CRANFIELD UNIVERSITY
SILSOE COLLEGE

M. Phil THESIS

ACADEMIC YEAR 1992 - 1993

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A GIS BASED DATASET TO ASSESS THE INFLUENCE OF COUNTRYSIDE PLANNING POLICIES ON LANDSCAPE CHANGE IN BEDFORDSHIRE

VOLUME 1

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February 1994

THIS THESIS IS SUBMITTED IN FULFILLMENT OF THE
REQUIREMENTS
FOR THE DEGREE OF MASTER PHILOSOPHY

ABSTRACT

A GIS database for a study area (96 Km^2) within the county of Bedfordshire (southern England) was established to provide statistical and mapped information on the distribution, extent and change through time of land-cover and landscape features between 1968, 1981 and 1991. A major aim of the project was to investigate the character of the countryside designation zones operating in Bedfordshire in terms of detailed local landscape. The effectiveness of the policies for the countryside was assessed in terms of the landscape changes monitored in each area.

To this purpose a census of landscape features was carried out by means of aerial photographic interpretation and the differences between the three dates were measured. The classification scheme included 19 land-cover types (area features), 6 linear features and 6 point features.

A Digital Terrain Model was used to analyse the land-form of the study area and its influence on the distribution of land-cover types.

The countryside designation zones were digitised from the Local Plans and processed with the land-cover maps.

The results of the project are represented by maps, tables and charts of landscape features for each date and their changes between each date, in the study area and in the countryside designation zones.

The study area is shown to be intensively managed since agro-pastoral and developed land cover most of its area. Countryside designation zones showed a strong agro-pastoral character, except for the Sites of Special Scientific Interest and the National Nature Reserve. Generally, over the two decades analysed, both the study area and the countryside designation zones suffered changes in landscape features.

ACKNOWLEDGEMENTS

I would like to thank Chris Bird, for reading the various drafts of this thesis and making constructive and helpful comments and overall for his support and encouragement in any stage of this project. I will never forget the help and availability he always had for me.

NATO-CNR provided the funding for this research through the Fellowship that brought me to Silsoe.

I am also grateful to :

Tim Brewer for the useful exchange of ideas during the photo-interpretation stage and for the use of his computer for the production of tables,

John Taylor for his helpful advice during the ground survey stage,

Mr Steward Cuff and Mrs. Mary Haw, planning officers in the Planning Department of the Bedfordshire County Council, for providing invaluable advice and essential documentation.

I would like to acknowledge the help of all my friends here in Silsoe, in particular Flavio, for their understanding and support.

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LIST OF ACRONIMS:

APA	Agricultural Priority Area
API	Aerial photographic interpretation
AGLV	Area of Great Landscape Value
AONB	Area of Outstanding Natural Beauty
ASPRS	American Society for Photogrammetry and Remote Sensing
BCC	Bedfordshire County Council
BNHS	Bedfordshire Natural History Society
CAP	Common Agricultural Policy
CC	Countryside Commission
CDZ	Countryside Designation Zone
CIS	Countryside Information System
CPO	Compulsory Purchase Order
CPS	Countryside Premium Scheme
CSC	Chilterns Standing Conference
DEM	Digital Elevation Model
DTM	Digital Terrain Model
DoE	Department of Environment
ECLUC	Ecological Consequences of Land-Use Change
EN	English Nature
ESAMP	Environmentally Sensitive Areas Monitoring Programme
FDS	Farm Diversification Scheme
FWS	Farm Woodland Scheme
GIS	Geographical Information System
Gr Blt	Green Belt
ITE	Institute of Terrestrial Ecology
LNR	Local Nature Reserve
LUC	Land Use Consultants
MAFF	Ministry of Agriculture Fishery and Food
MBDC	Mid Bedfordshire District Council
MLC	Monitoring Landscape Change
MLCNP	Monitoring Landscape Change in the National Parks
MLURI	Macaulay Land Use Research Institute
NC	Nature Conservancy
NCC	Nature Conservancy Council
NCMS	National Countryside Monitoring Scheme
NCO	Nature Conservation Order
NNR	National Nature Reserve
OS	Ordnance Survey
RAF	Royal Aerial Force
SAS	Set-Aside Scheme
SBDC	South Bedfordshire District Council
SSSI	Site of Special Scientific Interest
TPO	Tree preservation Order
VDL	Village Develpment Limits
WGS	Woodland Grant Scheme

1. INTRODUCTION

1.1 Historical Context

This project was carried out with the financial support of a fellowship awarded within the Advanced Research Programme of NATO-CNR, which aims to facilitate the work of young researchers abroad.

The decision to carry out a piece of research on the influence of countryside planning policies on the landscape of Bedfordshire was influenced by factors relevant both in the local context of the County and in a wider national context. The countryside of Bedfordshire has been subject to significant changes caused by the intensification of agricultural practices, a widespread presence of mineral works and quarries and an increase in developed land. In the last decades landscape and land-cover changes have occurred as a consequence of natural, economic and social factors.

Land-use policies, within the framework of the planning system, and agricultural policies had a major role in influencing these changes. The system of planning controls and of countryside designations has not always been given sufficient strength to prevent negative impacts from other land-uses on the landscape and the rural environment. For example agriculture and forestry, which are among the major land-uses, require no planning permission. Land-use and countryside policies applied in the UK since the 1950 s' often lacked integration into a coherent framework with a clear definition of objectives. Some of them were mainly addressed to control over development, others were more directly linked with the conservation of areas of countryside with outstanding landscapes. The overall effects of these policies at a county level in terms of gains and losses of landscape features or changes in land-cover over a range of time are generally not known.

More recently, changing attitudes both at European Communities and national level have lead to the introduction of policies and legislations more compatible with the need for conservation of the environment with important implications for land-use and landscape.

Within this dynamic scene the development of new strategies for conservation and management is dependent upon a knowledge, through periodic monitoring, of the changes that present and past policies have produced. The effectiveness of these strategies may be checked in relation to their original aims and improvements may be made. Carrying out this task requires landscape and land-cover data for a large area and related to different time series. These data are often not readily available with a sufficient level of detail: advanced technologies such as aerial photography and satellite imagery had a revolutionary impact in providing periodical and up-to-date information on landscape and land-cover. The investigation of the consequences of the implementation of new policies or the modelling, before their application, of the potential effects, is a process that requires the integration of different datasets. For example, data on land-form, soils, land-cover, landscape and various planning and environmental constraints are all elements that have to be taken into consideration in the decision making process of the allocation of the land to different land-uses. GIS technology, with its capability to provide quick access to large volumes of data, link different data sets and model the consequences of strategies before they are implemented, has the potential to be particularly suitable in the process of land-use planning.

This research covers a range of years from 1968 to 1991 during which policies for land-use have turned in the direction of greater regulation in the countryside, with a strong emphasis on conservation. Through the application of aerial photographic interpretation (API) and GIS technology the project aims to study landscape and land-cover changes and to investigate the effectiveness of countryside designations in relation to their primary objectives. The information provided can be an element upon which new conservation strategies can be based or existing policies can be more effectively addressed.

1.2 Project Overview

1.2.1 Aims

The main aim of this project was to investigate, at county level, landscape and land-cover trends in the last twenty years, from 1968 to 1991, through 1981, in relation to the influence that countryside designations (e.g. Areas of Outstanding Natural Beauty, Areas of Great Landscape Value, Green Belts) and land-use policies had upon them. The suitability for this purpose of API as the main data source and a geographic information system (GIS) for data management, analysis and output was assessed while carrying out the task. The land-cover and landscape of a selected study area within the County was characterised. Furthermore the character of each countryside designation was analysed in terms of land-cover types and their changes. To this purpose, a comparison of the changes outside and inside the designated areas was also performed.

The relationship between land-cover and the three terrain characteristics such as elevation, slope and aspect was analysed in the study area and selected countryside designations as a demonstrator of the role that land-form information may play in this type of analysis.

The digital format of all these data in the GIS database is very flexible and open to further developments: it can be a base for the establishment of new projects on the whole county.

Finally it should be pointed out that this project did not have the purpose of assessing the aesthetic or ecological value of landscape. The methodology of landscape mapping applied here does not imply a final evaluation of landscape or the partitioning of land into areas of different landscape character. The output is in terms of quantity of landscape features per unit of land and gains and losses of these features through time. The selection of the landscape features in the classification scheme was mainly influenced by the possibility of deriving them from the aerial photography, although aesthetic and ecological factors were taken into consideration. Landscape mapping can be a prerequisite for some methods of landscape assessment, but it is not sufficient to be considered as a method of landscape assessment itself.

1.2.2 Approach

The main approach, in Figure 1, consisted of using API to derive landscape features and land-cover data and a quadtree raster GIS for the data storage, management analysis and output. Through API, a census of landscape features was derived from three sets of photographs (1968, 1981, 1991) for a 96 Km^2 study area in Bedfordshire. These data were input in the GIS, together with the countryside designations boundaries and digital elevation model data to form the different layers of the database. The evaluation of the effectiveness of countryside designations and the analysis of the landscape dynamics in the study area, inside and outside the designated areas was performed within the GIS through the use of overlay modelling analysis.

1.2 3 Project Works

The project works included:

• **Literature review** on:

Land-use planning framework in a local and national context.
Use of aerial photography, satellite data and GIS in landscape and land-cover studies.

• **Preliminary survey of the study area** to obtain an overall impression of the main features of the landscape and to adjust the classification scheme to the landscape of Bedfordshire.

• **Photointerpretation of landscape** data from historic and contemporary aerial photographs.

• **Ground survey and accuracy assessment** of the data derived by aerial photographic interpretation.

• **GIS and computer work** such as input, processing and output of the data in mapped, graphic and tabular format.

• **Meetings** with planning officers from the Planning Department of the Bedfordshire County Council, Mid Beds District Council and South Beds District Council, before and during the project work.

• **Attendance at conferences** on project related subjects.

• **Presentation of a paper** with the first results of the work at the 1993 European Conference on GIS and an article with the definitive results to a journal.

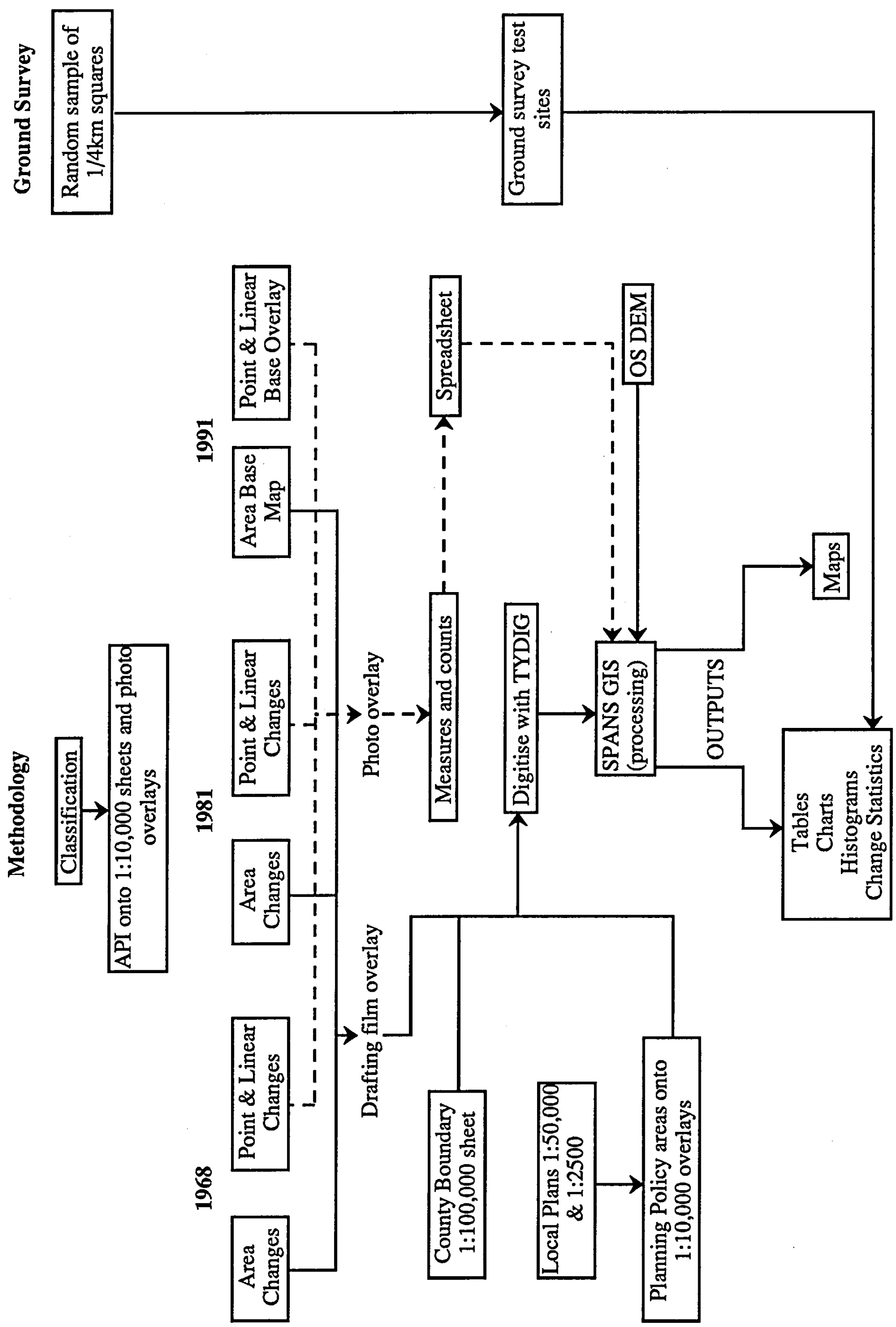

Figure 1: Flow diagram of the methodology

2. THE RURAL PLANNING CONTEXT: NATIONAL AND LOCAL PLANNING POLICIES AFFECTING THE LANDSCAPE AND LAND-USE IN BEDFORDSHIRE.

