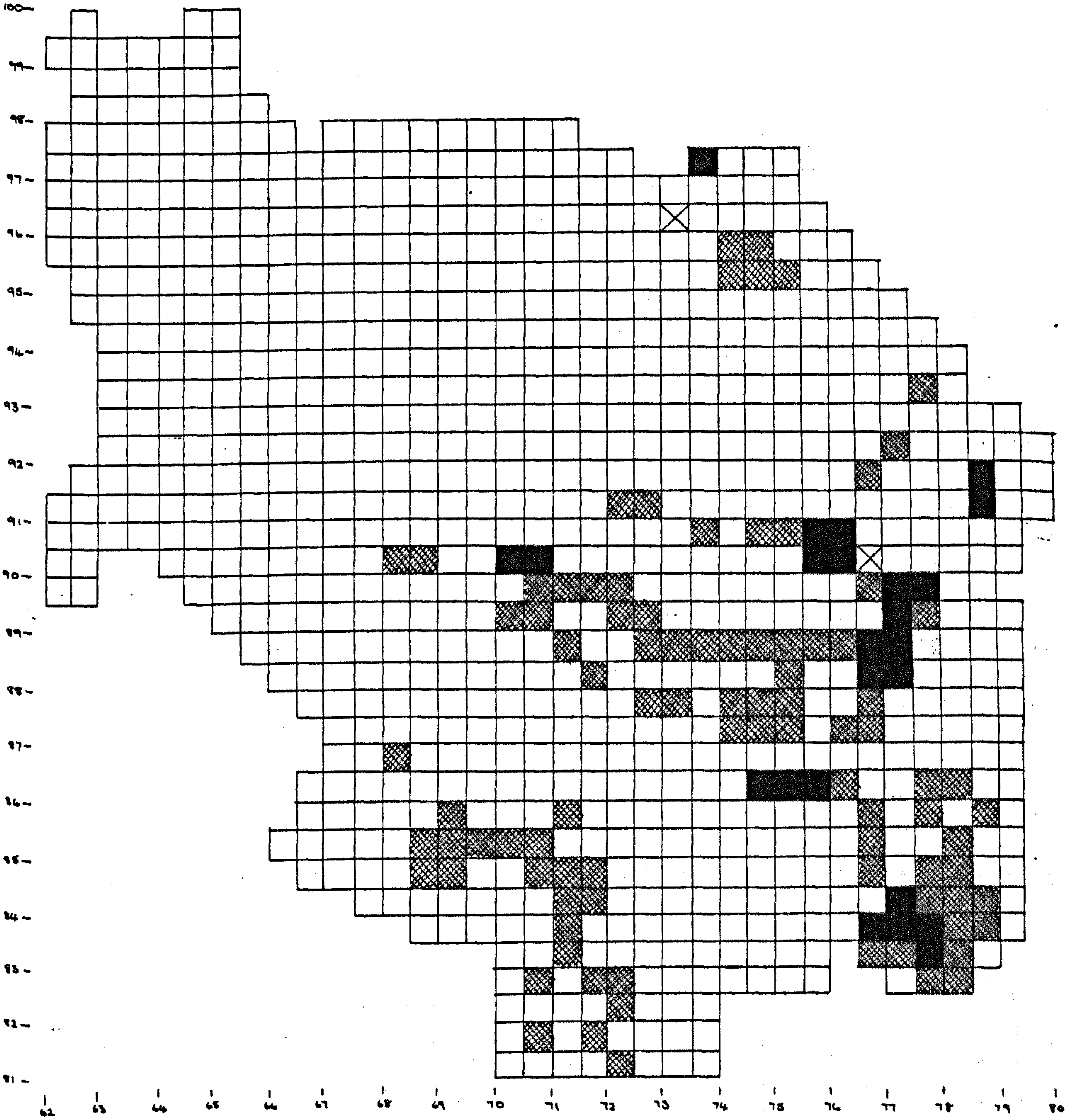
Existing forestry areas

Potential forestry area, land class 1)

Potential forestry area, land class 3)

Common land and conservation areas excluded.

Figure 10.3 Likely forestry areas in the Sedbergh district, assuming no afforestation on common land, 'conservation' areas or on land where land use activities are likely to be limited for recreation, landscape and nature conservation reasons



Key:

Existing forestry areas

Likely forestry area, land class 1)

Likely forestry area, land class 3)

Common land, conservation areas and any land area where land use activities are likely to be limited for recreation landscape and nature conservation reasons excluded.

The area likely to be available for afforestation is much reduced when one gives consideration to likely recreation, landscape and nature conservation limitations in the district (Cumbria County Council, 1980, p.57). Figure 10.3 shows the area where forestry is likely to be acceptable. The area of each of the upper land classes is reduced considerably by restricting planting on common land, conservation areas and on any land where land use activities are likely to be limited for recreation, landscape and nature conservation reasons. The area where forestry is likely in land class 1 is reduced to 59% of the total area available in that land class. Similarly, the area of land class 3 likely to be used for forestry is much reduced when considering these constraints (reduced to 3% of the area in land class 3 - two isolated grid squares). Only in this limited area (Figure 10.3) is forestry likely to be accepted as a form of land use by the interested parties and even in this area serious debate will arise concerning the actual size and design of the plantation and the species planted. Afforestation is restricted in National Parks as considerable attention is given to the landscape, and it is probable that this limited land area is the maximum land area likely to be used for forestry unless planning attitudes and government strategies change.

Land use changes suggested in the model and the associated benefits, will arise over a long term time period; in forestry this is because of the length of the rotation cycle, and in agriculture it is because of the long time lag associated with any change in farming systems, transferring knowledge and advising individuals on the benefits of land use activities. Integration of land uses, whether it be associated with livestock farming through mixed cattle and sheep grazing or with the controversial forestry and farming combination is not considered in the model; however with further research on this topic and information collection (Newton, J P, 1978), the integrated forestry/agriculture combination as a form of land use could possibly be considered within the model framework.

10.4 SUGGESTIONS FOR FURTHER RESEARCH

During the course of this study several issues were raised which could not be considered in this study but which are worthy of further research. The rural planning process is highly dependent on the organisational structure of existing planning organisations, their efficiency and degree of control over land use. A detailed study of the structural organisation of the rural planning system would be useful as this might lead to suggestions of changes in the present process which could significantly improve rural planning. Planning conflicts have been extensively investigated but few studies have been undertaken to assess the best means of reducing or controlling these conflicts. The current mechanisms used may be highly inefficient and inappropriate in particular circumstances (Section 9.2) and further study may indicate more acceptable ways of controlling land use.

The land use model discussed in this thesis has numerous limitations due to its wide-sweeping assumptions. It would be advantageous to look at how the model might be improved further in terms of both the model structure and the data input. The existing model framework could be improved by either adjusting the structure to consider additional land uses such as the integrated farming/forestry combination or to incorporate intangible variables (Section 8.1.2), or by defining a different framework such as a multi-time period model (Section 9.1). The problem of quantifying intangible variables is a subject of continual research but if an acceptable method could be derived and these variables incorporated into the land use model, additional information would be obtainable from the model which would be most useful to planners.

Despite the vast amount of information collected on a regular basis, there is a lack of statistics especially economic information, relating to different land use activities in different land areas and under different management schemes; particularly information relating to common land. Many studies have considered the historical and legal problems associated with common land and looked at the agricultural potential of such areas but little attention has yet been given to financial aspects of common land areas. A great deal of information is used in routine planning operations and an inventory similar to that produced by the Working Party on Rural Land Use Information Systems in Scotland (Scottish Development Department, 1977) indicating the sources and details of available data would be useful for both planners and researchers. If such an inventory was produced, this might help to identify areas where further information collection is desirable.

The land use model can only be of assistance to a small part of the planning process and further work is needed to look at the feasibility of using other planning methods, adopted in different disciplines, in rural planning. A planning method would be useful that could look at the factors influencing the spatial location of the land use allocations suggested by the current land use model. There is also a need to look at the use of the land use model approach in other fields of planning such as at a farm level where the idea of classifying the land area on a grid basis could be combined with existing models. The land use modelling approach needs to be related to the planning methods currently being used and to the existing organisational structure of rural planning. One needs to determine how the model and the information generated could best be used in planning, at what stage and by whom, which leads to further questions on the organisational structure of the existing planning organisations.

10.5 USE OF THE LAND USE MODEL IN PLANNING

The model is not, and never will be the 'truth', even if perfect data was available, as no one is willing to accept all of the assumptions made within the model framework as being the correct representation of reality. The model merely offers an aid to part of the planning process (strategy formulation) which will produce consistent results and can readily be used for reviewing and reformulating problems. It does not lead to one solution, nor does it give a detailed spatial allocation of land use, but suggests a number of feasible solutions. These solutions need to be considered in the light of other planning aspects not considered by the model through discussions by all of those concerned with the use of land, who are experts in their own field of interest. The wider implications of any results from the model must be investigated and discussed using appropriate aids where necessary. The political and aesthetic constraints to land use which reflect the nature of society's desires may turn out to be more important than any of the attributes determining the physical output from the land which are incorporated in the land use model.

Consideration of the actual implementation and use of the land use model leads to questions regarding who should take the responsibility for coordinating rural planning (Section 9.2). There is at present no one organisation which has the resources to handle such a task. Coordination of rural planning would involve using a range of planning methods and approaches, and this could initially involve considerable time and cost. For example, to adopt the modelling approach discussed in this thesis would initially involve considerable cost in terms of time and manpower, to understand, define and use the model, but once defined the model would be readily available for further discussions on the area concerned.

The Working Party associated with the research and development of the land use model discussed is aware of this potential planning approach, but the question remains as to whether, given the current land use model, those concerned will be willing to accept the approach as a useful aid to planning in rural areas. Integrated land use has been discussed considerably and is practised in a limited sense. The land use modelling approach offers one possible aid to integrated land use planning, and with further developments in the quality of the data input could be a practical possibility.