2.1 Landscape

The concept of landscape is widely used in common language and receives many different meanings.

In the Oxford English Dictionary (1971) "landscape" is defined as "A view or prospect of natural inland scenery such as can be taken in at a glance from one point of view; a piece of country scenery". In a recent piece of research by the Countryside Commission "landscape" is simply described in its most general sense as "the appearance of the land" (CC; 1991). Other authors recognise that there is not a generally accepted definition for "landscape" (Antrop; 1983) or "landscape quality" (Davidson and Wibberley; 1977). In the previous definitions and in many other pieces of research it seems however that major emphasis is given to the aesthetic perception of the landscape. In other words, the landscape as it appears to an observer (Briggs and France 1980; Dearden; 1980; Jaques 1980; Bishop and Bruce 1991). More recently, the application of notions of ecology at the scale of landscape, has moved the concept of landscape far beyond its simple visual appearance. According to this theory, the spatial relationships (e.g.. proximity, density, connectiveness) between elements of a landscape are important in affecting their ecological interactions, beside influencing their aesthetic perception. Therefore, according to this theory, a landscape can be of high value, although without a particular scenic beauty. Selman and Doar (1992) indeed conjecture that "aesthetic and ecological criteria are largely coincident". Although the study of landscape ecology has yet to gain popular recognition in Great Britain, a wide range of literature proves that some of its concepts have already been incorporated in landscape studies (Arnold 1983; Shreiber 1988; Harms and Opdam 1990).

Despite the different contents given to the concept of "landscape", there is a general agreement in recognising that the landscape, in type and quality, is the result of a large number of factors dating from different years (BCC 1973a; Peterken 1986; CC 1991). Land-form is a key element in shaping landscape and consequently is often considered in landscape studies (BCC 1973a; Dearden 1980; CC 1991). Soils, water courses and vegetation are the most evident natural elements in landscapes although they may have been more heavily influenced by man's activities during his long occupation of the land. Man has shaped landscapes to satisfy his socio-economic and cultural needs; land-use, one of the main elements of landscapes, is the expression of the exploitation of natural resources by man's activities. Elements deriving from this colonisation of the land are therefore an integral part of our landscapes. Some of them are a desirable inheritance of the past such as some historic features (old farmsteads, lanes and field walls), while some are the result of the more recent intrusion of the built environment in the countryside like pylons, roads, modern farmsteads and silos.

The presence and the spatial arrangements of these different (natural and man-made) elements and the way they interact together, gives origin to different landscapes. In areas where the dominance of land-form or hostile environmental factors restricted man's colonisation, landscape is still mainly dominated by natural features whereas those landscapes intensively used by man since the earlier times, have evolved over a long period in a mosaic characterised by a strong interaction between the natural and the artificial environments (e.g.. hedgerows from the enclosure period and conversion from grassland to arable land-use).

2.2 The Landscape of Bedfordshire

The landscape of Bedfordshire, a county whose land-use is dominated by cultivation, is mainly the result of the pattern of agriculture and, more generally, of the interaction of man's activities with the natural resources of this area over several thousands of years.

There are only a few areas were geological structure and its resulting land-forms are dominant in shaping the landscape. These are the chalk hills, part of the Chilterns, across the south of the county with its highest point (243 m) at Dunstable Downs; the Greensand Ridge, an outcrop of geological beds across the centre characterised by smaller and less rolling hills than the chalk downs; the north western plateau on the limestone which also has a major impact on the landscape, especially where it is dissected by the Ouse Valley, forming a shelf of high land rising to about ninety meters north of the river (BCC 1973a; BNHS 1980; BCC 1991).

There are few areas where the landscape has remained basically unchanged over the years. Agriculture has played a major role in landscape change in Bedfordshire. Indeed where the results of the farming economics of the past are still evident, the landscape tends to be more varied.

Most of the **hedgerows** (mainly as Hawthorn, Blackthorn and Elm) and their associated trees present in Bedfordshire date from the period of the Enclosures Movement in the 18th and early 19th centuries when by Act of Parliament open field systems were transformed into smaller fields bounded by newly planted hedges (BNHS1980; BNHS 1987). Although they were originally planted to establish properties and to control the movement of stock, from the aesthetic point of view hedges divide large scale landscape into a more human scale, bringing colour and seasonal change to the scenery.

Trees which are either isolated or associated with hedgerows are an important point of reference and indicate the scale of an open landscape (CC; 1988) although their function was not originally aesthetic, but as a traditional source of timber and shade for stock. The commonest species in Bedfordshire are Ash, Oak and Elm. (BNHS; 1980).

Another major imprint on the landscape was left by the growth of **great estates** in the 19th century characterised by a mixture of farmland, woodland and parkland to satisfy respectively the different needs of husbandry, timber provision, hunting and a pleasant view around the mansion. The estates of Woburn and Southill and the surrounding areas are good examples of this distinctive and diversified landscape (BCC; 1973a).

Woodlands, with their amenity value create a sense of enclosure and shelter in the generally flat landscape of Bedfordshire, although in this county they are very fragmented in nature and few are of an appreciable size. Indeed Bedfordshire is one of the least wooded of English Counties with only 5% of its surface tree covered (BCC; 1991). Woodlands are mainly concentrated along the Lower Greensand ridge of Mid-Bedfordshire, the limestone of the north west and the chalk of the Chilterns in the south and were originally composed of broadleaved trees although the proportion of coniferous species in managed woodlands has increased in the last decades for economic reasons.

Small spinneys and copses punctuating extensive areas of farmland in the corners of the fields are the inheritance of the past when coppicing of these small woodlands was part of the more extensive agricultural system (BCC 1973b; BNHS 1987). "Many of these small woods today provide a visual and ecological resource of enormous value, specially in England...." (Blacksell and Gilg; 1981). An important role in this system was also played by farm ponds, used for watering livestock and domestic water supply until the beginning of this century (CC; 1974).

Other minor features of agricultural landscapes are ditches, artificial drainage channels placed at the boundaries of fields often in association with hedgerows. They are linked with streams and therefore provide a continuous system of damp habitat in the countryside, although nowadays they often may be affected by pollution.

The landscape in Bedfordshire is very much influenced by the **agricultural pattern** which mainly depends on the quality of the land, which in this area is largely good (BCC; 1971). In the north, east and Mid-Bedfordshire the landscape is generally more uniform with large and intensively cropped fields, while in the west and south of the County the proportion of grassland increases due to the lower quality of the land (grade III in accordance with the Agricultural Land Classification System by Ministry of Agriculture Fisheries and Food) (BNHS; 1980). Some of the crops farmed in Bedfordshire, although intensive, give their contribution to the landscape with their colour and texture changing with the season. The contrast of the yellow colour of the flowers of oilseed rape with the green of grassland or wheat in May is a typical seasonal aspect of the Bedfordshire landscape.

Mineral works (mineral means in this context all substances extracted from the earth) dominate extensive areas of the County with the extraction of gravel, sand, chalk, clay and fullers earth. The impact on the landscape has been relevant, specially in areas like the Marston Vale where due to the open countryside the workings can be seen from many surrounding points of view. The Bedfordshire chalk downs are designated as Areas of Outstanding Natural Beauty (AONB) and although most chalk quarries are outside this area, they tend to be visible from within it. In addition, Bedfordshire has a higher proportion of derelict land if compared with England or the South East and 51% of this results from excavation and pits (BCC; 1992b). Some of these derelict areas, have provided conditions favourable to colonisation by wildlife (two biological SSSIs) or opportunities for geological studies (four geological SSSIs) (BCC; 1973c). Yet it is undeniable that in most cases they have drastic effects on the landscape.

Ancient monuments, artefacts (windmills, barns, walls), old farmsteads, field systems, fortifications and ritual monuments from different historical periods are an integral part of the landscape character of the countryside. Often constructed of traditional materials, they provide visual evidence of the landscape history, emphasise its character and are part of the national heritage of the country. In Bedfordshire there are approximately 2,200 "listed" buildings and over 70 scheduled monuments dating from prehistoric times to the 20th century (BCC; 1991).

Together with these historical features, as a result of the post war exodus from the cities, there is the more recent phenomenon of the expansion of urban areas and the **intrusion of urban elements** in the countryside. Commuters, retired people, second homers, encouraged by the tight planning controls around the major cities and the construction of motorways, have moved to the countryside with expectations of urban standards of service provision (Lowe et al.; 1986). Indeed the County Development Plan (1952) states that "Bedfordshire is within the expanding orbit and influence of London and is involved in the solution to be applied in dealing with that city's planning problems, especially the decentralisation proposals accepted as a basis of the Greater London Plan. Thus the rate of development within the County might reasonably be expected to increase.....". New roads, railways, sewage works, electricity lines in the countryside have been the necessary answer to this increasing demand for social and educational services (Blacksell and Gilg; 1981).

In addition, to satisfy the requirements of an "industrialised" agriculture, many **new farm buildings** are now built which are large and constructed from artificial materials creating therefore, in terms of colour and shape a strong contrast with the surrounding landscape. Although they are alien, like urban elements, to the countryside, from an aesthetic and ecological point of view, they have become an integral part of present landscapes.

2.3 Factors of Change in the Landscape of Bedfordshire

The past forty years have seen considerable changes in the landscape of Bedfordshire. These changes, having no precedent for their scale and pace, can be considered mainly as the expression of wider socio-economic modifications which occurred in the UK during the post war period (BNHS 1980; Blacksell and Gilg 1981; Lowe et al. 1986).

Agriculture has experienced a radical transformation as a result of deliberate government policy to fulfil the demand for food of a rapidly growing population. Increases in the productivity of crops or animal breeding were based on a more intensive use of mechanisation, artificial fertilisers, pesticides, genetically selected plants and animals. Farming has moved from a rather extensive and diversified system, characterised by a mixed husbandry, crop rotation, smaller size of farms and fields, to an industrialised enterprise with high levels of investments of capital and an increased efficiency in agricultural practices. The achievement of a high level of productivity was not pursued without considerable changes in the countryside. Many landscape features which in the past had their reason to exist because they were an integral part of the past farming economic cycle became hampering elements in carrying out the new farming techniques.