Appendix I

THE LAND CLASSIFICATION

Al 1 The land classification system

The land classification used was that devised by the Institute of Terrestrial Ecology, which is based on physical characteristics of the area concerned using data extracted from available maps. The method is based on the principle that 'the complex of features which interact together to produce a given land class are reflected in observable characters present on Ordnance Survey maps'. The squares of the National Grid were used as units for classification, providing an unbiased method of survey; a scale of 0.5 x 0.5 km was used (¼ square kilometres). Data extracted from the Ordnance Survey maps was analysed to determine the main sources of variation and to group the squares into classes with similar characteristics. Details of the classification are given in the publication 'An Ecological Survey of Cumbria: Structure Plan Working Paper No. 4' by Bunce, R G H and Smith, R S (1978), published by Cumbria County Council, Lake District Special Planning Board, and the Institute of Terrestrial Ecology.

Originally sixteen land classes were defined in the Sedbergh district (Cumbria County Council, 1980) but there were later reduced to seven land classes using principal component analysis, as many were shown to be identical in terms of production potential. The original land classes were grouped as follows:

Land Class Group	Original Land Classes defined
1	1, 2, 3, 4, 9, 12
2	5, 6, 7, 8
3	10, 11
4	13
5	14
6	15
7	16

A1 2 Description of the land classes defined in the Sedbergh district

A brief description of each land class group is given below, each of the original land classes being defined.

(All the land classes referred to in this thesis refer to the land class groups).

LAND CLASS GROUP 1

Land Class Group of upper and lower middle slopes, centring around the 351 metre contour, ie around and above 1150 feet. There is no distinct altitudinal boundary between land classes 1 - 4 and 9 - 12, reflecting the variability of the middle slopes of these fells and a variety of factors are of importance in distinguishing between the classes.

Land Class 1:

Occurs on land above 351 metres in elevation, the highest contour being between 351 - 517 metres, giving low gradients along the slope lines. It is situated close to a hill or outcrop between 421 - 577 metres in height. Little land above 488 metres is encompassed in this class, and there tends to be many stream forks, few paths and no settlements. There is a tendency for the land class to face north or south, hence Ayegill Pike, one of the smaller fells running east to west in between Garsdale and Dentdale, is clearly picked out. Approximately one quarter of this land class is rush infested, with a wide range of vegetation types occurring at low frequencies.

Land Class 2:

Usually occurs on land above 351 metres in elevation, although the highest contour is generally 518 metres or above. It has fairly high gradients along the generally long slope lines. It is often situated a short distance from a hill or outcrop of more than 578 metres in height. There are no settlements. Matgrass predominates, with some stands of bracken and areas of rushes being widespread.

Land Class 3:

Contains land above 351 metres with a highest contour of 351 - 517 metres, but with low gradients. Very little land occurs above 488 metres, though the land class tends to be fairly near to a hill or rise more than 578 metres in height. Generally a southern class, most of it occurring south of Dentdale, and it is absent from the Howgills. It contains a high proportion of rushes and cotton-grass and is generally very wet. The blanket peat begins to give way to mineral soils in the lower regions.

Land Class 4:

This class also contains land above 351 metres with a highest contour within the 351 - 517 metre range, giving fairly low gradients. It is situated fairly close to a hill of 578 metres or above, and has a tendency to be relatively near a valley bottom. It has an east/west trend that shows as well defined groups along the west sides of Baugh Fell and Widdale Fell. Around 50% of the land class consists of blanket bog.

Land Class 9:

Includes land above 351 metres with a highest contour in the range 351 - 517 metres, but with only one sample plot having any land above 488 metres. The distance from a hill or rise of 421 - 578 metres elevation, is usually large. There are few roads and wooded areas, and it is generally positioned relatively near a metalled road. This land class is infrequent in the Howgills and contains vegetation types with lowland affinities. More than half of the land class contains damp permanent pastures, with hay meadows on the gentle gradients.

Land Class 12:

This, the most frequent land class in the district, has a highest contour of 351 - 518 metres and a wide range of gradients on predominantly short slope lines. There is very little land above 488 metres or below 198 metres. It lies relatively near a valley bottom, stream lengths tending to be low. However, it contains rough grazing heath and there are few 'lowland type' pastures; coniferous afforestation occupying one-third of the land class.

LAND CLASS GROUP 2

Land Class Group of upper slopes over 488 metres, ie over 1600 feet, with moorland vegetation, upland grassland and bogs, though in better drained areas drier grassland occurs which may be grazed.

Land Class 5:

High level slopes and summits above 488 metres elevation. Usually found on the Millstone grit 'caps' on the rounded fells in the south and east of the district. The class does not occur on Silurian strata and is consequently absent from the Howgill area. This class has long slope lines and gentle gradients. 80% of the vegetation is species-poor acidic upland moorland, often with a cover of bilberry, or at a high level, eroding blanket peat.

Land Class 6:

High level slopes and summits above 488 metres. Very similar to land class 5 in distribution, although it tends to occur on the actual slopes lines and has a lower gradient than land class 5. This class is absent from Silurian strata and is dominated by the same vegetation types as in land class 5.

Land Class 7:

High level slopes and summits; this land class lying mostly above 488 metres. In the Howgills this land class is at a higher elevation than land class 8 and includes the summits of the fells. Elsewhere, no summits fall into this land class, and its distribution is limited to the steeper slopes, but again at a higher elevation than land class 8. Upland grassland and blanket bogs predominate.

Land Class 8:

High level slopes; the majority of squares in this land class have the 488 metre contour line running through them. It occurs mainly on the steeper escarpments of the other fells. The steeper slopes mean better drainage with drier upland grasslands and overgrazed acidic grassland predominating.

LAND CLASS GROUP 3

Land Class Group encompassing settlements and means of communication, lying mainly between 184 - 528 metres, ie between 604 - 1700 feet with gentle slopes. Wide range of vegetation types but many improved grasslands used for grazing.

Land Class 10:

This has the highest incidence of roads and buildings in the lower middle slopes group. It tends to occur nearer the valley bottom than land classes 9, 11 and 12. The highest contours occur in the 184 - 518 metres and the gradients are fairly gentle. In contrast to land class 11, there is a bias towards the gentle slopes of low level land, and approximately one-third of the land class contains some wooded areas and 40% of the area contains well maintained pasture and hay meadows. There is also a tendency for it to face west.

Land Class 11:

This is the second most frequent land class but it is absent from Silurian strata being predominantly on Carboniferous rocks and is therefore scarce in the Howgills. The highest contours range from 184 - 518 metres and the gradients are fairly gentle. This land class generally contains more settlements than land class 12. Accessibility is fairly good, with 90% of it being within 2 km of a metalled road. The land class preferentially faces north and south. It contains a very wide range of vegetation types, indicating a complex environment at the local scale.

LAND CLASS GROUP 4

Land Class 13:

This land class contains no land above 184 metres and is the only land class to contain land below 76 metres. It occurs on Silurian strata and has alluvial soils, and contains the town of Sedbergh and most of the adjacent land. Gradients are low and the land class contains approximately half the woodland in the whole district.

Accessibility is good since there are many roads and tracks. 60% of the vegetation is meadowland with no upland vegetation types represented.

LAND CLASS GROUP 5

Land Class 14:

This occurs along the flood plain bordering the River Dee. It contains a high proportion of buildings, including the villages of Dent and Gawthrop. The highest contour ranges from 76 to 350 metres, with gentle gradients down the long slope lines. 75% of this land class is intensively maintained grassland (let and hay meadow) with no upland vegetation types.

LAND CLASS GROUP 6

Land Class 15:

This contains no land above 488 metres or below 76 metres; roughly 55 - 79% of the land class falls within the 76 - 198 metre range. The distance to a hill or rise is small. There are few wooded areas and no alluvial soils. There is a high proportion of meadow land with some mineral rich flushes occurring at the higher levels.

LAND CLASS GROUP 7

Land Class 16:

This contains relatively few settlements for a lowland class. Highest contours are no more than 350 metres, and it generally occurs at a higher elevation than the rest of the lowland classes. Together with land class 14 it contains a high proportion of wooded areas and accessibility is good, being mostly within 1 km of a road. It is primarily found on the west side of the Howgills, along the Rawthey and Dee valleys, but not in Garsdale. It occurs at the bottom of the fells but above the flat valley bottoms and contains a high proportion of overgrazed acidic grassland. This land class exhibits strong affinity with the marginal classes, ie land class group 3.

Appendix 2

MODEL INPUT COEFFICIENTS

A2 1 Production Coefficients

A2 1.1 Agricultural Production Coefficients

The agricultural production figures are taken from the study by Cumbria County Council, 1980. The figures (A2, Table 1) give the production of each form of output per annum, from 25 ha of each land class under each type of farming category. For example, beef production from 25 ha of land class 1 devoted to livestock rearing - mostly cattle, is estimated to be 217 kg per annum.

The production estimates are based on the potential number of Grazing Livestock Units (GLUs) in each land class. The number of GLUs in each land class is determined by the land capability within each class and the most common form of land usage. The capability of the land within each land class was estimated from a series of surveys (vegetation, nature conservation, soil and agricultural capability surveys) undertaken for Cumbria County Council in connection with the preparation of the local plan for the district. Each land class therefore contains land of different capability, eg land class 7 contains land of which 12% is capability class 4, 70% capability class 5, 18% capability class 6, and 0% capability class 7. Assuming land of each capability was only suitable for that use which is most likely today eg land of capability class 4 is only suitable for dairy farming, enabled a stocking rate per hectare to be calculated, and given the livestock equivalents to GLUs plus a consideration for unproductive areas, an estimate of the number of potential GLUs in each land class was made.

Conversion from the number of GLUs per land class to estimates of the level of each form of output in each land class, were based on assumptions of practised farm management systems and expected yield/output levels in the Sedbergh district. Each type of farming runs a combination of enterprises in different proportions

Appendix 2, Table 1 Agricultural Production Coefficients

(i) Beef Meat Production - kg per annum per 25 ha

Land Class	Land Use							
	PW	SD	MD	C	CS	S	KS	PS
1				217	144	63		
2				43	29	12		
3				590	393	170		
4				6280	4187	1815		
5				4406	2937	1273		
6				3807	2538	1100		
7				1990	1327	575		

(ii) Sheep Meat Production - kg per annum per 25 ha

Land Class	Land Use							
	PW	SD	MD	C	CS	S	KS	PS
1		48	131	106	184	225	107	107
2		29	79	64	111	136	62	62
3		75	203	164	285	349	174	174
4		270	735	592	1032	1263	655	655
5		218	593	477	831	1018	528	528
6		182	496	399	695	851	441	441
7		142	387	312	543	666	343	343

(iii) Milk Production - 000s kg per annum per 25 ha

Land Class	Land Use							
	PW	SD	MD	C	CS	S	KS	PS
1		6.0	4.4	0.4	0.4	1.3		
2		1.3	0.9	0.1	0.1	0.3		
3		16.4	12.0	1.0	1.0	3.5		
4		95.0	69.7	5.7	5.7	20.2		
5		73.7	54.1	4.4	4.4	15.7		
6		59.3	43.5	3.6	3.6	12.6		
7		43.3	31.8	2.6	2.6	9.2		

Appendix 2, Table 1 continued

(iv) Dairy Meat Production - kg per annum per 25 ha

Land Class	Land Use							
	PW	SD	MD	C	CS	S	KS	PS
1		86	63	5	5	18		
2		18	13	3	3	4		
3		236	173	14	14	50		
4		1174	861	71	71	250		
5		943	692	57	57	200		
6		785	576	47	47	167		
7		595	436	36	36	126		

(v) Wool Production - kg per annum per 25 ha

Land Class	Land Use							
	PW	SD	MD	C	CS	S	KS	PS
1		9	24	20	34	42	60	60
2		5	13	11	19	23	35	35
3		16	42	34	59	72	98	98
4		61	167	134	234	286	370	370
5		49	134	108	188	231	298	298
6		42	112	90	157	192	249	249
7		32	87	70	122	149	194	194

(vi) Food Energy Production - Giga joules (GJ) per annum per 25 ha

Land Class	Land Use							
	PW	SD	MD	C	CS	S	KS	PS
1		18	14	5	5	7	1	1
2		4	4	2	2	3	1	1
3		48	37	11	11	16	2	2
4		274	208	88	72	92	8	8
5		213	162	64	53	71	7	7
6		172	130	54	45	58	6	6
7		126	96	32	28	41	4	4

Key: As given in Table 5.1

leading to a range of outputs - milk, meat either beef, sheep, or from culled dairy beasts, and wool. The potential level of each form of output, from each type of farming, in each land class was estimated, assuming the range of outputs was related to the combination of enterprises undertaken in each type of farming (A2, Table 2).

Appendix 2, Table 2 Land use and livestock characteristics by farm type*

Type of farming category	Production		
	Milk	Beef	Sheep
Specialist dairying	87	-	13
Mainly dairying	64	-	37
Livestock rearing:			
mostly cattle	5	65	29
cattle and sheep	5	44	51
mostly sheep	18	19	63

* Proportions (%) are based on GLU assessments.

A2 1.1.1 Common land and conservation areas

Common land and conservation areas, ie areas of high ecological, historical and amenity importance are regarded as land areas in which land use will not change as long as current legislation and attitudes prevail. If common land does not exist and conservation areas are not recognised, the production of such areas under any land use activity is expected to be equal to that defined per land class. Sheep grazing is the main use of common land and conservation areas at present, and although sheep could belong to any type of farming category, such areas are regarded as being devoted to sheep farming. The output of meat and wool from these areas is related to the estimated output from hill flocks per GLU.

A2 1.1.2 Assumptions

1. Initial surveys assessing land capability realistic.
2. Each land capability class is used for what is at present the most common/likely usage and therefore stocking rates are realistic.
3. 15% of each land class area ie of each 25 ha, is non-productive due to buildings, roads and boundaries.
4. GLU equivalents acceptable.
5. Enterprise combination representative for each type of farming in the district.
6. Management systems adopted in the calculations are acceptable and the figures realistic to the Sedbergh district.
7. Common land and conservation areas are devoted to sheep farming, ie livestock rearing - mostly sheep.
8. Farms rearing mostly sheep have sufficient facilities to cater for those animals grazing on common land and conservation areas.

A2 1.1.3 Data sources

1. Survey reports prepared by different organisations for Cumbria County Council in connection with the preparation of the local plan for the Sedbergh district. The surveys undertaken were as follows:
   - soil and agricultural land capability survey
   - forestry capability survey
   - vegetation and nature conservation survey
2. The Sedbergh Rural Land Use Study Report prepared by Cumbria County Council, 1980.
3. Nix J, Farm Management Pocket Book (9th edition), 1978.

A2 1.2 Forestry Production Coefficients

Forestry production is expressed in terms of cubic metres per annum per land class and was estimated by the Forestry Commission (Kendal) for the Cumbria County Council Study (1980). Each land class was assessed in terms of the best species to plant and over what area, using a sampling approach (14% sample). Using

Forestry Commission guidelines, the height limit was taken as 1000 - 1500 ft (304 - 457 m) according to location, and the species planted including Sitka Spruce, Lodgepole Pine, Norway Spruce, Douglas Fir, Larch, Scots Pine and Broadleaved species were assessed according to soil and vegetation type and altitude. Yield classes were estimated from published data and consideration was given to the success of existing plantations. A 15% allowance was made for non-productive areas ie roads and buildings.

The Headquarters of the Forestry Commission (Edinburgh) who provided the financial data, regarded the production figures estimated by Kendal too detailed to be of use in considering financial returns as it would involve an unmanageable volume of data. For this reason the Forestry Commission (Edinburgh) provided production and financial details relating to single species stands of Sitka Spruce on different soil types and at different altitudes, which were related to each land class. Although of a more general nature, these production figures were adopted (Chapter 8) because of their relationship to the financial details used in the model (A2, Table 3).

Appendix 2, Table 3 <u>Forestry Production Coefficients</u>
(Production expressed in m^3 per annum per 25 ha)

(i) SRLUS* coefficients based on survey information from Forestry Commission (Kendal)

Land Class	Land Use					
	F	SD	MD	C	CS	S
1	154	1	1	1	1	1
2	15	-	-	-	-	-
3	186	2	2	2	2	2
4	173	2	2	2	2	2
5	206	3	3	3	3	3
6	208	4	4	4	4	4
7	218	5	5	5	5	5

(ii) Coefficients based on information from Forestry Commission (Edinburgh)

Land Class	Land Use
	PW
1	174
2	17
3	239
4	142
5	142
6	304
7	271

* SRLUS represents the Sedbergh Rural Land Use Study undertaken by Cumbria County Council (1980)

Key: As given in Table 8.7

Only a small land unit is being considered (25 ha), and therefore the accuracy of assessing production yield in each unit, ie the species planted and yield class, is questionable, particularly as the land within each land class belongs to a range of capability classes, and each land class brings together a range of soil types and elevation zones which are not recognised as being standard by the Forestry Commission. The actual production of timber may be lower than that used as input to the model (Forestry Commission, Edinburgh) due to the range of species more likely to be planted with landscape and nature conservation in mind. Also, the economic return might be lower because of the difficulties in managing small units of highly mixed stands. Forestry production estimates are expressed in terms of cubic metres per annum. This assumes that the area of afforestation is of a sufficient size and age range to give a regular yield per annum. Some degree of error arises because although a large part of the existing forest area is "self-sufficient" ie of mixed aged stand giving regular output, new plantings will increase in yield per annum but timber output will only be attained from thinning operations undertaken approximately 25 years after planting, and clear felling at the end of the rotation cycle, approximately 50 years after planting.

A2 1.2.1 Assumptions

1. Forestry planting height limit taken as 1000 - 1500 ft.
2. Surveys of land capability and soil type realistic.
3. Forestry Commission principles and approach to afforestation adopted.
4. Relationship defined between species, soil and yield class and the land classification acceptable, and not over-generalised.
5. 15% non-productive area due to buildings, road and boundaries.
6. Sitka Spruce details representative of any new plantings (Forestry Commission, Edinburgh figures).
7. Acceptable to define production per annum despite the time lag associated with timber production; assume existing forest area is a mixed age stand giving regular output.

A2 1.2.2 Data sources

1. The Sedbergh Rural Land Use Study Report - survey details.
2. Forestry Commission (Kendal) - Published data and field estimations.
3. Forestry Commission (Edinburgh - Published data and information from the Sedbergh Rural Land Use Study (Cumbria County Council, 1980).

A2 2 Economic coefficients

A2 2.1 Agricultural Economic Coefficients

The agricultural economic coefficients assess for each farming activity in each land class, the potential contribution to fixed costs of that area of land ie the potential 'gross margin' (GM) of each land class under each land use activity. Owing to the need for comparison with forestry activities which have a rotational cycle of 50 years, the economic coefficients are discounted over a 50 year time period and expressed in terms of the net present value (NPV) of potential 'gross margins'.

Price estimations per unit of output are very difficult to define due to the wide fluctuations in prices throughout the year and the variability in the quality and type of output being considered. Production from each land use activity is expressed in general terms, and therefore one can only attempt to define a generalised feasible price relationship. All of the economic values are based on 1977/78 market prices (A2, Table 4) and production figures are taken from the Sedbergh Rural Land Use Study (Cumbria County Council, 1980). The model assumes constant prices throughout the time period considered. Any estimation of the relative movements of prices, costs or of 'terms of trade' between agricultural activities and forestry in fifty years is bound to be speculative, but assuming current market prices and analysing the model indicates significant variables which need to be measured and considered more carefully.

Appendix 2, Table 4 Market Prices adopted

Production	Market price 1977/78	Source of information	
Milk	9.94p/litre	Milk Marketing Board	MMB
Meat:			
Sheep - fat sheep	120p/kg	Ministry of Agriculture	MAFF
- hill sheep	135p/kg	Ministry of Agriculture, Meat and Livestock Commission	MAFF MLC
- culled	78p/kg	Meat and Livestock Commission	MLC
Beef Cattle -			
- stores	116p/kg	Meat and Livestock Commission, Ministry of Agriculture, Intervention Board for Agricultural Produce	MLC MAFF IBAF
- fat	105p/kg	Meat and Livestock Commission	MLC
- culled	80p/kg	Meat and Livestock Commission	MLC
Dairy Cattle -			
- culled	80p/kg	Nix, 1978	
Wool	97.2p/kg	Wool Marketing Board	WMB

Estimations of revenue were based on the potential production figures and current market prices. The economics are considered from the point of view of the individual farmer, and therefore subsidies are of critical importance. Numerous grants and schemes exist to aid agriculture, eg Farm Capital Grant Scheme (FCGS), Farm and Horticultural Development Scheme (FHDS), but they largely rely on individual circumstances. For this reason only the livestock subsidies were included in the coefficients ie the Hill Livestock Compensatory Allowances (HLCA). Estimates were made on the total amount of subsidies relevant to each land class according to GLU equivalents per head of livestock; ie 0.1 GLU is equivalent to one head of sheep for which one is eligible to a subsidy of £2.85, which leads to a subsidy input of £28.5 per GLU (allocation to each land class was based on the estimated number of potential GLUs in each land class). The subsidies were assigned to each type of farming category according to the combination of enterprises defined previously in association with the production figures.