One of the most obvious expressions of these new trends has been the **clearance of hedgerows with associated amenity trees** (BNHS 1980; Lowe et al. 1986). The main reasons for their removal can be found in part in the enlargement of fields, required by the new machinery to carry out agricultural operations efficiently and in part in the cost in terms of money and labour involved in their maintenance and trimming. Barbed wire and fences are cheaper to maintain and more flexible in changing the grazing management. Other valid reasons from the productivity point of view of the farmer for removing hedgerows, are the control of weeds, since they diffuse from hedgerows, the gain of land and an easier mechanical maintenance of the ditches with which they were often associated. Furthermore the mechanical trimming of the hedgerows, while time and labour saving, has often acted too drastically on their size and shape, making them lose their ecological and scenic value. Amenity trees in or out of hedgerows, fared no better, partially because they were overmature or a cause of shade for the crops or because they hampered mechanical operations. Different authors point out that losses of hedgerows and trees have proved to be higher in arable land. (Lowe et al. 1986; Ward et al. 1990). Data from 1947 to 1985 for the South East Region (where Bedfordshire is placed) confirm this statement. Indeed there had been total losses of 30,000 Km of hedgerows, 2,000 Km of ditches and an increase of 4,000 Km of fences. (CC; 1990a). In Bedfordshire from 1940s to 1970s, 2,025 Km (31% of length) have disappeared (BCC; 1989). Despite the existing countryside policies and an increasing level of awareness in the people towards environment a recent piece of research (Ward et al.; 1990) indicated that from 1970 to 1985, in a study area in north Bedfordshire there was a loss of 50% of total vegetated boundaries (mostly in the form of hedgerows).

Small spinneys and copses (under 1 ha) since they represent a less economic use of the land (obstructing modern machinery operations) have been heavily cleared causing one of the main reasons of deterioration of the landscape in Bedfordshire (BNHS; 1980).

Farm ponds, once they had lost their original function, became redundant due to the changing technology of farm machinery or they dried up for the lowering of aquifers; the result of a survey carried out in Bedfordshire in a sample area was an 87% loss from the beginning of this century to 1976 (BNHS; 1980).

In this changing farming economy moving from the traditional mixed husbandry towards a more specialised form of agriculture the **agricultural pattern** has suffered radical transformations. The obvious result has been a drastic increase of intensive arable crops and a decline of the areas of grassland. In the South East Region from 1947 to 1980 there was a decrease of 2,701 Km^2 in areas of grassland (improved+unimproved) while the increase of cultivated land for the same period was 2,098 Km^2 (CC; 1990a). In 1939 grassland in Bedfordshire accounted for 54% of agricultural land; by 1985 there was only 15% coverage (REAP; 1987). Even in more recent times from 1970 to 1985, in Bedfordshire, arable land increased at the expense of grassland (Ward et al.; 1990). This trend is expected to be reversed in the next few years with the introduction of the Set-Aside Scheme in 1988, resulting in an area of land under grazing or permanent fallow of 29.194 Km^2 under this scheme in 1991 (BCC; 1991).

Woodland composition and area in Bedfordshire have changed in the last decades. The amount of losses of broadleaved woodlands in Bedfordshire from the 1940s to the 1970s was 12.02 Km^2 correspondent to the 30% of area present in 1940s (BCC; 1989). Yet for the same period there was an increase of 12.43 Km^2 of new plantations (predominantly conifers) grown mainly at the expense of valuable semi-natural habitats like broadleaved woodland, unimproved grassland and scrub (BCC; 1989). These trends agree with those occurred in the South East Region and England from 1947 to 1980, mainly as the result of different Forestry Grant Schemes aimed at the promotion of forestry in Britain. Indeed in these areas there were respectively a decrease of 578 Km^2 and 1709 Km^2 for broadleaved wood and an increase of 560 Km^2 and 2364 Km^2 for conifers (CC; 1990a). These schemes, nevertheless, were mainly designed to produce marketable timber rather than to protect those woodlands (eg. broadleaved ancient woodland) which, although having a high landscape and ecological value, were not economically competitive with the product of the conifer woodlands. Indeed the post war period saw a rapid increase in coniferous plantations, fast growing and easy to use, both in Bedfordshire (BCC 1973b; BNHS 1980) and in the UK (Gilg 1978; Blacksell and Gilg 1981). Beside the economical reasons, the decrease in deciduous woodlands was also caused by the Dutch Elm Disease, which has been spreading in Bedfordshire since the 1950s. This disease affected elm trees present in wooded areas, hedgerows or simply as amenity trees. Losses in the population of elms were estimated to be around 90% (BNHS; 1980).

Big changes in the **social structure** also played an important role in transforming the landscape to its present appearance. Between 1951 and 1976 the population of the County grew by 178,266 people, an increase of 56%. (BNHS; 1980). The fringes of the two main cities, Bedford and Luton, subjected to rapid growth, expanded their built up areas at the expense of the surrounding agricultural land. 8 Km^2 were taken by urban uses from 1968 to 1978 in Bedfordshire and 4.7 Km^2 around Luton, despite the presence here of a Green Belt since the 1960s (BNHS; 1980). The countryside, in the whole UK, simultaneously faced the opposite trend of rural depopulation, with the number of agricultural full time workers (and therefore of their families) declining by 70% between 1950 and 1980 (Lowe et al.; 1986) and the immigration of the middle or upper class population for whom a house in the countryside was an attractive prospect for a new style of life. The consequence was an increase in the countryside settlements, in services and communication networks and in new recreation facilities which altered the aspect of the rural landscape as it appears in the present.

A last important factor in modifying the landscape of Bedfordshire has been the **mineral works**, which had the greatest impact in the post war period and whose extent is exceptional for a county as small as Bedfordshire. The size of the quarries varies with the minerals worked but the area of land consumed has doubled from the 1950's to the 1970's. Indeed the working of minerals has been subjected to the attention of the County Council since they assumed the duties of Planning Authority with the Town and Country Planning Act of 1947. In the County Development Plan of 1952 it is stated that " The restoration of the large areas of land left derelict by the working of the minerals excavated prior to planning control provides an additional problem, the extent of which in terms of acreage, suitability and cost is now being examined..." (BCC; 1952). Yet in a more recent publication (BNHS; 1980) it is pointed out that only sand and gravel workings have been restored to a satisfactory level. The most devastating effects on the landscape are recognised to be the brickworks of the Lower Oxford Clay of the Marston Vale. Other mineral works like sand and gravels did not have the same devastating effect, because they were smaller in size and more erratic, although their area increased from the 1950s to the 1970s. The area of chalk works did not increase in the same period; any extension in their area would be very significant both for their great impact on the landscape and because they are very close to the designated Area of Outstanding Natural Beauty of Bedfordshire chalk-lands.

2.4 Countryside and Landscape Conservation Policies in Bedfordshire

The Town and Country Planning Act 1990, as amended by the Planning and Compensation Act 1991, provides the basis for land-use planning, the preparation of development plans and the system of development control. This is a consolidating Act which still essentially follows the national framework for land-use planning which was laid down in 1971 in accordance with which the first Bedfordshire County Structure Plan 1980 was drawn up and adopted. Indeed both the Town and Country Planning Acts require each planning authority to prepare one **structure plan**, and a number of **local plans**, which together constitute the development plan. The approved structure plan is prepared by the county planning authorities and sets out policies and general proposals for a County. Subsequent to the approval of the structure plan, district planning authorities can prepare local plans, under a Local Plan Scheme (programme for preparing statutory local plans) which develop and apply the provisions of the structure plan in greater detail. All these documents, therefore, formulate the policies for the development and use of land, including conservation of the countryside and landscape. In addition the Government agencies and local authorities are enabled to further the objectives of landscape and wildlife conservation by a legislative framework where the most significant measures in influencing the countryside change are contained in **The National Parks and Access to the Countryside Act 1949, The Countryside Act 1968**, which modifies much of the **Act of 1949 and the Wildlife and Countryside Act 1981**. Therefore in the structure and local plans a wide variety of countryside planning regimes is applied, deriving from both the environmental legislation and national planning policies previously mentioned. These are concerned with the restriction of the development in protected areas or on good agricultural land, conservation of the quality of the landscape and natural resources and enhancement of the countryside.

2.4.1 Green Belt

Green Belts are special regimes set out by the Government in the 1950s with the main aim of containing the outward growth of urban areas. Originally the purposes of Green Belts were to check the unrestricted sprawl of large built up areas, to prevent neighbouring towns from merging into one another and to preserve the special character of a town (HLGM; 1955). Subsequently, the recreational use of Green Belts for the urban population was stressed by enhancing their function in safeguarding the surrounding countryside from further encroachment and assisting the process of urban regeneration (DoE; 1988a). These areas, acting as a buffer between the cities and the countryside, suffer a considerably high pressure for development. The Green Belts have to be approved by the Secretary of State but they have no statutory basis; in other words they do not confer extra powers except that they have to be included as specially protected areas in approved structure plans and their precise boundaries must be shown in approved local plans. Their principles have Government support. They are expected to be several miles wide around the cities and to be maintained in the long term. Inside a Green Belt the general policies controlling development in the countryside apply but, in addition, there is a presumption against the construction of new buildings or the change of use of existing buildings "for purposes other than agriculture, forestry, outdoor sport, cemeteries, institutions standing in extensive grounds, or other uses appropriate to a rural area." (DoE; 1988a). Mineral works are not incompatible with Green Belt provided that the sites are well restored.

In Bedfordshire there is a non statutory Green Belt in the south of the county (South Beds Green Belt, 12 miles wide) submitted to the Minister in July 1960. The purpose was to contain the growth and coalescence of Luton, Dunstable and Houghton Regis; Leighton-Linslade; Ampthill and Flitwick (BCC 1980; BCC 1992a). The Green Belt was never formally approved until the County Structure Plan was approved by the Secretary of State in January 1980. Furthermore, the local planning authorities (in line with Government advice) applied Green Belt policies since 1960 and their decisions were well supported at planning appeals.

2.4.2 Areas of Outstanding Natural Beauty (AONBs)

Areas of Outstanding Natural Beauty were designated by the Countryside Commission under the powers of the National Parks Act 1949 (the same Act which enabled the designation of the National Parks in England and Wales) and the Countryside Act 1968. They are administered by local authorities and policies for them are contained in Structure and Local Plans. AONBs although smaller than National Parks are considered to have a landscape of equal beauty to that of the National Parks' and therefore worthy of the same level of protection. Government policy in these areas is primarily concerned with the conservation of scenic beauty of the landscape. Control of environmental policy is conducted largely through normal planning control (General Development Orders) and, therefore, without special planning controls the local planning authorities must exercise special care in controlling development. The conservation of AONBs can be achieved with management plans which set out the policy objectives in conservation, recreation and community affairs. Industrial or commercial development is inconsistent with the aims of the designations, but "proven national interest or lack of alternative sites can justify any exception" (DoE; 1988b). Quarrying, new road construction, routing of super grid power lines are forms of development where AONBs are likely to be sacrificed in the interest of the country.

The Chiltern Hills, part of which is in south Bedfordshire, were designated an Area of Outstanding Natural Beauty in 1964 for their valuable landscape features and sites of great historical value (SBDC; 1990). In the Chilterns area the local planning authorities apply the policies contained in "A Plan for the Chilterns" prepared by the Chiltern Standing Conference 1971 (CSC; 1971). These policies are concerned to "preserve the natural beauty of the landscape, to encourage uses appropriate to a rural area and to conserve wildlife. Special attention is paid to the siting, design and external appearance of buildings which are permitted, including those required for agricultural purposes (SBDC; 1990).

2.4.3 Areas of Great Landscape Value (AGLVs)

Areas of Great Landscape Value are smaller areas of land, identified by the County Council, where the quality of the landscape is considered equal to that in the approved AONBs. The significance of these areas is local rather than regional or national like AONBs. This is a local planning policy implemented in the 1950's by the local authorities who were primarily concerned with the conservation of the landscape character of these areas (BCC 1980; BCC 1992a). In AGLVs local planning authorities will not grant planning permission for development which would adversely affect the area. The designation strengthens planning controls, upholding reasons for the refusal of planning permission in the case of an unsuitable development, but does not confer additional statutory powers of control (BNHS; 1980). As for the AONBs the AGLVs are likely to be utilised for developments which, although considered unsuitable for the preservation of the landscape value of those areas, is recognised as being of national economic interest. As for AONBs informal recreation is encouraged and agriculture and forestry uses are considered compatible with the conservation aims for these areas, although "proposals for farm diversification will be treated sympathetically" (MBDC; 1989).

Bedfordshire County Council has defined ten AGLVs and their location and the policies related to them are reported in the structure and local plans.

2.4.4 National (NNRs) and Local Nature Reserves (LNRs).

National Nature Reserves were also designated under powers contained in the 1949 Act. The selection of Nature Reserves is made on the ground of providing a nationwide set of representative habitats and a balanced range of major types of plant and animal communities existing in England and Wales. The selection is primarily for scientific purposes. In England NNRs are either owned or leased and managed by English Nature (EN) (successor body of Nature Conservancy Council (NCC), previously Nature Conservancy) on which the protection of these areas depends. Local authorities also have statutory powers to acquire areas of land with outstanding ecological value to set up Local Nature Reserves. The protection of the environment from development in the Nature Reserves depends on management agreements made with English Nature or a local authority. The agreement is intended to legally protect the area from any operation damaging the integrity of the nature reserve.

In Bedfordshire there are 5 LNRs (BCC; 1991) and 2 NNRs at Barton Hills and Knocking Hoe (BCC; 1989).

2.4.5 Sites of Special Scientific Interest (SSSIs)

Since 1949 the Nature Conservancy and its successors bodies have identified areas of land or water containing plants, animals, geological features or land-forms of special interest as Sites of Special Scientific Interest. Most of them are representative of a particular type of habitat whose special interest depends on the continuation of traditional management practices. Although each area was notified by the NC to the local planning authority as an SSSI, owners and occupiers of SSSIs often carried out damaging operations to the site, without knowing it was notified because they did not have any formal relationship with the NC. Indeed by a survey carried out randomly on 399 out of nearly 3,000 biological SSSIs by the then Nature Conservancy Council in 1980, it was discovered that significant damage had been suffered in 13 % of the sites (Withrington and Jones; 1992). Under the provisions of the Wildlife and Countryside Act 1981 SSSIs were given increased protection by setting out a renotification programme of all the sites to owners and/or occupiers, to the Secretary of State and to the Local Planning Authority. The notification comprises a statement of the special interest, a boundary map and a list of operations which appear to EN to be likely to damage the site. EN can offer a management agreement where the owner or occupier is going to perform any damaging operation prohibited in the site. If a management agreement cannot be concluded the only way for EN to protect the site is to obtain a Nature Conservation Order (NCO) by the Secretary of State for the Environment and ultimately if an agreement still cannot be concluded, a Compulsory Purchase Order (CPO).

In Bedfordshire 37 sites have been defined by EN as being of particular wildlife value and 4 of geological interest (BCC; 1991). Their boundaries are defined in local plans.

There are other land-use and/or agricultural policies which, although they are not proper countryside conservation regimes, are worth considering as they can have an important influence on land-use and landscape changes in the countryside. They are:

2.4.6 Agricultural Priority Areas (APA)

From the post war years to the 1970's the annual rates of transfer of farmland to urban uses were high and especially so in the urban fringe. The awareness that agricultural land is a national resource, being at the basis of UK food production and therefore of the necessity to protect this land from irreversible development, became a crucial factor in the allocation of the land for development in the late 1970's. Indeed the planning authorities lacked information upon which to decide any application for planning permission and it was only in the late 70's that MAFF produced an Agricultural Land Classification System (MAFF; 1988) aimed, in part, at providing detailed information on the quality of agricultural land for land-use planning. This system divides the land into five grades (grades I and II are excellent and very good quality land) and although the resulting set of maps were at too small a scale for using in the evaluation of individual sites (Blaksell and Gilg; 1981), it was used as a base for the outlining of the APAs. The APA is a designation where, as stated in policy 3 of the Beds Structure Plan Alterations No.3 (1992), "in recognition of the high agricultural quality of the land ....the local planning authorities will resist proposals which would reduce the long term availability of the land for agricultural and countryside recreation purposes". This policy was first implemented through the County Structure Plan in 1980 (BCC; 1980). The areas are shown in the Structure plan and in more detail in the Local Plans. It applies to land of grades I, II and upper III of the MAFF Agricultural Land Classification System (MAFF; 1988). Where development, not in accordance with a development plan, would involve a loss of over 20 ha of this protected land, which was previously used for agricultural purposes, local planning authorities are required to consult with MAFF before granting planning consent (Harte; 1992).

In Bedfordshire much of the north and east of the county is designated as "Agricultural Priority Area": indeed 4% of Bedfordshire farmland is classified as grade I and 40% as Grade II (BNHS; 1980).

2.4.7 Set Aside Scheme (SAS) and Other Grant Schemes for Diversification of Farming

Set-Aside Scheme (SAS) and other diversification schemes such as **Farm Woodland Scheme (FWS), Woodland Grant Scheme (WGS), Farm Diversification Scheme (FDS)** are the product of more recent policies set out in the

1980's in the UK partly as the result of a revised Common Agricultural Policy (CAP) (Robinson; 1991). These policies aim at reducing intensive agricultural production by encouraging farmers to grow less of the foods in surplus, either by changing the use of farm land, or by diminishing the production from it. The FWS, SAS, and WGS are agricultural policies more concerned with the containment of over-production than with the conservation of the environment.

The **Set-Aside Scheme** was launched in the UK in June 1988 with the primary purpose of reducing the surplus production of cereals and other crops by the voluntary removal of land from arable production by farmers (Lennon; 1992). Under an arrangement which runs for either one or five years, farmers receive grants for leaving such land fallow, converted to woodland or used for other non agricultural purposes (eg farm-based tourism or keeping horses). The application of pesticides and fertilisers on land set aside is generally permitted, but payments for environmentally friendly practices are not included in the scheme. Another scheme, tightly linked with the SAS, administered by the Countryside Commission in six counties in Eastern England, among which is Bedfordshire, is the **Countryside Premium Scheme (CPS)**. It applies in addition to a five years Set-Aside Scheme for the payment to the farms of a Countryside Premium for managing the land principally for the benefit of wildlife and/or landscape (eg creation of wooded margins, meadowland and wildlife fallow) (Lennon; 1992). The total amount of Set Aside in Bedfordshire at February 1991 was 33.33 Km^2 (3.6% of Bedfordshire agricultural land) of which 29.08 Km^2 were in permanent fallow; under the Premium Countryside Scheme the area of land entered from 1989 to 1991 was 6.14 Km^2. (BCC 1992b).

The other two schemes introduced in 1988 in the UK are complementary to the previous ones in that they aim to promote, with a system of grants, farm forestry in set aside land. The **Farm Woodland Scheme (FWS)**, operating over a three year period, aims to persuade farmers to plant new woodlands on productive agricultural land or grassland (Robinson 1991; Gregory 1992); the **Woodland Grant Scheme (WGS)** operates in tandem with the FWS to stimulate the growing of timber on farms with the special intent to encourage broadleaved tree planting (Gregory; 1992).

Furthermore the diversification of agricultural business and the reduction of intensive agricultural production is promoted by the **Farm Diversification Scheme (FDS)**, introduced in January 1988 and by the Farm Land and Rural Development Act 1988. The former encourages non agricultural farm related business on land previously used for agricultural production; it is destined to last at least five years and includes activities such as farm-shops, the processing of farm products, sport and recreation activities like pony trekking or picnic sites (Gregory;1992). The latter provides grants for feasibility studies and for marketing costs of new on-farm activities in the cause of diversification.

Some of the more recent local countryside initiatives undertaken in Bedfordshire in 1990 and 1991 include:

• **The Luton/Dunstable Countryside Project** which aims to maintain and enhance the landscape character of urban fringe, the archaeological and wildlife value and to improve opportunities for public access to the countryside.

• **The Marston Vale Project** is one of the twelve currently being undertaken throughout England by the Countryside Commission and the Forestry Commission in conjunction with local communities. The main aim of the project is the increase of woodland cover in that area from 5% to 35% during the next 30 years and the restoration of derelict land from mineral works.

- **The Ivel Valley Countryside Management Project,** aiming to environmental enhancement of the area together with improvements in access and opportunities for informal recreation.

In addition grant schemes are available for the restoration of ponds in the county and the increase of the woodland area.

2.4.8 Tree Preservation Orders (TPOs)

The planning control over trees, groups of trees or small woodlands is exercised by the local planning authority through the Tree Preservation Orders which first appeared in the Town and Country Planning Act 1947 (later in the 1971 and 1990 Acts). The local planning authority can make orders for the preservation or planting of specified trees or groups of trees to inhibit cutting down, lopping, topping, wilful damage or destruction. The powers which local authorities have with regard to trees can be exercised only if it is "in the interest of amenity". If trees are lost they must be replaced with similar specimens and a fine may be payable, although an irreversible damage to the landscape has already been carried out.

2.5 Influence of Countryside and Landscape Conservation Policies in Bedfordshire

It can be seen, from an analysis of the main planning controls applied in the countryside, that the system of development control [1] which, from 1947 to the present has been mainly based on the Town and Country Planning Acts, has served a valuable purpose in keeping the countryside free from built up area encroachment.

While all private development has been subject to stringent controls by the local planning authorities since 1948, **development by Government Departments** and Statutory Undertakers [2], is often responsible for major land-use and landscape changes, but in various respects is independent of the normal planning system because such departments secure planning clearance by means of separate consultative procedures (CSC 1971; Harte 1992). They are generally obliged to allow public debate before introducing new schemes but they are only required to notify local planning authorities of their intentions. In Section 11 of the Countryside Act 1968 it was stated that "Every minister, government department and public body shall have regard to the desirability of conserving the natural beauty and amenity of the countryside". Although later it has become increasingly common to require government bodies to take account of the impact on the landscape of any new schemes introduced, no definitive guidelines or methodologies are provided to explain how a likely impact on the landscape is going to be assessed. Indeed it is generally recognised that landscape evaluation is a particularly difficult exercise partly because

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[1] Development is defined in section 55 (1) of the Town and Country Planning Act 1990 as "the carrying out of building, engineering, mining or other operations in, on, over or under land, or the making of any material change in the use of any building or other land (HMSO; 1990).

[2] "Statutory undertakers means persons authorised by any enactment to carry on any railway. tramway, road transport, water transport,......." in section 262 (1) of Town and Country Planning Act (1990).

of the difficulty of valuing, in accountancy terms, the visual deterioration of the landscape and partly because this evaluation must satisfy different purposes and uses (e.g. recreation, conservation).

Another main factor which has made policies concerned with maintaining and improving the quality of the landscape difficult to implement is the freedom which **agriculture and forestry** have always had from the system of development control. The use of land and building for the purposes of agriculture and forestry, including afforestation, does not constitute development within the meaning of the Town and Country Planning Acts and hence planning permission is not required for these activities. The exception is for large farm buildings which do require express permission.

The exclusion of agriculture and forestry from development control occurred in the post war period when an emphasis was stressed on food and timber production. Agriculture was not viewed as a threat to the countryside but as the prerequisite to a viable rural environment.

Agriculture and forestry are the major land-use activities in the countryside both for the scale and extent of their land-uses and for the detail of their day to day activities. Because of this factor and being largely exempt from planning controls they can be considered responsible for the major changes in the rural environment. This freedom from planning permission originally guarantied a privileged position to the farmers by providing the maximum flexibility in changing from one crop or agricultural activity to another depending on the conditions of the market. This exemption from development control becomes less understandable when applied to long-term land-use changes such as afforestation, conversion from grassland to arable land or estate improvements such as drainage and the enlargement of fields. Indeed these changes, more than the conversion from one crop to another, often implied the greatest impact on landscape features, such as the removal of hedgerows to enlarge fields. Furthermore, another visible result of this permissive policy is the intrusion in the countryside of many isolated farm buildings which for materials and size are recognised to alter the aesthetic quality of the landscape.

Despite the generally recognised impact that agriculture and forestry has had in modifying the landscape in section 55 (1)(e) of the most recent Town and Country Planning Act 1990 it is still stated that "the use of any land for the purposes of agriculture and forestry (including afforestation) and the use for any of those purposes of any building occupied together with land so used" shall not be taken to involve development of the land.

Under the statutory planning system there is a **little or no control over the loss of many minor elements of the countryside** such as hedgerows, small spinneys, ditches and ponds whose cumulative effect is very important. Generally there is nothing to prevent tree removal, unless a timber felling licence (under the Forestry Act 1967) is required or a Tree Preservation Order is in force. Felling licenses only apply when quite large quantities of timber are to be cut. Tree Preservation Orders have been only rarely used to preserve trees in the open countryside because of the lengthy and complex administrative process. Local Authorities rather tend to apply them mainly in areas used for recreation, in new village estates or in the open countryside but just for trees of amenity value (BCC 1973c; Blacksell and Gilg; 1981). Beside, the weak point in the application of TPOs is whether an Order should be made or not on the ground of "a loss of amenity" if the trees were felled or lopped; Local Authorities are not provided by the planning apparatus with any guide-line or method to assess a possible "loss of amenity" and therefore the choice is at their own discretion. Furthermore TPOs cannot normally be applied to hedgerows (BCC; 1973c).