Data relating to costs within different types of farming and/or enterprises is extremely difficult to collate, and often it is only available in a generalised form. Cost data were taken from a number of sources:

1. "Financial results and measures of efficiency - the Northern Region, 1977/78", MAFF (Farm Management Department) and Newcastle University, 1979.
2. "Farm Management Handbook - Northern Region, 1977/78", MAFF (Farm Management Department), 1979.
3. "Farm Incomes in England and Wales, 1977/78", No. 31, MAFF, 1979. Data relating to the Northern Region of England.
4. "Farm Incomes in England and Wales, 1977/78", No. 31, MAFF, 1979. Data relating to farms with low labour input, 275 - 599 smd.

All of the data are derived from information from the Farm Management Survey but collated and presented in different forms (Section 8.2).

The farm types adopted by the Farm Management Survey (FMS) were related to that defined in the Sedbergh Rural Land Use Study. Considerable variation is believed to exist between these descriptions, and the cost data can only be regarded as an overall impression. The cost data per adjusted hectare are converted to that per GLU according to the density of stocking per farm type given in the FMS data sources. The costs included, are the variable costs plus the manual labour of the farmer and his wife. This is included for compatibility with the forestry financial data (Section 4.4.2). Management labour on the part of the farmer is excluded.

The variable costs include:

Feed - purchased concentrates, homegrown concentrates, hay and straw, agistment, other feed.
Veterinary/medicines
Other livestock costs
Seeds - purchased, homegrown
Fertiliser
Sprays and other crop costs
Casual labour
Manual labour of farmer and wife.

Using the estimated potential grading livestock units (GLUs) per land class, estimates were made of the potential total costs in each land class under each type of farming considered. Subtracting potential costs from the potential revenue and subsidies gives an indication of the potential return from each land class under each type of farming (A2, Table 5), from which the NPV of the contribution can be calculated (A2, Table 6).

A2 2.1.1 Common land and conservation areas

There appears to be no study into the economics of 'farming' common land or areas recognised as being of conservation value.

Using production figures from the study undertaken by Cumbria County Council (1980) implies assuming that common land and conservation areas are devoted totally to sheep grazing, defined as livestock rearing - mostly sheep. Accepting current laws relating to common land, one assumes that no actual farm will be situated in these areas, and therefore one must assume that the sheep farms on non-common land have the right to run sheep on the common land and the facilities to provide housing and additional food supply when necessary.

The costs associated with sheep grazing in such areas were regarded as including:
Casual labour
Livestock costs
Veterinary/medicine
Agistment

Appendix 2, Table 5 Agricultural economic coefficients - potential "GM" per annum (£) per 25 ha according to different data sources

(i) Financial results and measures of efficiency

Land Class	Land Use							
	PW	SD	MD	C	CS	S	KS	PS
1		-304	-151	179	157	243	301	301
2		-417	-262	4	25	69	175	175
3		240	285	587	459	606	490	490
4		4412	3619	6556	4662	4175	1852	1852
5		3275	2711	4606	3300	3112	1426	1426
6		2505	1995	3300	2388	2399	1246	1246
7		1657	1418	2081	1529	1672	969	969

(ii) Farm Management Handbook

Land Class	Land Use							
	PW	SD	MD	C	CS	S	KS	PS
1		-357	47	-299	56	282	301	301
2		-963	-498	-574	-370	-111	175	175
3		556	865	111	411	869	490	490
4		7089	6740	3051	3771	5083	1852	1852
5		5360	5184	2273	2882	3967	1426	1426
6		4181	4124	1742	2443	3207	1246	1246
7		2857	2933	1145	1594	2352	969	969

Appendix 2, Table 5 continued

(iii) Farm Incomes in England and Wales - Northern Region of England

Land Class	Land Use							
	PW	SD	MD	C*	CS	S	KS	PS
1		-613	-529	n/a	136	504	300	300
2		-600	-484		11	220	175	175
3		-264	-330		424	1032	491	491
4		2496	1284		4523	5778	1852	1852
5		1731	829		3157	4404	1426	1426
6		1215	523		2294	3478	1247	1247
7		653	195		1456	2512	969	969

(iv) Farm Incomes in England and Wales - 275 - 599 smd input

Land Class	Land Use							
	PW	SD	MD	C*	CS	S	KS	PS
1		-625	-483	n/a	-142	283	245	245
2		-606	-457		-151	92	142	142
3		-282	-256		- 28	672	398	398
4		2425	1563		2815	4419	1504	1504
5		1675	1055		1811	3309	1145	1145
6		1168	711		1145	2563	1012	1012
7		616	341		561	1800	787	787

* The category livestock rearing - mostly cattle is not defined in the publication 'Farm Incomes in England and Wales'.

Key: As given in Table 5.1

Appendix 2, Table 6 Agricultural economic coefficients - potential "GM" expressed in terms of £000s NPV at r = 3% per 25 ha, according to different data sources

(i) Financial results and measures of efficiency

Land Class	Land Use							
	PW	SD	MD	C	CS	S	KS	PS
1		-7.8	-3.9	4.6	4.0	6.3	7.7	7.7
2		-10.7	-6.7	0.1	0.6	1.8	4.5	4.5
3		6.2	7.3	15.1	11.8	15.6	12.6	12.6
4		113.5	93.1	168.7	120.0	107.4	47.7	47.7
5		84.3	69.8	118.5	84.9	80.1	36.7	36.7
6		64.4	51.3	84.9	61.4	61.7	32.1	32.1
7		42.6	36.5	53.5	39.3	43.0	24.9	24.9

(ii) Farm Management Handbook

Land Class	Land Use							
	PW	SD	MD	C	CS	S	KS	PS
1		-9.2	1.2	-7.7	1.4	7.3	7.7	7.7
2		-24.8	-12.8	-14.8	-9.5	-2.9	4.5	4.5
3		14.3	22.3	2.9	10.6	22.4	12.6	12.6
4		182.4	173.4	78.5	97.0	130.8	47.7	47.7
5		137.9	133.4	58.5	74.2	102.1	36.7	36.7
6		107.6	106.1	44.8	62.9	82.5	32.1	32.1
7		73.5	75.5	29.5	41.0	60.5	24.9	24.9

Appendix 2, Table 6 continued

(iii) Farm Incomes in England and Wales - Northern Region of England

Land Class	Land Use							
	PW	SD	MD	C	CS	S	KS	PS
1		-15.8	-13.6	n/a	3.5	13.0	7.7	7.7
2		-15.4	-12.5		0.3	5.7	4.5	4.5
3		- 6.8	- 8.5		10.9	26.6	12.6	12.6
4		64.2	33.0		116.4	148.7	47.7	47.7
5		44.5	21.3		81.2	113.3	36.7	36.7
6		31.3	13.5		59.0	89.5	32.1	32.1
7		16.8	5.0		37.5	64.6	24.9	24.9

(iv) Farm Incomes in England and Wales - 275 - 599 smd input

Land Class	Land Use							
	PW	SD	MD	C	CS	S	KS	PS
1		-16.1	-12.4	n/a	- 3.7	7.3	6.3	6.3
2		-15.6	-11.8		- 3.9	2.4	3.7	3.7
3		- 7.3	- 6.6		- 0.7	17.3	10.2	10.2
4		62.4	40.2		72.4	113.7	38.7	38.7
5		43.1	27.1		46.6	85.1	29.5	29.5
6		30.1	18.3		29.5	65.9	26.0	26.0
7		15.8	8.8		14.4	46.3	20.2	20.2

Key: As given in Table 5.1

Such costs were examined for three types of farming:

livestock rearing - mostly cattle
- cattle and sheep
- mostly sheep

Little variation was shown in the costs and that related to sheep farming were taken as being representative of common land and conservation areas. The cost per hectare was converted to cost per GLU according to the given stocking rate (Cumbria County Council, 1980). The revenue, subsidies and the NPV contribution value from land classes in these areas, were estimated as previously indicated.

A2 2.1.2 Assumptions

1. Current market prices adopted and are an acceptable representation of the situation.
2. Production figures are realistic, particularly those relating to common land and conservation areas.
3. The data sources used are applicable to the farming environment in the district and are applied correctly, ie classification of farm types defined in data sources and the Sedbergh Rural Land Use Study area are comparable.
4. Type of farming enterprises defined are a realistic indication of feasible land use activities.
5. Expressing economic information in terms of grazing livestock units is acceptable.
6. The crude assessments associated with common land and conservation areas are acceptable.
7. Discounting over the time period concerned implies assuming constant prices and production, and takes no account of risk or uncertainty.

A2 2.1.3 Data sources

1. "Financial results and measures of efficiency - the Northern Region, 1977/78", MAFF (Farm Management Department) and Newcastle University, 1979.
2. "Farm Management Handbook - Northern Region, 1977/78", MAFF (Farm Management Department), 1979.

3. "Farm Incomes in England and Wales - 1977/78", No. 31, MAFF, 1979.
4. Sedbergh Rural Land Use Study Report (Cumbria County Council, 1980) Production and farm management details.
5. Range of market price sources - local markets, Ministry of Agriculture, Newcastle University.

A2 2.2 Forestry Economic Coefficients

Financial details relating to potential timber production in each land class in the Sedbergh district were obtained from the Forestry Commission (Edinburgh). The details were based on information from the study undertaken by Cumbria County Council and were specific to the North-West Conservancy.

Information on the potential cash flows associated with various operations throughout the forestry rotation was obtained, and after ensuring compatibility between the revenue and expenditure data and with the agricultural financial coefficients, estimates were made of the Net Present Value of the potential contribution per land class (A2, Table 7).

The expenditure data covered the following operations:

- ground preparation
- fencing and maintenance
- planting
- weeding
- beating up
- cleaning and brashing
- road construction and maintenance
- protection of wildlife and insurance against fire
- and accounted for "direct costs, direct wages, machinery charges and costs and oncosts associated with labour".

The revenue data were presented on the same basis as the expenditure data and gave the sale value of the timber at different points of time in the forest rotation net of direct harvesting cost and oncosts. All financial flows were expressed in terms of £, 1977/78 and per ¼-square kilometre (25 ha).

Appendix 2, Table 7 Forestry Economic coefficients - potential "GM", expressed in terms of £000s NPV at r = 3%, per 25 ha

Land Class	Land Use						
	PW	SD	MD	C	CS	KS	PS
1	15.7						
2	1.6						
3	26.0			No			
4	41.0			Forestry			
5	41.0			Production			
6	33.8						
7	30.8						

Key: As given in Table 5.1

The economics are considered from the point of view of the private individual, and therefore available grants and subsidies were included in the coefficients.

It was assumed that the individual would receive a dedication grant (Basis III) which is an outright payment in planting, plus maintenance grants over the first 25 years. Also a reduction in net costs by between 0.60 - 0.75 was made due to anticipated tax concessions (Forestry Commission, Edinburgh - pers comm).

Existing forestry areas are of different species and ages, and therefore of different economic value. It is assumed that such areas will remain afforested during the time period considered in the model, and that the estimated forestry value (NPV) per land class will be acceptable for all areas of forestry (A2, Table 7). This means that it is highly likely that current plantings are under-estimated as such areas will realise higher levels of income in earlier time periods and cost more in the later years when replanting is necessary.

A2 2.2.1 Assumptions

1. Forestry Commission (Edinburgh) production figures are acceptable although more generalised than those adopted in the Sedbergh Rural Land Use Study (Cumbria County Council, 1980).
2. The forestry financial flows are related to Sitka Spruce plantings, and it is assumed that these are representative of most species usually planted.
3. The forestry and agricultural information is compatible.
4. The length of the forestry rotation is fifty years.
5. Financial results are constant per hectare, ie no economies of scale, and are applicable to units of 25 hectares.
6. Forestry dedication scheme (Basis III) adopted.
7. Forestry cost reduction by 0.60 due to tax concessions for the private individual investing in timber (Forestry Commission, Edinburgh).
8. Discounting over the time period concerned implies assumptions related to constant prices and production throughout the time period considered, and one assumes that the rotation cycle is completed.
9. Acceptable to use the forestry economic estimates to cover current plantings, any error being of minor importance.

A2 2.2.2 Data sources

1. Forestry Commission published routine information, specific to the North-West Conservancy.
2. Sedbergh Rural Land Use Study Report (Cumbria County Council, 1980).

A2 3 Labour Requirement Coefficients

A2 3.1 Agricultural labour requirements

Agricultural labour coefficients are taken from the study undertaken by Cumbria County Council which were estimated as described below.

Labour requirements associated with agricultural activities were divided into that related to:

(i) stock management

and (ii) the land itself.

The labour requirement associated with livestock management was related to different agricultural activities on land belonging to different capability classes. Estimates were initially made of the labour input (smd) associated with each form of output considered in the model such as beef, meat and milk, on land of each capability. These estimates were in turn related to each type of farming category, according to the assumed livestock characteristics of each type of farming category. (The smd equivalents per head to livestock were taken from MAFF estimations.) Assessment of labour input to the land itself assumed that there were no labour requirements associated with rough grazing land (capability class 6), ie transferring livestock to and from such areas was assumed to be negligible, and no consideration was given to labour requirements for farm maintenance ie the maintenance of both farm machinery and buildings. Land of capability class 5 is equated to permanent grassland and land of capability class 4 to grass-leys. MAFF estimate the labour input to such areas as being 1.0 and 2.0 smd per ha per annum. Taking a 15% allowance for the area under buildings, roads and boundaries into consideration, the labour input to land capability class 4 and class 5 is 1.7 and 0.85 smd per ha per annum respectively.

From this information a series of conversion coefficients were obtained for each form of output in each land capability class, for each type of farming category, from which estimates were made of the agricultural labour requirements to each land class (A2, Table 8). *It is assumed that the input to the land is equal* between different types of farming.

The validity of the coefficients is not known and is believed to be highly variable, as estimates of current labour input from agricultural returns data exceeds that estimated according to the model input coefficients (Section 8.2.5).

Appendix 2, Table 8 Labour requirement Coefficients (SMD per annum per 25 ha)

Land Class	Land Use							
	PW*	SD	MD	C	CS	S	KS	PS
1	47	21	23	17	20	23	19	19
2	5	6	9	7	10	12	11	11
3	61	51	49	36	38	42	30	30
4	85	245	219	143	146	164	114	114
5	85	198	177	118	120	134	92	92
6	80	166	148	101	102	113	77	77
7	65	132	114	79	80	88	60	60

* PW Coefficients based on information from Forestry Commission (Edinburgh), specific to the North West Conservancy.

Key: As given in Table 5.1

A2 3.1.1 Common land and conservation areas

There is little information available on the use of common land and estimates of the level of labour input to such land areas was based on input estimates associated with hill sheep. Input levels were chosen at levels lower to that expected on 'non-common' land, because less management is associated with sheep grazing on common land, ie mostly shepherding.

A2 3.2 Forestry labour requirements

The forestry labour coefficients actually used were obtained from the Forestry Commission (Edinburgh). (See Section 8.2.2, and Appendix 2, Table 8).

It was assumed that the area of forestry was of a sufficiently mixed aged stand to enable an average labour input per year to be estimated. Forestry employment is likely to be on a part-time basis and this approximation appeared acceptable. Figures relating to the labour requirements (s.m.yr./ha) associated with each forestry operation throughout the rotation cycle were obtained and related to the specific land classes. This enabled an estimation of the number of smds of labour required throughout the whole forestry rotation.

Forestry labour input estimates do not take management labour into consideration, which may be considerable as the establishment of any plantation is usually organised by an outside organisation/contractor. The agricultural labour estimates similarly do not consider management input, only that of manual labour. By excluding management input one is assuming that management labour is available, and that the level of management input is equal between all land use activities and the cost equal. The financial calculations similarly do not include any details on management costs. Forestry and agricultural activities are treated in the same manner though for improved accuracy an estimate should be made, but this is very difficult. Management costs associated with forestry operations are available from the Forestry Commission, but are included in the overhead figures for which no breakdown is readily available. However, it is much more difficult to determine the management cost associated with agricultural activities. The agricultural data collected makes no attempt to estimate management cost though it is often argued that such a cost should be included in the Farm Management Survey details, charged against farm income before stating a return on capital (D S Simon, 1979).

A2 3.3 Labour Assumptions

1. One standard man-year equals 300 standard man-days (1 SMY = 300 SMD).
2. Annual forestry estimate acceptable, assuming mixed aged stand and part-time employment.
3. Forestry Commission data is related to the land classes realistically.
4. The Sedbergh Rural Land Use Study assessment of labour requirements associated with agricultural activities is acceptable.

A2 3.4 Data Sources

1. Forestry Commission (Edinburgh).
2. Nix, J, Farm Management Pocket Book (9th edition), 1978.
3. Sedbergh Rural Land Use Study Report (Cumbria County Council, 1980).

Appendix 3

LIST OF ABBREVIATIONS

ADAS	Agricultural Development and Advisory Service
Agri.	Agricultural
AIDA	Analysis of Interconnected Decision Areas
ANPV	Agricultural net present value
C	Livestock rearing - mostly cattle
CAS	Centre for Agricultural Strategy
CC	Countryside Commission
CRT.	current
CS	Livestock rearing - cattle and sheep
CST.	Constraint
DAFS	Department of Agriculture for Scotland
DOT	Decision Optimising Methodology
EFG	Economic Forestry Group
eg	for example
EHP	Experimental Husbandry Farms
F	Forestry
FC	Forestry Commission
FMS	Farm Management Survey
FNPV	Forestry net present value
For.	Forestry
ft	Feet
GJ	Giga joules
GLU	Grazing livestock unit
ha	Hectare
HFRO	Hill Farming Research Organisation
ie	that is
kg	Kilogram
km	Kilometre

m^3	cubic metres
m	metre
MAFF	Ministry of Agriculture, Fisheries and Food
MD	Mainly dairying
MLC	Meat and Livestock Commission
MMB	Milk Marketing Board
NFU	National Farmers' Union
NPV	Net present value
PW	Private woodland
r	Discount rate
RHS	Right-hand-side
S	Livestock rearing - mostly sheep
SD	Specialist dairying
SMD	Standard man day
SMYr	Standard man year
SSSI	Site of special scientific interest
SRLUS	Sedbergh Rural Land Use Study
UMEX	Upland Management Experiment
YDNP	Yorkshire Dales National Park

Appendix 4

DEFINITION OF THE LAND USE MODEL

The land use model defined in this thesis is based on the idea proposed by Bishop (1978). The model incorporates elements considered in the model which was used in the study coordinated by Cumbria County Council (1980) (Table 9.1) together with other factors which improve the accuracy and validity of the land use model. Economic factors have been added to the current land use model and constraint restrictions have been more explicitly defined. The model has been used to explore a range of problems which reflect likely planning actions. Considerable attention has been given to the sensitivity and limitations of the model which were recognised as being vitally important in the earlier models defined but which were little studied. A basic land use model framework is defined which can be adjusted and adapted to the planning problem being explored.

The land use model is based on linear programming and looks at how a desired objective such as maximising timber production in a defined area, can be achieved subject to a series of constraints on the amounts of commodities required or resources available.