The appearance of the countryside is not only determined by the inadequacy of the statutory planning system to prevent many of the major landscape changes, but also by policies in grants and subsidies, promoted by MAFF in part under the European Common Agricultural Policy. Some of these have been assigned in the 1960s' for hedge removal, for ploughing up moor and grassland and for land drainage. The consequences were so effectively described by Blacksell and Gilg (1981; p.12): "In combination, they have not only hastened the trend towards field enlargement and hedge removal in existing arable areas, but also allowed arable systems to encroach on land previously too poor for cultivation due to limitations of slope, drainage or climate." The Countryside Commission's New Agricultural Landscapes study (1974) was important in demonstrating that alteration on the whole landscape, more than on individual features, depended on agricultural activity and the existing landscape policies at that time had little effect on the impact of agriculture in the countryside.

The trend of encouraging UK farmers to increase their production with aids and grants continued until the 1980s (Ward et al.; 1990), when due also to an increasing influence by the European Community new grant schemes like Set-Aside or Farm Diversification (already described above) more compatible with environmental conservation were introduced by MAFF. In the Set-Aside Scheme for instance, fallowed land has to be kept in good agricultural condition; hedgerows, shelter belts, and other features have to be maintained. Most recent regulations have extended the list of environmental features which farmers will have to maintain and protect including stone walls, "vernacular buildings", unimproved grassland, moor land and heath (Lennon; 1992). Yet the objection arises that these new schemes were primarily addressed to the containment of surplus production of food although they have also been aimed at the protection of the environment; furthermore within these schemes, farmers retire their least productive land first, but it is proved that the most dramatic alterations of the landscape have occurred on the most productive and intensively cropped land. This is why a new one year set aside scheme has been introduced (with the "old style" five years scheme) which involves the 15% of the land taken out of production, but on a rotational basis.

The attention of the Government has concentrated in selected areas appointed with special countryside designations (previously examined), statutory, linked to planning powers, or merely advisory. Yet these special regimes are also recognised not to offer adequate protection even for particularly valuable or sensitive areas (Lowe 1986; Harte 1992). One of the express purposes of these landscape designations is to ensure that higher standards of development control are adopted in such areas than elsewhere. Yet in general these exhortations are not accompanied by any extra powers or statutory procedures.

Shaw has discussed (1982; p.68) the ineffectiveness of AONB status and stated that: "It brought no special administrative and few obvious financial advantages. It had no impact on the open landscape and development control research indicates that planning practice scarcely reflected the existence of AONBs". This point of view has been supported later by other authors (Lowe et al 1986; Harte 1992). The same considerations can be attached to the AGLV designation. Insufficient strength in the action of such designations derives from the fact that controls over abuses is conducted through the normal planning system, with the limits reviewed above, enforced by guidelines which are not supported by any statutory power. Although in these areas the main aim stated is the conservation of natural beauty, the needs of other users such as agriculture and forestry are emphasised (Harte; 1992).

Statutory and non-statutory Green Belts acted as valid tools in preventing new development in urban fringes and managed to withstand the pressures placed upon them (Blacksell and Gilg; 1981). Nevertheless since their earlier development, they have not been conceived to influence the effect of other activities on landscape and land-use.

Together with the already mentioned negative tools for controlling development a system of **financial incentives** for environmental improvement or safeguarding have been applied in two main forms: grants and compensation payments. The former have mainly encouraged landowners to plant trees for amenity purposes and the latter have been used as a back - up to management agreements.

In areas designated as worthy of special protection among which there are also the already discussed SSSI, Natural and Local Nature Reserves, the Wildlife and Countryside Act 1981, section 39 empowers the Nature Conservancy Council and all planning authorities to make **management agreements** with owners and occupiers of the land. They "may impose...restriction...(on)...the method of cultivation the land, its use for agricultural purposes or the exercise of the rights over the land and may impose obligations...to carry out works or agricultural or forestry operations or do other things on the land." Up to the present they are the principal means which gave statutory powers to the local authorities to enforce controls over agricultural land-use. They vary depending on the requirements of the area and designation, but they make provision for a compensation in money made on the principle of lost income or fixed rate payments per hectare to reward farmers for adopting forms of agricultural production that conserve the environment. The entering by a owner and\or occupier into a management agreement is on a voluntary basis, but compulsory purchase orders and criminal sanctions may be used to encourage the conclusion of a satisfactory accord. The use of this power is actively encouraged by central government but, having compensation for management and purchase to be paid from the limited budget of conservation agencies rather than by MAFF, it is often limited by financial constraints and lack of personnel (Lowe et al.; 1986). Beside it is proved that management agreements work where both parties share conservation aims; when an agreement is violated or in case of compulsory purchase orders the enforcement is difficult for practical legal reasons and because of the lack in the NCC of any in-house legal expertise or prosecution unit which guarantee a professional approach to these problems (Withrington and Jones; 1992). Although the management agreements have proven their effectiveness as a positive measure to promote environmental protection, they act on too small areas (only in some areas with special designations - AONBs or AGLVs are not included) to be useful as a comprehensive means of control.

From an analysis of the countryside regimes discussed above, it emerges that the mere designation of land by itself does not guarantee a sufficient level of protection of landscape. The policies stated in these designations in most cases may be regarded as means to strengthen the statutory instruments but with no authoritative power. Indeed under the umbrella of "proven national interest and lack of alternative sites" any exception can be justified and many developments contrary to the spirit of designated areas have been permitted. Often decisions such as whether to give permission for a proposed development are left to administrators who often benefit from a wide discretion in interpreting the law. If erroneously applied this relative freedom may bring them to overrule areas with countryside designations because of the pressures of local issues concerning jobs and housing, ignoring the importance of a landscape change in its national context (Gilg; 1978).

It emerges that landscape conservation policies continue to remain peripheral in affecting farm decision making and their application can lead to conflicts with other pieces of legislation. Furthermore it is pointed out by several authors that countryside designations concentrate the attention on few designated areas leaving large tracts of the countryside as "white land", without any protection (Blacksell and Gilg 1981; Lowe et al. 1986; Ward et al. 1990). As a consequence of this and for the relative "soft" action of countryside designations the question rises as to whether or not to strengthen the system of designations with statutory powers or to redirect agriculture and forestry within a frame of more coordinated national policies for conservation. A better synergism between MAFF, conservation agencies and planning authorities would help to produce more integrated forms of environmental policy.

As a consequence of poorly coordinated countryside management; local authorities have taken initiatives in this direction. Apart from exercising these statutory controls within the framework laid down in the county structure plans, augmented where appropriate by local plans, local authorities have been active in promoting and undertaking landscape conservation and improvement schemes (e.g. restoration of mineral workings, tree planting). Yet from a survey carried out in 44 county council planning departments in England and Wales designed to determine the resources devoted to landscape conservation (Penning-Roswell; 1983) it appears that successful results depended also on the resources available in terms of personnel and budgets. The author pointed out that although "Many of these counties have cursory analyses of landscape issues within structure plans, little overall landscape strategy, are not proceeding with landscape subject plans, and have a poorly coordinated approach to tackling the "problems" they themselves have identified as significant within their area" and: "The present attempts of county planning departments in the landscape conservation field - apart from the basic development control provisions - are likely to have little effect on the overall appearance of future landscapes." (Penning-Roswell; 1983).

The Bedfordshire County Council is concerned with the conservation of the physical environment and the appearance of the countryside. In the County Structure Plan (BCC; 1980) major emphasis is given to the improvement of social and physical environment and the conservation of the County's natural resources. The Plan promotes the management principles set out in the Countryside Commission's document "New Agricultural Landscapes" (CC; 1974) and supports the policies contained in "A Plan for the Chilterns" (CSC; 1971). Support is also given to the broad policies agreed for the AONBs and AGLVs and the conservation of the higher grades of agricultural land is achieved through the Agricultural Priority Areas Designations. The Plan seeks to retain and increase the proportion of woodland, trees and hedgerows in the county and indeed many programmes of tree planting have been undertaken under different schemes with positive results. Furthermore a Countryside Strategy has been developed by the County Council with the aim of "creating a more attractive and interesting countryside, prosperous and widely accessible to the public" (BCC; 1990).

Although the schemes and strategies are having a valuable action in conserving and improving the environment of some selected areas, the land-use in most of the countryside in Bedfordshire is mainly under the control of the statutory planning framework with all the limits that have been previously reviewed. APA designations, aim to preserve the best agricultural land from development and the conservation of the landscape in these areas cannot be considered their natural consequence. Indeed the most valuable landscapes often fall in marginal areas of agricultural activity while APA designation may overlap with the most intensively cultivated fields and a consequent higher threat to the landscape elements. The landscape components of the Structure Plan are mainly very generalised and broad and although they can influence positively the use of the statutory planning tools and strengthen their action, they cannot do more. This is valid especially when elements proving national interests and lack of alternative sites are taken into account in making decisions. Indeed the by-pass (double carriageway) of the A6 Route built in the 1970s in Barton -le-Clay fell in the already designated Chilterns AONB. Again it is recognised in a report prepared by the County Council that "if chalk is to be worked in Bedfordshire on a National or Regional basis, permissions will almost unavoidably be sought in areas of landscape value" (BCC; 1973a). In another report by the BCC (1973b) difficulties are recognised in using T.P.O.s in preventing the continuous loss of tree cover from the County; an extensive application of the T.P.O.s is admitted to be beyond the resources of the County Council and, if undertaken, would represent an enormous task.

It emerges that, although the local planning authorities such as County and District Councils have focused on the main landscape and countryside conservation issues, often the resources available and the tools provided by the national planning and legislative frameworks are insufficient to start an effective strategy on the landscape of the overall countryside.

2.6 The Landscape Mapping in Land-Use Planning

As previously seen, a more positive and coordinated approach is required in tackling landscape and countryside issues at a national and county level. In recognising the importance which correct landscape management practices have in influencing the ecological, aesthetic, recreational and historical value of the countryside and the tight interaction existing between landscape and land-use it is clear that policies for landscape should be seen as a part of the policies for land-use planning.

Already in the 1980s different authors have pointed out the need for landscape management plans as part of structure plans (Blacksell and Gilg; 1981). In a more recent document published by the Countryside Commission (1990b) entitled "Countryside and nature conservation issues in district local plans" the importance of incorporating policies and proposals for landscape, nature conservation and countryside recreation into local plans is particularly stressed. The policies stated by local plans should be consistent with those set out in other plans (e.g. Structure Plan, District Plan, Mineral and Waste Disposal Plan, Restoration of Derelict Land Plan, Countryside Recreation Plan). They should identify those areas with the more valuable landscapes where policies of protection and conservation have to be implemented with higher priority or areas of damaged landscapes deemed worthy of restoration. Tree planting schemes or other schemes for the protection of minor landscape elements would be managed in a better coordinated approach. The CC (1990b) emphasises the need to adopt in the local plans an approach to landscape conservation "based on landscape character - the characteristics and features that make one landscape different from another, rather than necessarily better or worse." The focus at county or district level on landscape character, would also allow areas that have no specific designations (like AONBs, AGLVs, SSSIs) to be treated on their own merits. Many areas with outstanding landscapes lie astride two or more counties, it would be appropriate for the development of these plans to lie within a more general framework of regional plans which would provide common elements for strategic decisions and investments in a better coordinated and uniform action. A "joint working between county councils, adjoining districts and other bodies" is also stressed by the CC (1990b) in its guidelines. Furthermore the CC (1990b) strongly recommends the use of the technique of landscape assessment [3] in preparing local plans.

It emerges that a necessary step for the implementation of the policies for landscape and the conservation of the environment and for carrying out the landscape assessment mentioned above, is the availability of landscape and land-use data. Regarding this, different authors have pointed out the shortage of landscape data at an extensive scale (Gilg 1978; Blacksell and Gilg 1981; Lowe et al. 1986). Yet, even when landscape changes can be quantified, because of the shortage of satisfactory methodologies, it is always difficult to assess the degree to which the quality of the landscape has been affected, with the judgement depending very much on individual factors. Practical guidance on different techniques of landscape assessment is given in several publications by the Countryside Commission (CC 1987; CC 1988; CC 1991). Indeed several studies have been undertaken by different counties in the past to provide information on landscape as input for producing structure plans (BCC 1973a; DCC; 1974) or landscape local plans (DCC; 1985). Despite this there is not a single method for landscape assessment.

The practice of landscape mapping, although it cannot be considered a landscape assessment technique, is a prerequisite of some of the methods of assessment. The term landscape mapping in this context refers to a technique of showing the geographical distribution of different landscape elements, chosen after setting up a classification scheme, by deriving them from field work, aerial photographic interpretation or remotely sensed data. These elements, subsequently have to be quantified on an area basis. The opportunity to incorporate landscape mapping in the land-use planning process finds its reason mainly in the possibility to provide support information for developing landscape management plans, for planning land-uses (new settlements, mineral workings) which conflict with conservation and for studying the influence that implemented policies have already had on the landscape. The ideal approach would be to supply planning authorities with a common

[3] Landscape assessment is a general term comprising the processes of description, classification and evaluation of landscape.

classification scheme, with enough detail to distinguish single landscape elements such as trees, hedgerows, walls and with a selection of classes suitable for all the areas in Great Britain. The scheme should be a part of a common landscape mapping method applicable in an extensive way. To this purpose the method should make provisions for grouping the classes in main categories depending on the level of detail required. The landscape mapping process is a quantitative approach which, by providing sets of data of measured landscape features, reduces the degree of subjectivity in the characterisation of landscapes to minimum levels. For this reason the method can be applied with a good level of consistency and the sets of results can be easily interpreted by administrators and councillors.

The use of aerial photography to derive the data or relatively new technologies such as geographic information system to manage the database, together with the selection of representative areas to be mapped as a sample, can help in optimising this process, saving staff resources or time spent. The creation of a database through the process of landscape mapping, therefore would provide information to identify areas of special landscape value. The database, would provide a basis for reviewing existing areas formally recognised as having special significance in landscape terms and for designating any new area which should be formally recognised. It would also provide a basis for decisions on action of conservation and enhancement of desirable elements of the overall landscape or for improving areas of damaged landscapes. In planning new developments the ready availability of landscape data may help to detect the extent to which any landscape can absorb pressures arising from them. Furthermore, landscape mapping allows the location of landscape features, including those in designated areas, and the analysis of their spatial relation with other land-uses such as nearness to centres of population or accessibility through the road system. Finally, the use of landscape mapping would provide a basis whereby future changes can be compared realistically with the present situation. This practice of monitoring landscape changes on a periodical basis would allow the checking of the effectiveness of countryside and land-use planning policies on a more objective basis.

3. GIS AND REMOTE SENSING AS TOOLS IN LAND-USE AND LANDSCAPE STUDIES.

3.1 Landscape and Land-Use/Cover Data in the Rural Planning Framework: Some Applications

The need for collecting land-use and landscape data is demonstrated by a wide range of existing users and applications at different levels (Bird; 1991). These data integrate both the natural and human developed environments and therefore are a good focal point for studies on planning and the environment.

Much of the research that has been carried out, analyses land-cover and/or landscape change as a direct consequence of planning policies (Ehlers et al. 1990; Lo and Shipman 1990; Richman et al. 1992). These studies consider the different categories of land-use/cover and their spatial arrangement before and after the application of planning policies. The effectiveness of the measures applied is assessed by analysing the relationship between changes and their causes. This task requires the acquisition of different temporal datasets for two dates or more.

In the urban fringe (Hathout 1988; Treits et al. 1992) the pressures for development are higher and changes of land-use occur very rapidly as a consequence of planning policies. In these areas of high intensity of land-use, the landscape changes in a short period of time and therefore the availability of up-to-date information and frequent collection of data is essential.

Landscape and land-cover changes have been investigated in relation to the application in the countryside of special statutory designations such as AONBs, National Parks, Green Belts (Dunn et al. 1991a; Taylor et al. 1991; Hooper 1992; LUC 1993; Peccol et al. 1993; Wilcock and Cooper 1993). These studies aimed to investigate the impact of these more restrictive policies for the countryside on the features or qualities of the landscape which justified the designation. To this aim landscape data may be analysed in the more complex framework of a method for landscape assessment (Hooper 1992; LUC 1993). However to monitor the influence of countryside designations on landscape changes it is necessary to integrate the data on landscape, collected at different dates, with those derived from the boundaries of these areas. The analysis may lead to the comparison of the changes inside and outside the zones of constraint (Peccol et al.; 1993).

In other research the relationship between planning policies and land-use/landscape data is analysed within a modelling approach. The models may be developed for different aims such as for land evaluation, for resource development planning and policy analysis (Schultink; 1992), for evaluation of the consequence of new policies on the biophysical and socioeconomic environment (Aspinall; 1993), for the accommodation of new development in relation with land availability and accessibility (Quarmby et al.; 1988), or for simulation of hypothetical landscape plans for the rural environment (Selman and Doar; 1992). In these models landscape and land-use data are generally analysed in association with other collateral information relevant to the purposes of the study such as land-form, soils, geology, transport network, constraints zones. Often the assignment of weights to the data is required according to their relative importance in relation to the purposes of the model (Quarmby et al. 1988; Aspinall 1993).

The collection and measurement of landscape elements and land-cover data is essential in several methodologies of landscape assessment, either applied within the framework of land-use planning or for the conservation, restoration and enhancement of landscape (CC; 1988).

Some more recent research outlines the possibility to tackle planning and land management issues within the guiding framework of landscape ecology (Selman and Doar; 1992). Here landscape elements and land-cover are analysed in terms of quality, quantity and their spatial arrangement as they seem to influence greatly the ecological processes and the suitability of habitats for different species (Turner and Gardner 1991; Griffiths et al. 1993). Spatial pattern analysis including the number, size and juxtaposition of landscape elements or patches (Griffiths and Wooding 1989; Turner 1990; Bridgewater 1993) is a focal element in this type of investigation. Therefore the structural analysis of landscapes forms a fundamental base for landscape ecological studies.

It emerges that the availability of data on landscape and land-use is one of the most sensitive points in all the applications listed above. Furthermore it is increasing the need for accurate, up-to-date information collected rapidly and on a wide extent. Moreover this information is often needed at different scales, becoming larger with higher detail going from regional planning to the management of specific areas of land. The collection of landscape data for inventories and the need for its up dating is often influenced by constraints in terms of time and money and new technologies for the collection of data suitable to these purposes are required. The improvement of the comparability of data in space and time is another key factor in these studies. The need for analysing landscape and land-cover data with other datasets, modelling future scenarios, managing and retrieving information in a flexible way, documenting the results in a format suitable for decision makers such as politicians and councillors requires the use of techniques capable of handling large amounts of information in a quick and efficient way.

Conventional information sources such as topographical and thematic maps, statistics together with manual overlaying techniques have intrinsic limitations (Berry and Berry 1988; Moffatt 1990) and therefore now are integrated or replaced by relatively new technologies such as remote sensing and geographical information systems which have already proved their suitability for tackling these issues.

3.2 Remote Sensing for the Collection of Landscape and Land-Cover Data

It emerges clearly from the applications described above that the acquisition of information on landscape and land-cover is the first step to be undertaken for monitoring the effects of planning policies.

Remote sensing is the science of obtaining information about an environment through the analysis of data acquired without making physical contact with it (Lillesand and Kiefer 1987; Budd 1991). Within the different remote sensing technologies available, the use of aerial photography and satellite imagery has proved to be the most suitable to study landscape, land-use/cover and their changes.
The use of aerial photography and/or satellite imagery for the collection of landscape data is preferred by an increasing number of users for the following reasons:

• Provision of a synoptic view of the area: This allows the detection of structural aspects of landscapes such as connectivity or patterns of patches otherwise impossible from the ground. Components of landscapes are analysed in their integration and synthesis, the dominance of certain categories of land-cover and areas with different landscape character may be easily recognised.

• Availability of multiscale imagery: The amount of detail shown in a remotely sensed image is subject, among other factors, to the scale of the image. Depending on the purpose of the application, landscape data may be quite general when derived from satellite or small scale aircraft imagery or they can be very detailed when derived from large scale photography.

• Availability of multi-spectral imagery: The capability of measuring the spectral reflectance of objects in different regions of the electromagnetic spectrum is central to the identification and separation of the features on the ground.

• Availability of stereo imagery: This allows the study of the the land-form or the identification of minor features such as trees, walls, hedges.

• Availability of multi-temporal imagery: This allows the monitoring of short term changes and trends over longer periods of time. It may also assist the updating of already existing databases.

• Availability of data for the whole Great Britain: When considering aerial photography and satellite imagery together this is the case for a period of more than 40 years.

• Availability of remotely sensed data in digital form: Therefore they can be directly analysed with computer based technologies such as image processing and GIS with all the benefits related to information handling with such a systems.

3.2.1 Aerial Photography

Aerial photography remains the most widely used type of imagery in landscape studies and one of the major sources of such information (Antrop 1983; Dunn et al. 1991b; Bunce et al. 1992).

The discussion of the following points, related with the use of aerial photography, will intentionally focus on those aspects of major interest for the extraction of landscape and land-cover/use information. They are :

- **Spatial resolution**
- **Type and format**
- **Stereoscopic effect**
- **Photointerpretation**
- **Accuracy**
- **Availability**
- **Limits**

• **Applications**

3.2.1.1 Spatial Resolution

The spatial resolution of aerial photography is directly related to the scale. Since aerial photography allows an easy identification of most significant landscape elements it is preferred in those applications which require the extraction and measurement of minor elements of landscapes such as hedgerows, walls, ditches, trees, otherwise impossible with satellite imagery (Antrop; 1983).

The spatial resolution of aerial photographs is situated between 25 cm and 1 m (Antrop; 1983). For black and white aerial photography at a scale of 1:20,000 it is at least 25 cm on the ground and 30 cm for colour films (Budd; 1991). Aerial photography at 10,000 scale, which is the one used in this project, has approximately 16 cm resolution on the ground (Budd; 1991). 1:10,000 scale is considered good also for technical flying reasons, for general resource studies of areas from 45 to 120 Km^2 (Williams; 1971).

In studies on vegetation cover the most utilised scales vary from 1:2,500 to 1:20,000 (Fuller; 1983). For vegetation mapping 1:10,000 scale is considered the optimum scale for discernment of composition and boundaries (Ward et al.; 1971). For example panchromatic 1:10,000 scale has been used for determining the boundaries of vegetation communities in an area of lowland Britain (Williams; 1971). Lillesand and Kiefer (1987) refer that crown shape can still be determined from tree shadows for large trees growing in the open on 1:15,840 scale photographs. At scales smaller than 1:20,000, individual trees generally cannot be recognized when growing in strands.

In past applications which included the extraction of minor landscape elements (trees, walls, rows of trees) the scale adopted varied from 1:5,000 (LUC; 1993) to 1:28,000 (Budd; 1988) through a different series of values: 1:10,000 (Peccol et al; 1993), 1:20,000 (Taylor et al.; 1991), 1:24,000 (Taylor et al. 1991; Richman et al.; 1992). Main categories of land-cover type may be derived with a satisfactory level of accuracy from photographs at smaller scale such as 1:50,000 (CC; 1991) or 1:40,000 (Turner; 1990).

3.2.1.2 Type of Film and Format

Aerial photography is available in many different types such as monochromatic (which includes all forms of black and white photography), true colour or false colour (e.g. infra-red photography). Other authors discuss in detail the aspects related to the use of different types of film for general resource studies (Williams 1971; Paine 1981; Lillesand and Kiefer 1987). Until recently the most widely used type of film for landscape studies has been black and white panchromatic. This film was the only available when the earlier surveys were carried out and therefore is associated with most of the historic series. Furthermore it has a good resolution and low costs of the film and for the processing. However the superiority of colour film over panchromatic films for photointerpretation purposes is generally recognised because it represents an extremely important aid in the identification of objects (Jones 1969; Williams 1971; Lindgren 1985).

The format of photography most frequently used in land-cover applications is 230 x 230 mm (Fuller 1983; Budd 1991). It is best suited to covering large areas and providing a high degree of spatial accuracy.

3.2.1.3 Stereoscopic Effect

The stereoscopic effect obtained by an examination of a stereo pair of aerial photographs, provides information on the vertical dimension of objects. The analysis of landscape in integration with land-form aids the understanding of possible relationships between these two components, makes the process of photointerpretation easier for the location of the features on the new map and allows landscape elements to be distinguished such as trees from bushes, crops from grassland, woodland from scrub.