Each land use activity considered ie forestry (PW), specialist dairying (SD), mainly dairying (MD), livestock rearing mostly cattle (C), cattle and sheep (CS), mostly sheep (S), sheep on common land areas (KS) and sheep on conservation areas (PS), in each of the seven land classes is identified as a separate variable in the model. If we represent the land areas as x_{ij}, where i represents the land class and j represents the land use activity, the objective function which is the output of some commodity c is given by:

$$Z = \sum_{i=1}^{7} \sum_{j=1}^{8} c_{ij} x_{ij}$$

The land use model examines a series of single objective functions and in turn particular constraints are optimised and the problem reformulated. The land use model might be used to consider the following objectives:

Maximise economic return discounted over the fifty year time period considered, ie net present value of potential gross margins (Section 4.4.2)

Maximise timber, beef, sheep or milk production

Maximise labour requirements.

While maximising the chosen objective one is concerned about the output of certain commodities such as beef production or labour requirements and one may wish to prescribe values above or below which these may not rise and fall. These specifications become the constraint formulations.

The problem may then be defined as:

MAXIMISE: $$Z = \sum_{i=1}^{7} \sum_{j=1}^{8} c_{ij} x_{ij}$$

where c_{ij} represents the potential production or economic return according to the chosen objective, associated with each variable defined;

x_{ij} represents each land activity (j) in each land class (i).

SUBJECT TO:

Production constraints

$$\sum_{i=1}^{7} \sum_{j=1}^{8} am_{ij} x_{ij} \geqslant b_m$$

where am_{ij} represents the level of potential production for the output being considered (m) in each land area (x_{ij});

b_m represents the defined production specifications eg the estimated current level of production from the defined area;

m represents the production output under consideration.

The land use model looks at the production of timber, beef meat, sheep meat and milk.

Labour requirements

$$\sum_{i=1}^{7} \sum_{j=1}^{8} an_{ij}\, x_{ij} \geq b_n$$

where an_{ij} represents the potential level of each form of labour being considered (n) associated with each land use in each land area (x_{ij});

b_n represents the defined labour requirement specifications eg these might state that, the land use allocation must provide labour requirements at least equal to the current estimated level of labour input to the land use activities considered in the model in the defined area.

n represents the labour types under consideration, ie agricultural and forestry labour are identified separately.

Land area availability

Total land area available:

$$\sum_{j=1}^{8} x_{ij} \leq b_i \quad \text{for all i where i = 1 - 7}$$

where b_i represents the total number of grid squares in the area classified as belonging to land class i.

Land use restrictions in particular land areas:

(i) $x_{ij} = b_{ij}$ for defined i and j; and/or

(ii) $x_{ij} \geq b_{ij}$ for defined i and j.

where b_{ij} represents the number of grid squares in the area classified as belonging to land class i restricted to land use j;

j represents land use activities which may be restricted.

Type (i) restriction will arise if one recognises areas of common land on which land use activities are limited to the current land use defined as sheep rearing on common land (KS) and, or one regards certain land areas as being restricted in land use for conservation reasons (PS).

Type (ii) restriction arises when one restricts any existing area of forestry to forestry, not allowing such land areas to be allocated to different land use activities.

Non-negativity constraints

Production (a) from each area defined can never be negative:

$$a_{ij}\ x_{ij} \geq 0 \text{ for all } i,\ j$$

Economic return (c) from each land use activity can never be negative:

$$\sum_{i=1}^{7} c_{ij}\ x_{ij} \geq 0 \text{ for all } j \text{ where } j = 1 - 8$$

Right-hand-side constraint specifications can never be negative:

$$b_m,\ n,\ i,\ j,\ \geq 0$$

The land use model may be defined in a number of ways according to the problem being explored. The model may be reformulated and the objective and constraints adjusted eg the constraint target specifications may be revised or the restrictions on the land area available tightened or relaxed. The model may also be used to estimate the levels of wool and dairy meat production, food energy production, agricultural and forestry subsidy inputs associated with the suggested optimal land use pattern. These commodities were regarded as secondary products and therefore not taken as model objectives or constraints influencing the land allocation.

The model was run using a standard computer package; the MPOS package (Multi-purpose Optimisation System) available at the University of Manchester Regional Computer Centre. Considerable information is generated by the land use model as described in Section 4.5 and illustrated in Chapters 5 to 8. Valuable information on shadow prices and opportunity costs is available but was not explored in detail as this thesis aimed to illustrate how the land use model could be used and applied in planning, and the vast number of problems explored made presentation of such details difficult.

BIBLIOGRAPHY

ASHTON, J and LONG, W. 1972. The Remoter Rural Areas of Britain. Oliver and Boyd.

BATEY, P W H and BREHENY, M H. 1978a. 'Methods in strategic planning. Part I: A descriptive review'. Town Planning Review vol. 49, no. 3. July 1978, pp 259 - 273.

BATEY, P W H and BREHENY, M J. 1978b. 'Methods in strategic planning. Part II: A prescriptive review'. Town Planning Review, vol. 49, no. 4. pp 502 - 518.

BENDELOW, V C and CARROLL, D M. 1980. 'The soils in the parishes of Sedbergh, Garsdale and Dent, Cumbria'. In "Sedbergh Rural Land Use Study: draft for consultation (Appendix 4)". Cumbria County Council.

BEN-SHARER, H, MAZOR, A and PINES, D. 1969. 'Town Planning and Welfare maximisation: a methodological approach'. Regional Studies vol. 3, pp 105 - 113.

BENSON, W A. 1971. 'Interdisciplinary approach to land capability analysis and land-use planning'. Transactions 35 Federal Provincial Wildlife Conference, Canada, p 40 - 46.

BIGGS, W D. 1980. Sedbergh district plan: report of survey and draft written statement. Cumbria County Planning Department.

BIGGS, W D, and TAYLOR, A. 1980. Cumbria and Lake District Joint Structure Plan Written Statement. Cumbria County Council and Lake District Special Planning Board.

BISHOP, I D. 1978. 'Land Use in rural Cumbria - a linear programming model'. Institute of Terrestrial Ecology, Merlewood Research and Development Paper No. 75.

BISHOP, I D. 1979. 'Modelling, programming and policy making - a study of land use in Cumbria, UK'. PhD Thesis, Centre for Environmental Studies, University of Melbourne, Australia.

BISSET, R. 1980. 'Methods for Environmental Impact Analysis: recent trends and future prospects'. Journal of Environmental Management 11 no. 1, pp 27 - 43.

BODDINGTON, M A. 1978. 'Classification of Agricultural land: England and Wales: a critique'. Rural Planning Services, Publication No. 4.

BOOTH, D and JAFFE, M. 1978. 'Generation and evaluation in structure planning: a review'.
Town Planning Review, Volume 49, no. 4, pp 445 - 458.

BOWMAN, J C, DOYLE, C and TRANTER, R. 1978. 'Why we need a coordinated land use policy'.
Town and County Planning, Vol. 46, No. 9, pp 405 - 409.

BRAZIER, S and HARRIS, R J P. 1975. 'Inter-authority planning: appreciation and the resolution of conflict in the new local government system'.
Town Planning Review, Vol. 46, No. 3, pp 255 - 265.

BRIDGES, E M (ed). 1979. 'Problems of common land: the example of West Glamorgan'.
Proceedings of a joint symposium, September 1978, by the University College of Swansea and West Glamorgan County Council.

BUCKWELL, A E and SHUCKSMITH, D M. 1979. 'Projecting farm structural change'.
Journal of Agricultural Economics, Vol. 30, No. 2, pp 131 - 143.

BUNCE, R G H, MORELL, S K and STEL, H E. 1975. 'The application of multivariate analysis to regional survey'.
Journal of Environmental Management, Vol. 3, pp 151 - 165.

BUNCE, R G H, and SHAW, M W. 1973. 'A standardised procedure for ecological survey'.
Journal of Environmental Management, Vol. 1, pp 239 - 258.

BUNCE, R G H and SMITH, R S. 1978. An ecological survey of Cumbria: Structure Plan Working Paper No. 4.
Cumbria Councy Council, Lake District Special Planning Board, Institute of Terrestrial Ecology.

BURRELL, A and BERKELEY HILL. 1980. 'The problem of inputing a charge for farmers' management: a comment and reply'. (Simon, D S).
Journal of Agricultural Economics, Vol. 31, No. 2, pp 243 - 249.

CAMERON, J B. 1979. 'The role of agriculture and forestry'.
British Association for the advancement of Science Annual Meeting, Heriot-Watt University.

CAMPBELL, I. 1976. 'A guide to the law of commons'.
Commons, Open Spaces and Footpaths Preservation Society, London.

CAPSTICK, M. 1972. 'Some aspects of the economic effect of tourism in the Westmorland Lake District'.
Department of Economics, University of Lancaster.

CARROLL, M. 1979. 'Rural land use control in Great Britain'. Natural Resources Journal, Vol. 19, No. 1, January, pp 145 - 149.

CENTRE FOR AGRICULTURAL STRATEGY. 1976. Land for Agriculture. CAS Report No. 1.

CENTRE FOR AGRICULTURAL STRATEGY. 1980. Strategy for the UK forest industry. CAS Report No. 6.

CHARLTON, P J. 1973. 'Effective interdisciplinary research: an elusive goal'. New Zealand Journal of Agricultural Science, Vol. 7, pp 151 - 158.

CHARLTON, P J and THOMPSON, S C. 1970. 'Simulation of Agricultural Systems'. Journal of Agricultural Economics, Vol. 31, No. 3.

CHIPPERFIELD, E, PILLING, R, GIBSON, R, BROWN, A, SMITH, R S and BUNCE, R G H. 1978. An ecological survey of the parishes of Sedbergh, Dent and Garsdale in the Yorkshire Dales National Park. Cumbria County Council (unpublished).

CLAWSON, M. 1959. 'Methods of measuring the demand for and value of outdoor recreation'. Resources for the future. Washington D C, Report Series No. 10.

CLOUT, H D. 1971. 'End of the road for the Northern Pennines Rural Development Board'. Geographical Magazine, No. 43, p 433.

COLLINS, J H and THOMAS, A R. 1973. 'A systems study of the Uplands of Northern England and Southern Scotland - Report of a pilot study'. University of Lancaster ISCOL Ltd and Nature Conservancy, Merlewood Research Station.

CONACHER. 1980. 'Environmental problem solving and land use management: a proposed structure for Australia'. Environmental Management Vol. 4, No. 5, September, pp 391 - 407.

COOMBER, N H and BISWAS, A K. 1973. Evaluation of environmental intangibles. Genera Press, New York.

COPPOCK, J T. 1977. 'The challenge of change: problems of rural land use in Great Britain'. Geography, Vol. 62, Part 2, April, pp 75 - 86.

COPPOCK, J T. 1979. 'Rural land management in Scotland'. Town and County Planning, Vol. 48, No. 2, pp 47 - 49.

COPPOCK, J T and GEBBETT, L F. 1978. 'Land use and town and county planning'. Review of UK Statistical Sources, Vol. VIII, Maunder (ed).

COUNTRYSIDE COMMISSION. 1974. 'North Riding Pennines study Methods Report'.
CCP, 84.

COUNTRYSIDE COMMISSION. 1976. 'The Lake District Upland Management Experiment'.
CCP, 93.

COUNTRYSIDE REVIEW COMMITTEE. 1976. The countryside - problems and policies.
Department of the Environment, HMSO.
Also Discussion Papers:
1. Rural Communities. 1977.
2. Leisure and the countryside. 1977.
3. Food production in the countryside. 1978.
4. Conservation and countryside heritage. 1979.

CUMBRIA COUNTY COUNCIL. 1980. 'Sedbergh Rural Land Use Study, Draft for consultation'.

CUNNINGHAM, J M M. 1979. 'The role of agriculture and its relationship with other land uses'.
British Association for the Advancement of Science Annual Meeting, Heriot-Watt University.

CUNNINGHAM, J M M and SMITH, A D M. 1978. 'The impact of technical advances on hill and upland cattle systems'.
The future of upland Britain, Vol. II, pp 34 - 45.
CAS Paper 2, Centre for Agricultural Strategy.

DANE, C W, MEADOR, N C and WHITE, J B. 1977. 'Goal programming in land-use planning'.
Journal of Forestry, June, pp 325 - 329.

DALTON, G E (ed). 1975. Study of Agricultural Systems.
Applied Science Publishers Ltd, London.

DAVIDSON, J and WIBBERLEY, G. 1977. Planning and the rural environment.
Urban and Regional Planning Series, Vol. 18, Pergammon Press.

DEPARTMENT OF THE ENVIRONMENT. 1978. 'Common land: preparations for comprehensive legislation'.
Report of an interdepartmental Working Party, 1975 - 77, London.

DEPARTMENT OF THE ENVIRONMENT - WELSH OFFICE. 1974. Report of the National Park Policies Review Committee (Chairman, Lord Sandford).
HMSO.

DYE, A O. 1973. 'Simulation of land use in upland Yorkshire'.
Journal of Environmental Management, Vol. 1, pp 169 - 199.

EARWICKER, J. 1974. 'The future of planning - an exploration using future techniques'.
The Planner, Vol. 60, No. 4, April, pp 650 - 652.

EDWARDS, A M and WIBBERLEY, G P. 1971. An agricultural land budget for Britain, 1965 - 2000.
Studies in Rural Land Use No. 10, Wye College, London.

FANSTONE, G H and HIMSWORTH, K. 1976. Choices for Cumbria, Report of Survey.
Cumbria County Council, Lake District Special Planning Board.

FEGE, A S, INMAN, R E and SALO, D J. 1979. 'Energy Farms for the Future'.
Journal of Forestry, Vol. 77, No. 6, pp 358 - 361.

FEIST, M J. 1979. 'Management agreements: a valuable tool of rural planning'.
The Planner, Vol. 65, No. 1, pp 3 - 5.

FEIST, M J, LEAT, P M K and WIBBERLEY, G P. 1976. A study of the Hartsop Valley: a report to the Countryside Commission and Lake District Special Planning Board.
CCP, 92. Countryside Commission.

FORESTRY COMMISSION. 1977. The Wood Production Outlook in Britain - a Review.
Forestry Commission..

FOXALL, G R. 1979. 'Agricultural improvement of common land: the relevance of cooperative management'.
Journal of Environmental Management, Vol. 8, pp 151 - 161.

GASSON, R. 1977. 'Farmers' approach to cooperative marketing'.
Journal of Agricultural Economics, Vol. 28, No. 1.

GASSON, R. 1973. 'Goals and values of farmers'.
Journal of Agricultural Economics, Vol. 24, No. 3, pp 521 - 542.

GILG, A. 1978. Countryside Planning.
David and Charles.

HAGUE, M. 1972. Structure Plan Opportunities.
Journal of Royal Town Planning Institute, Vol. 58, No. 9, pp 400 - 402.

HALL, P. 1974. 'Planners, forecasts, the public and the future'.
The Planner, Vol. 60, No. 4, pp 634 - 635.

HART, P. 1977. Countryside implications of the decisions of rural landowners: A Leicestershire case study.
Area, Vol. 9, No. 1, pp 46 - 48.

HARVEY, R. 1978. Initial National Park Plan.
Yorkshire Dales National Park Authority.

HEAP, D (ed). 1978. 'An outline of planning law'.
Sweet and Maxwell, 7th edition.

HICKLING, A. 1978. 'AIDA and the levels of choice in structure plans'.
Town Planning Review, Vol. 49, No. 4, pp 459 - 475.

HILL, M. 1968. 'A goals achievement matrix for evaluating alternative plans'.
American Institute of Planners Journal, January, pp 19 - 29.

HILL FARMING RESEARCH ORGANISATION. 1979. Science and Hill Farming 1954 - 1979.
HFRO.

HINE, R C. 1973. Structural policies and British agriculture.
Journal of Agricultural Economics, Vol. 24, No. 2, pp 321 - 328.

HITCHENS, M T, THAMPAPILLAI, D J and SINDEN, J A. 1978. 'The opportunity cost criterion for land allocation'.
Review of Marketing and Agricultural Economics, Vol. 46, No. 3, pp 275 - 293.

H M TREASURY. 1972. 'Forestry in Great Britain - an interdepartmental cost/benefit study'.
HMSO.

H M TREASURY. 1978. The Nationalised Industries.
Command 7131, HMSO.

HOLMES, G D. 1979. 'Relating forest to farming'.
British Association for the Advancement of Science Annual Meeting, Heriot-Watt University.

HOSKINS, W G and STAMP, L D. 1963. 'The common land of England and Wales'.
Collins.

HOUSE, J W. 1976. 'The geographer and policy-making in marginal rural areas in the Northern Pennines Rural Development Board'.
Chapter 6, Spatial Dimensions of Public Policy (Coppock, J T and Swell, W R D (eds).)

IGNIZIO, S P. 1978. 'A review of goal programming: a tool for multiobjective analysis'.
Journal of the Operational Research Society, Vol. 29, No. 11, pp 1109 - 1119.

INSTITUTE OF TERRESTRIAL ECOLOGY. 1978. 'Upland Land Use in England and Wales'. A desk study compiled for the Department of the Environment.
CCP, 111. Countryside Commission.

JAMES, P G. 1964. 'An economic appraisal of the use of hills and uplands for forestry and agriculture respectively'. The Farm Economist, Vol. 10, pp 497 - 506.

JAMES, G. 1974. 'Land use in upland Britain - an economist's viewpoint'. Conservation in Practise. Warren, A and Goldsmith, F B (eds), J Wiley and Sons.

JEFFERS, J N R. 1973. 'Systems modelling and analysis in resource management'. Journal of Environmental Management, Vol. 1, No. 1, pp 13 - 28.

JENKINS, P M and ROBSON, A. 1974. 'An application of linear programming methodology for regional strategy making'. Regional Studies, Vol. 8, pp 267 - 279.

KENT, B M. 1980. 'Linear programming in land management planning on National Forests'. Journal of Forestry, Vol. 78, No. 8, pp 469 - 472.

KILKENNY, J B. 1976. 'Economic significance of wool in meat production systems'. Agricultural Systems, Vol. 1, pp 313 - 320.

KINGMA, O T and SINDEN, J A. 1975. 'Towards practical guidelines for multiple use management'. Canadian Journal of Agricultural Economics, Vol. 23, No. 3, pp 59 - 65.

KNETSCH, J L. 1963. 'Outdoor recreation demands and benefits'. Land Economics, Vol. 39, No. 4.

LAND USE STUDY GROUP REPORT. 1966. 'Forestry, Agriculture and the multiple use of rural land'. Department of Education and Science, HMSO.

LEACH, S. 1979. 'County - district relationships in planning and organic change'. The Planning Magazine, Vol. 65, No. 3, pp 76 - 77.

LICHFIELD, N. 1970. 'Evaluation methodology of urban and regional plans: A review'. Regional Studies, Vol. 4, No. 2, pp 151 - 165.

LOCKETT, A G. 1976. Resource allocation for management - a mathematical programming approach. Gower Press.

LYALL, G. 1980. 'Planning and land assessment in Scotland - role of the rural land use information systems working party'. Land Assessment in Scotland, Thomas, M F and Coppock, J T (eds), Chapter 10.

MacEWAN, M. 1977. 'Britain's national parks - why haven't they worked?'.
The Architects Journal, 7 September, pp 434 - 435.

MAFF. 1974. Agricultural Land Classification of England and Wales.
ADAS.

MAFF. 1979. Annual Review of Agriculture.
Cmnd 7436, HMSO.

MAFF. 1979. Farming and the nation.
Cmnd 7458, HMSO.

MAFF. 1979. 'Farm Incomes in England and Wales, 1977/78'.
No. 31, HMSO.

MAFF (Farm Management Department). 1979. Farm Management Handbook - Northern Region, 1977/78 .

MAFF. 1979/80. At the Farmer's Service.
HMSO.

MAFF/ADAS. 1979. Farm Planning by Computer .
GFM2, HMSO, London.

MAFF, DAFS, DANI. 1975. Food from our own resources.
Cmnd 6020, HMSO.

MAFF, DAFS, DANI. 1977. The changing structure of agriculture, 1968 - 1975.
HMSO, London.

MAFF (Farm Management Department) and Newcastle University. 1979. 'Financial Returns and measures of efficiency - the Northern Region, 1977/78'.
ADAS/Newcastle University.

MANNING, R E and MONCRIEF, L W. 1979. 'Land use analysis through matrix modelling: theory and application'.
Journal of Environmental Management, Vol. 9, No. 1, pp 33 - 40.