3.2.1.4 Aerial Photographic Interpretation

The extraction of landscape features from aerial photography is performed through aerial photographic interpretation. For a detailed discussion on fundamentals of photointerpretation see ASPRS (1983), Lindgren (1985), Lillesand and Kiefer (1987). Since on the photography there is a varying amount of distortion the image of these features, especially over long distances, may significantly change in scale and allowances must be made for this (Fuller; 1983). To this purpose the information is transferred directly on to a topographic base map by using a stereoscope. Elements clearly visible both on the photography and on the map such as fields boundaries, roads, tracks are utilised as a good reference for the location of the features. If large areas of semi-natural vegetation are present, because of the lack of fixed boundary information marked on the topographic maps it is often necessary to use photogrammetric plotting machines which, by correcting automatically the distortion, allow an accurate location of the boundaries. A consistent interpretation of landscape features depends also on other factors such as the skill of the photointerpreter, land management, atmospheric conditions, season of the flight (Hooper; 1992). For land-cover studies, summer months are indicated as the most suitable. In this period it is possible to identify woodland feature types, because of the presence of the canopy, and to distinguish between cereal crops and grassland (Budd; 1988).

3.2.1.5 Accuracy

The accuracy assessment is usually based on the comparison of data from photointerpretation with data collected from ground surveys in sample areas, in a moment as close as possible to the date of aerial photography. The accuracy of land-cover data derived through photointerpretation is generally high, having values between 85% and 90% (Taylor et al. 1991; Hooper 1992). Other authors indicate values of 90% or higher (Dunn et al.; 1991b).

3.2.1.6 Availability

Many of the earlier aerial photographs were taken by the Royal Aerial Force (RAF) which in the 1940s obtained comprehensive air photo coverage of Great Britain (Fuller 1983; Budd 1991). In the late 1960s and throughout the 1970s, most of Great Britain was resurveyed by the Ordnance Survey (OS) as part of a mapping programme (Fuller 1983; Budd 1991). Local authorities such as counties frequently commission aerial coverage. The survey may cover the whole administrative area or more restricted areas such as National Parks, AONBs, SSSIs. If considering that the earliest satellites for earth resources observation date back to the 1970s it is understandable how, aerial photography still remains at the present the major source of historic data on landscape and land-cover.

3.2.1.7 Limits

Although aerial photography remains the most important document in landscape studies, its limitations should be taken into account.

The opportunities for frequent coverage of extensive areas are restricted. Therefore the analysis of changes is limited to those dates on which aerial photographs were taken which might not include some important stages in landscape change. In other cases they are unique registrations without comparable repetitivity (Antrop; 1983) and if up-to-date information is not available the interval between registration and ground data collection may affect the results of the accuracy assessment.

The photointerpretation is generally described as tedious, tiresome and time consuming (Lindgren 1985; CC 1988; Taylor et al. 1991). This last factor makes the extraction of data extremely costly in terms of personnel.

The quality of the photographs might be of limited value for distinguishing certain land-cover types and problems in registration and distortion can affect the accuracy of the results (CC 1988; Dunn et al. 1991b).

Multi-spectral capacities are limited (Antrop; 1983) if compared with those of satellite data. A comparison of aerial photographic interpretation for land-cover mapping with the visual interpretation and classification of satellite imagery performed by Griffiths and Wooding (1989) indicated that although a greater number of cover types could be mapped from aerial photography, satellite imagery enabled broad cover types to be interpreted more effectively. Furthermore the same authors report:" the higher number of cover types interpreted from aerial photointerpretation is only gained at the cost of a considerable increase in interpretation time".

Although complete national coverage does exist for the 1940s, it is rare to find aerial photographs before that date. Problems are reported in finding complete and up-to-date cover especially for individual areas where gaps in the coverage can be a problem (CC; 1988).

3.2.1.8 Applications

The significance of aerial photography as a source of landscape and land-cover data is demonstrated by a wide range of applications. In this section some of the most relevant ones in Great Britain will be examined.

The first survey which used aerial photography as the major data source to study the current and past distribution of land-cover and its trends on a national basis was the Monitoring Landscape Change (MLC) project in 1986 (Hunting; 1986). A stratified sample by county was used and land-cover and landscape features were recorded from a series of sites in England and Wales, to obtain national estimates of the nature and extent of these categories. The potentials for mapping land-cover with

Landsat TM imagery were also assessed although the conclusions were that within a complete scene covering a wide range of landscape types and environmental conditions there was considerable misclassification between cover types.

A similar approach was used in the National Countryside Monitoring Scheme (NCMS) carried out by the Nature Conservancy Council (NCC). Aerial photography was the main source of information to provide quantitative data on defined structural components of rural landscapes and their changes from 1940s to the 1970s (Budd; 1988). Features like hedgerows, rows of trees and land-cover classes within habitat were analysed in samples stratified by county and then into lowland, upland and midland regions. The information so collected for the whole of Great Britain was to provide a basis upon which the effects of past, present and future countryside policies might be assessed.

The project Monitoring Landscape Change in National Parks (MLCNP) was carried out for the Countryside Commission to obtain statistical and mapped information on a wide range of landscape features which exist in the National Parks of England and Wales. The information on 38 land-cover classes, 8 linear features, 2 point features was derived on a census basis and 2 point features on a sample basis from the mid 1970s to the mid/late 1980s. The data were analysed with a GIS for each Park, the National Parks as a whole, counties, districts and parishes within Parks (Taylor et al.; 1991).

MAFF, in its Environmentally Sensitive Areas Monitoring Programme (ESAMP) started in 1987, used aerial photography as the basic source of information for land-cover and linear feature change. Having recognised that this means is less suited for monitoring the quality or condition of features, field survey was used for this purpose (Hooper; 1992). The ESAMP was designed to identify any significant changes to wildlife, landscape or historic features which occur after designation. This was going to provide a baseline for comparison with later resurveys and against which any changes can be measured.

The Land-Cover of Scotland Project was carried out by the Macaulay Land Use Research Institute for the Scottish Development Department in 1989 to compile a comprehensive database of the land-cover throughout Scotland. The source of information was aerial photography of 1988/89 at 1:24,000 scale from which 124 types of land-cover were recorded divided in principal, major, main features and sub-categories based on natural features such as presence of scattered trees, rockiness, erosion etc. (MLURI; 1990). The compiled information was then digitised and handled with a GIS for the creation of a raster dataset.

In the previous applications aerial photography was the major source of land-cover and landscape data for surveying extensive areas.

In the Warwickshire Landscapes Project, initiated by the Countryside Commission in 1988 (CC; 1991) aerial photography at 1:50,000 scale was used to derive land-cover data as one of the input datasets for a new method of landscape assessment. This application is significant because this new approach, which seeks to identify specific means for conserving and enhancing landscape character, is the first of its kind and its use is strongly recommended by the CC in the preparation of local plans (CC; 1990).

A number of other studies have been undertaken at a more local level where aerial photography is the main source of data for assessing the effects of planning policies. Some of these focus on the landscape change in London's Green Belt and Metropolitan Open Land (LUC; 1993), land-cover and landscape changes in part of the Central Valley of Scotland" (Richman; 1992), the estimate of temporal changes in agricultural and urban land-use in the outskirts of Birmingham (Ilbery and Evans; 1989), the analysis of farm landscape change in selected study areas in Upland and Lowland England (Ward et al.; 1990).

All the applications discussed prove that aerial photography has provided a valuable assessment of landscape changes especially when integrated with other types of data. This source of data combines the advantage of obtaining information over large area rapidly and creating a permanent record. This can be compared with data obtained subsequently to monitor the effect of land-use policies in the countryside or in urban fringe areas.

3.2.2 Satellite Imagery

Remote sensing technology has advanced rapidly and at the present is accessible to the majority of government bodies and research institutes around the world. Since photointerpretation has proved to be particularly suitable for the extraction of landscape and land-cover data, as demonstrated by a wide range of applications, the use of remote sensing to these purposes has encountered some resistance in its initial stage (Trotter; 1991). However, remote sensing data from satellites have nonetheless become well established as a primary source of information in many applications related to landscape and land-cover studies. Satellite such as Landsat and SPOT series have been specifically developed for the monitoring of earth resources and are the ones that most expanded the possibility of acquiring information on landscape and land-cover (Lillesand and Kiefer; 1987). Their sensors record reflectance of the objects on the ground in the visible and infrared part of the electromagnetic spectrum. The digital data are then transmitted back to earth, to ground stations equipped to receive and process the data (Campbell 1987; Lillesand and Kiefer 1987). The analysis of the data and the extraction of the information (e.g. land-cover classifications, qualitative and quantitative measures on land-cover types) is performed with computer processing techniques. These procedures aim to correct the image (radiometric, geometric, atmospheric etc), to enhance it to increase the visual distinction between features (Lillesand and Kiefer 1987; Mather 1992) and to categorise the pixels into land-cover classes or themes (Campbell 1987; Lillesand and Kiefer 1987). Since the first satellite for environmental monitoring was launched in 1972 there have been many improvements in the spatial and spectral resolution of the sensors as shown in Table 1.

3.2.2.1 Main Advantages of Using Satellite Data in Landscape and Land-Use/Cover Applications

One of the main factors which is generally recognised to be of main relevance in the practical applications of satellite remote sensing is that the raw data derived with it are in digital form and as already seen they can be analysed using computers (Quarmby et al. 1988; Budd 1991; Trotter 1991). The digital analysis, although it is an extremely costly and complex process if compared with conventional photointerpretation, has a series of intrinsic advantages for studies over large areas. Campbell (1987) reports that "the values of reflectance in digital form can be treated as numeric values so that they can be conveniently added, subtracted, multiplied, divided and in general subjected to statistical manipulations that are difficult to perform on a hard copy image".

Table 1: Remote Sensing Satellite Sensors Specifications
(Adapted from Budd; 1991).

SATELLITE PLATFORM	SENSOR	SPATIAL RESOL. (m)	SPECTRAL RESOL. (μm)		REPEAT (days)
Landsat 1-5	Multi spectral scanner (MSS)	79 x 79	Band 4	0.50-0.60	18
			Band 5	0.60-0.70	
			Band 6	0.70-0.80	
			Band 7	0.80-1.10	
Landsat 4-5	Thematic Mapper (TM)	30 x 30	Band 1	0.45-0.52	16
			Band 2	0.52-0.60	
			Band 3	0.63-0.69	
			Band 4	0.76-0.90	
			Band 5	1.55-1.75	
		120 x 120	Band 6	10.40-12.50	
		30 x 30	Band 7	2.08-2.35	
SPOT-1	Multi-Spectral	20 x 20	Band 1	0.50-0.59	26
			Band 2	0.61-0.68	
			Band 3	0.79-0.89	
	Pan-chromatic	10 x 10	Band 1	0.51-0.73	
SPOT-2	Identical in operation to SPOT-1				

These analyses can be carried out simultaneously in different spectral bands and precise measures of small differences in spectral values may be obtained (Lindgren; 1985). The computer based analysis yields consistent results if the same series of operations on the same data are performed. Furthermore data in digital format can be manipulated quickly and in large quantities and, once stored, their retrieval is instantaneous. Finally they may be integrated in a GIS with other data such as maps, databases etc. (Lindgren 1985; Campbell 1987) without the expensive data capture through digitising.

Broad multi-spectral range and high temporal repetitivity (Antrop 1983; Budd 1991) make satellite data particularly suitable to study rapid changes in the landscapes or in areas such as the urban fringe (Ehlers et al. 1990; Treitz et al. 1992). The area coverage per frame is much larger for satellite imagery than for conventional aerial photographs. Lillesand and Kiefer (1987) report that "more than 1600 aerial photographs at a scale of 1:20,000 with no overlap are required to cover the area of a single Landsat MSS image!". Consequently satellite images provide the coverage and a synoptic view which can be particularly useful for characterising the temporal dynamics of large areas or short-lived phenomena. If compared with aerial photography the cost of the data is much lower and thus particularly suitable for the analysis of extensive areas (Budd 1991; Trotter 1991).

All the factors just reviewed suggest that satellite images are unique for providing data on landscape and land-cover on a multi-temporal basis and for large areas.