MASSEY, D B and CORDEY-HAYES, M. 1971. 'The use of models in structure planning'.
Town Planning Review, Vol. 42, pp 28 - 44.

MATTHEWS, J D. 1973. The integration of agriculture, forestry and recreation.
Supplement to Forestry Report of the 13th discussion meeting, Edinburgh, 30 march - 1 April.

MAXWELL, T J, SIBBALD, A R and EADIE, J. 1979. 'Integration of forestry and agriculture - a model'.
Agricultural Systems, Vol. 4, No. 3, pp 161 - 188.

McCONNELL-WOOD, M M and FOXALL, G R. 1977. 'Cooperative management of common grazing land: a pilot study'. Newcastle University, Department of Agricultural Marketing.

McDOUGALL, G. 1973. 'The systems approach to planning: a critique'. Socio-economic Planning Science, Vol. 7, pp 79 - 90.

McFARQUHAR, A M M. 1961. 'The practical use of linear programming in farm planning'. Farm Economist, Vol. 9, No. 10, pp 472 - 497.

McHARG, I. 1969. Design with nature. Doubleday, New York.

MOSELEY, M J. 1980. 'Is rural deprivation really rural?'. The Planner, Vol. 66, No. 4, July/August.

NATIONAL FARMERS' UNION. 1978. Agriculture and forestry - a policy statement.

NATURAL RESOURCES (TECHNICAL) COMMITTEE. 1957. Forestry, agriculture and marginal land - a report. HMSO.

NEWBOULD, P. 1979. 'The limitations and potential for pasture production in the hills and uplands'. British Association for the Advancement of Science Annual Meeting, Heriot-Watt University.

NEWTON, J B. 1978. 'Farming and forestry in the hills and uplands: competition or partnership'. The future of Upland Britain, Vol. 1, Tranter, R B (ed), pp 114 - 135. Centre for Agricultural Strategy Paper No. 2.

NIX, J. 1978. Farm Management Pocket Book (9th edition). Wye College, London.

NORTH RIDING COUNTY COUNCIL. 1975. North Riding Pennines Study Report. North Riding County Council.

OPENSHAW, S. 1977. 'Models in planning - a state of the art review.' Planning Outlook, Vol. 20, pp 30 - 34.

OPENSHAW, S and WHITEHEAD, P T. 1975. 'A decision optimising technique for planners'. Planning Outlook, Vol. 16, pp 19 - 33.

OPENSHAW, S and WHITEHEAD, P T. 1977. 'Decision making in local plans: the DOT methodology and a case study'. Town Planning Review, Vol. 48, pp 29 - 41.

OPENSHAW, S and WHITEHEAD, P T. 1979. 'The generation and evaluation of structure plans using decision optimising technique (DOT_2). London Papers in Regional Science, 9, pp 178 - 202, Cullen, I G (ed).

PARRY-LEWIS, J. 1969. 'Mis-used techniques in planning (1) Linear programming'. Occasional Paper No. 1, Centre for Urban and Regional Research, University of Manchester.

PARRY-LEWIS, J. 1970. 'The invasion of planning'. Journal of Town Planning Institute, Vol. 56, Nos 3/4, pp 100 - 103.

PETERS, G H. 1970. 'Land Use Studies in Britain'. Journal of Agricultural Economics, Vol. 21, pp 171 - 214.

PETRINI, F. 1964. 'Competition between agriculture and forestry under Swedish conditions'. Lantbrukshögskolans annaler, Vol. 30, pp 3 - 333.

PHILLIPS, A and ROBERTS, M. 1973. 'The recreation and amenity value of the countryside'. Journal of Agricultural Economics, Vol. 24, No. 1, pp 85 - 102.

PRICE, C. 1973. 'To the future: with indifference or concern? - the social discount rate and its implications in land use'. Journal of Agricultural Economics, Vol. 24, No. 2, May, pp 393 - 397.

PUTNEY, A D and WAGER, S A. 1973. 'Objectives and evaluation in interpretive planning'. Journal of Environmental Education, Vol. 5, No. 1, pp 43 - 44, New York.

RANKIN, K R. 1973. 'Forestry in Britain - the pattern of industry'. Commonwealth Forestry Review, 52, pp 31 - 53.

REYNOLDS, I K. 1978. 'The relationship of land values to site characteristics - some implications for scenic quality management'. Journal of Environmental Management, 6, pp 99 - 106.

ROYAL COMMISSION ON COMMON LAND. 1958. Report, 1955 - 1958. Cmnd 462, HMSO, London.

SCOTT, J (Chairman). 1942. The Scott Report - Report of the Committee on land utilisation in rural areas. Cmnd 6378, HMSO.

SCOTTISH DEVELOPMENT DEPARTMENT. 1977. Data inventory working party on rural land use information systems. SDD.

SELECT COMMITTEE ON SCOTTISH AFFAIRS. 1973. Land Resource Use in Scotland. (Report and proceedings of the Committee, 1972. No. HC 511, 1971/72 Session, House of Commons.) Cmnd 5428, HMSO.

SELECT COMMITTEE ON THE EUROPEAN COMMUNITIES. 1979. 'Forestry'. House of Lords Session 1979/80. 6th Report (HL 28).

SELMAN, P. 1978. 'Alternative approaches to the multiple use of land - a review'. Town Planning Review, Vol. 49, No. 2, April, pp 163 - 174.

SHAW, M. 1980. 'Rural planning in 1980: an overview'. The Planner, Vol. 66, No. 4, pp 88 - 90.

SINDEN, J A. 1974. 'A utility approach to the valuation of recreational and aesthetic experiences'. American Journal of Agricultural Economics, 56, No. 1, pp 61 - 72.

SINDEN, J A. 1970. 'Poplar growing and farm adjustment on the north coast of New South Wales'. Review of Marketing and Agricultural Economics, Vol. 58, No. 3, September, pp 1 - 16.

SINDEN, J A and KINGMA, O T. 1972. 'Land tenure in the cyprens areas of North-Western New South Wales'. Australian Journal of Agricultural Economics, April, pp 11 - 21.

SIMON, D S. 1979. 'The problem of inputing a change for farmers management: a model solution'. Journal of Agricultural Economics, Vol. 30, No. 2, pp 169 - 176.

SKELLAM, J G. 1969. 'Models, inference and strategy'. Biometrics 25, p 457.

SMITH, R J. 1971. 'The evaluation of recreation benefits: the Clawson Method in practice'. Urban Studies 8, No. 2, pp 89 - 102.

STATHAM, D C. 1972. 'Natural Resources in the Uplands'. Journal of the Royal Town Planning Institute, Vol. 52, pp 468 - 477.

STEELE, R C and BALFOUR, J. 1979. 'Nature conservation in Upland forestry - objectives and strategy'. British Association for the Advancement of Science Annual Meeting, Heriot-Watt University.

STEWART, G G. 1977. 'The inter-relations between agriculture and forestry in the uplands of Scotland: a forestry view'. Symposium, 13 May 1977 at Edinburgh.

SWARTZMANN, G L and van DUNE, G M. 1972. 'An ecologically based simulation optimisation approach to natural resource planning'. Annual Review of Ecology and Systematics, Vol. 3, pp 347 - 398.

THAMPAPILLAI, D S and SINDEN, J A. 1979. 'Trade-offs for multiple objective planning through linear programming'. Water Resources Research, Vol. 15, No. 5, October, pp 1028 - 1034.

THOMAS, M F and COPPOCK, J T (eds). 1980. Land assessment in Scotland. Symposium of the Royal Scottish Geographical Society, 1979.

THOMPSON, J R. 1978. 'The future of upland farming'. The future of upland Britain, Tranter, R B (ed), pp 46 - 49. Centre for Agricultural Strategy, Paper No. 2.

TRANTER, R B (ed). 1978. 'The future of Upland Britain, Volumes I and II'. CAS Paper No. 2, Centre for Agricultural Strategy, Reading.

UNIVERSITY OF MANCHESTER REGIONAL COMPUTER CENTRE. 1978. MPOS (Multi-purpose optimisation system) User's Guide, version 4.

WADE, B F. 1971. 'Some factors affecting the use of the new techniques in planning agencies'. Environment and Planning, Vol. 3, pp 109 - 114.

WAGER, J. 1967. 'Outdoor recreation on common land'. Journal of Town Planning Institute, Vol. 53, No. 9, pp 398 - 403.

WHITBY, M R and THOMSON, K. 1979. 'Against coordination'. Town and County Planning, Vol. 48, No. 2, pp 51 - 53.

WHITBY, M C and WILLIS, K G. 1978. Rural Resource Development - an economic approach. Methuen, 2nd edition.

WHITEHEAD, P. 1974. 'Flexibility in structure plans'. Planning Outlook, 14, pp 31 - 42.

WIBBERLEY, G. 1976. 'Rural resource development in Britain and environmental concern'. Journal of Agricultural Economics, Vol. 27, No. 1, pp 1 - 19.

WIBBERLEY, G. 1974. 'The proper use of Britain's Rural Land.' Journal of the Royal Town Planning Institute, July/August, 60, pp 779 - 782.

WIBBERLEY, G B and DAVIDSON, J. 1977. Planning and the rural environment. Pergammon Press.

WILLIAMS, H P. 1978. Model building in Mathematical Programming . J Wiley and Sons.

WILLIS, K G and THOMSON, K J. 1980. 'Decision Optimising technique - a critical comment.' Town Planning Review, Vol. 51, No. 1, January, pp 67 - 75.

WILSON, P N and BRIGSTOKE, T. 1978/79. 'The sheep market - meat and wool as it affects UK farmers'. Farm Management, Vol. 3, No. 10, Winter 1978/79, pp 465 - 476.

WRIGHT, D. 1980. Ecological survey of the Sedbergh - Dent area by the Nature Conservancy Council. Sedbergh Rural Land Use Study: draft for Consultation (Appendix 7), Cumbria County Council.

YORKSHIRE and HUMBERSIDE ECONOMIC PLANNING BOARD. 1976. 'The Pennine Uplands: Socioeconomic interactions and opportunities in the Yorkshire Pennines'. HMSO.

YOUNG, M D. 1979. 'Influencing land use in pastoral Australia'. Journal of Arid Environments, Vol. 2, No. 3, September, pp 279 - 288.