3.2.2.2 Spatial and Spectral Resolution in Landscape and Land-Cover Applications: a Discussion

The major restraint for the application of satellite data in landscape studies on a wide extent remains their poor spatial resolution which, for these purposes, seems to be more important than the higher spectral resolution offered by these systems (Antrop; 1983). Although many improvements have been carried out since the first satellites were launched the spatial resolution is still not sufficient to single out minor elements of landscapes or small areas of land (Antrop 1983; Dunn et al. 1991b). This problem seems to affect particularly the applications in those areas of Great Britain where the pattern of land-cover is particularly fragmented and heterogeneous. SPOT-HRV or Landsat-TM may provide the thematic interpretation of primary components of landscapes such as land-cover with a good level of accuracy (Bird and Taylor 1990; Kershaw and Fuller 1992). Accuracy has been demonstrated to be quite similar in the data from the two sensors despite the differences in spectral and spatial resolution (Shimoda and Sakata; 1988). Yet linear features like hedgerows or walls and point features like isolated trees or group of trees cannot be identified even with the highest spatial resolution of SPOT panchromatic data (Botelle; 1989). Gulinck et al. (1993) report that woodland strips need to have a minimum width of 10 m to be identified with SPOT multi-spectral 20 m imagery and scrub patches and strips are identified as wood if the minimum width exceeds 15 m. The same authors recognise that in general, linear elements such as hedgerows, streams, country roads in SPOT multi-spectral data often appear as mixed pixels due to their narrow width; yet the classification of some linear features smaller than 20 m but higher than 15 m could be achieved in relation to their orientation. The possibility of detecting small surface phenomena such as country roads and patches smaller than the pixel size does not depend only on the spatial resolution of the sensor but also on the reflectivity of the objects and their contrast with their surroundings (Bodechtel and Jaskolla 1983; Budd 1991).

SPOT data may be used for deriving structural elements of the landscape such as proximity, connectedness, patch size and form (Gulinck et al.; 1993). Through the measurement and the spatial distribution of land-cover categories, useful information may be provided in landscape studies. Image analysis techniques have been applied successfully on Landsat-TM data to derive and measure, the number and size of different land-cover in land parcels, boundary lengths and the level of fragmentation between them (Griffiths and Wooding; 1988).

The poor spatial resolution in relation to the size of the parcels and the cost of the data of Landsat-MSS data and to some extent the Thematic Mapper, was regarded as being inappropriate for local planning purposes (Quarmby et al.; 1988): SPOT panchromatic (10 m) and multi-spectral (20 m) are preferred in these applications (Quarmby et al. 1988; Ehlers et al. 1990; Treitz et al. 1992). Also

Wilcock and Cooper (1993), who used MSS for monitoring the losses of semi-natural vegetation to agricultural grassland in an AONB in Northern Ireland, state that although Landsat-MSS imagery can provide information on these dynamics of change, the smaller pixel size in Landsat-TM and SPOT imagery extends the number of land-cover classes for which training signatures can be derived.

Through the merging of SPOT's 20 m multi-spectral and SPOT 10 m panchromatic data the quality of the resulting image is improved by combining the spatial resolution of the latter with the spectral resolution of the former to analyse areas characterised by a high fragmentation of parcels (Quarmby et al. 1988; Ehlers et al. 1990).

Landsat-TM data provided useful information to classify the semi-natural habitats of Cambridgeshire, such as scrub, deciduous and coniferous woodland, haycut, grazed and main arable crops for a total of 13 classes (Kershaw and Fuller; 1992). Despite many problems encountered, the authors report that depending on the class, the exact classification objectives and the measure of accuracy used, success rates varied between 75 and 95 % and no other methods could have provided greater accuracy in a full census of general land-cover.

Legg (1991) states that with Landsat images acquired during broader time windows it is possible to classify automatically cereals, root crops, grassland and woodland. The mapping of deciduous and coniferous woodland could be carried out with a high degree of accuracy over lowland Britain on an annual basis and upland areas biannually. The same author concluded that mapping urban change and up dating county land-use maps could be undertaken on an operational basis with these data. From other studies it emerges that broadleaved, coniferous and mixed woodland can be differentiated and mapped with an accuracy of 90-95% (Wooding; 1986). Another application in the Netherlands reports that the overall reliability of the land-cover classes (maize land, grassland, heathland etc.) derived from the Thematic Mapper imagery was 89.9% with a variation per class from 41.5 to 100% (Van der Lann and Meijer; 1988). Yet the accurate classification of some cover types such as (e.g bracken, broadleaved woodland, cereals and other crops) may require the use of multi season imagery which is not always available or free from clouds (Griffiths and Wooding; 1989). Furthermore in several applications it emerges that due to the relatively broad spectral bands of the Landsat-TM and SPOT-HRV and the high number of different land-cover types it is not possible to distinguish all categories of interest and some classes have to be merged (Townshend; 1992).

3.2.2.3 Limits

The utilisation of satellite imagery for deriving information on landscape and land-cover have significant limitations, beside the already discussed parameters of spatial and spectral resolutions.

Detection of change in images of the same areas may be affected by the lack of consistency due to variations in atmospheric conditions prevalent at the time of data collection or to changes in the surface reflectivity of the area. (Moffat 1990; Budd 1991). The presence of clouds may compromise the possibility of comparing different temporal datasets or the availability of uniform data for large areas (Bodechtel and Jaskolla 1983; Campbell 1987; Townshend 1992). Legg (1991) states that there is a significant regional variation in clear-view acquisition in Great Britain, resulting inland in the north of England worst areas. Radar systems may have the potential to solve this problem in the future (Antrop; 1983).

Steep slopes cause differences in the spectral characterisation of the features on the ground; this factor may limit the application of remote sensing in areas of uneven land-form (Budd; 1991).

The availability of historic series is restricted to a relatively short period of time if considering that the first Landsat was launched in 1972. Beside, data with improved spatial resolution for satellite imagery are available only from 1982 for Landsat-TM and 1986 for SPOT. Studies on land-cover before these dates have necessarily to rely on Landsat-MSS data whose spatial resolution is often too coarse for this type of application (Bird and Taylor; 1990).

3.2.2.4 Applications

Notwithstanding the considerable limitations discussed above, there are many examples of applications of satellite imagery in landscape and land-cover studies in Great Britain.

The Land-Cover Map of Great Britain produced using Landsat-TM data is the first such map since the 1960s and the first in digital form (Metcalfe et al.; 1992). The map is a composite winter/summer image using imagery gathered between 1989 and 1992. 25 land-cover types, including 17 types of semi-natural vegetation were mapped at field by field scale for the whole of Great Britain (excluding Northern Ireland). The accuracy corresponds to 85% of agreement with the field survey. The selection of 1 Km squares for the field survey was made from a stratification based upon the Institute of Terrestrial Ecology (ITE) National Countryside Survey. This database provides records on soils, plant species and cover, boundaries, land-use and management which may provide information to make inferences on the situation of the countryside in the whole Britain. (Metcalfe et al.; 1992). The range of possible uses of the data is broad, including planning of landscape management, detection of changing land-cover, assessment of landscape sensitivity to pollutants etc.

Within the project "Ecological Consequences of Land-Use Change" (ECOLUC), by DoE and ITE, the potentials of satellite imagery (mainly Landsat Thematic Mapper) has been investigated for detecting land-cover change and landscape pattern for ecological modelling. It was recognised that it was not possible to subdivide agricultural grassland into improved and permanent categories or to subdivide woodlands by species. Further subdivisions like arable land into wheat and barley might have been possible with imagery from specific dates and multi-date imagery (Griffiths and Wooding; 1989). According to the conclusions of the study Landsat-TM imagery provided satisfying result to map broad land-cover types rather than for detailed subdivision according to species.

Other applications include: Upland vegetation classification in Snowdonia using Thematic Mapper data (Williams; 1987), the National Peatland Resource Inventory (Mortimer; 1992) and the Moorland Mapping pilot project (Mortimer; 1992).

3.2.3 Conclusions

From the applications discussed above it emerges that aerial photography is more suitable for the extraction of landscape features or detailed land-cover classes than satellite imagery. Satellite imagery has been tested in different projects (Hunting 1986; Taylor et al. 1991) for use in landscape applications but did not give good results for the distinction of a sufficiently wide range of land-cover types over large areas with a uniformly high degree of accuracy. Yet satellite imagery has proved to be an unrivalled source of data for surveys of land-cover over large areas when very detailed cover types are not required. However several applications demonstrate that the most from these two different remote sensing technologies may be derived when they are used in integration: aerial photography may provide additional information for land-cover classification of satellite imagery and be a basis for accuracy testing (Griffiths and Wooding 1989; Ehlers et al. 1990) while the analysis of the spectral response of some features may give better results when carried out on satellite imagery. One of the technologies where this integration may be realised and the resulting output analysed together with other sources of information is GIS.

3.3 Geographic Information Systems

GIS is a computerized mapping system for capture, storage, management, analysis and display of spatial and descriptive data (Burrough; 1986) and at present it is one of the main technologies available for investigations on land-cover and landscape change.

Two factors were indicated in the "Chorley Report" (1987) as mainly responsible for an increasing impact of this relatively new technology on present and future applications:

- A reduction in the computer costs, associated also with a reduction in development costs of the software;
- An increased availability of commonly used data in digital form, which facilitates the manipulation and linkage with other datasets.

These factors, together with new development in GIS have increased the possibilities of running GIS with microcomputers and have led to a wide diffusion of these systems in agencies and research centres in the last decade.

Although GIS have different designs, depending on the main field of application, there are some components common to all the systems that are:

- Data input module: to collect and process spatial and descriptive data from maps, aerial photographs, remote sensors, and other sources.
- Database management module: to store the data and retrieve them rapidly and efficiently.
- Analysis module: to interpret the information stored in the database within and among different data layers.
- Displaying module: to present spatial and statistical results as maps, tables charts, reports.

The power of GIS lies also in the possibility of being interfaced with existing databases or other software such as packages for statistical analysis or spreadsheets that enhance the capabilities of these systems of acquiring and processing information.

3.3.1 Data Input

The input of data in a GIS is generally from different sources. The main ones are:

Topographic and thematic maps;
Remotely sensed data such as aerial photography and satellite imagery;
Published data such as censuses and statistical information.

The acquisition of the database is the most costly and time consuming process in the establishment of a GIS (Baker 1988; Johnston 1990). Most of the information is derived by digitising existing maps (Trotter; 1991) which is recognised to be a time consuming and expensive process (Campbell; 1987). The availability of data in a digital format such as those from existing databases or digital maps is increasing and raster input from satellite sensors is becoming more important in creating databases with the benefits of a more rapid data acquisition at a lower cost.

3.3.2 Storage and Integration of GIS Data

The digital database is defined by Johnston (1990) as "the single most important and expensive feature of a GIS".

The spatial data structure of the database and the storage mechanisms may influence greatly the memory requirements and the performances of the GIS. The major advantages of raster data structures in applications such as monitoring landscape change or natural resources in general, is a more straightforward spatial analysis and modelling together with an easier overlay and combination of maps with remotely sensed data (in raster format)(Burrough; 1986). In a quadtree raster based GIS these advantages are associated with a reduction of data redundancy and storage requirements achieved by using elements of the grid with varying sizes (Stow; 1993). However the trend is to move towards systems where vector and raster information are fully integrated (Burrough; 1988) although significant impediments still exist to achieving this target (Trotter; 1991).

By combining remotely sensed data with existing spatial, image and statistical data within a GIS it is possible to maximize the information content and analysis capabilities upon which responsible decisions for land-use planning can be made (Nellis et al.; 1990). Satellite data may not only be a direct source of data such as land or vegetation cover within a GIS. The information extraction capabilities from remotely sensed data can be improved by using some of the data layers in the GIS such as terrain, soil, vegetation type (Stow; 1993). For example, the accuracy of the classification of a satellite image for up-dating land-use information may be improved by using, as a frame of reference, the topographic information digitised from an out-of-date land-cover map of the same area (Van der Laan and Meijer; 1988). Improvement in the classification of features may be achieved by correcting their values of reflectances for the topographic effect with a digital terrain model (Trotter; 1991).

Yet the easy combination of different layers of data in a GIS to produce a derived thematic map may often lead to a final product whose absolute accuracy may not be well defined. This problem can arise particularly when combining data originally recorded at different scales and dates by different agencies and operators (Burrough 1986; Trotter 1991).

3.3.3 Analysis and Modelling

The large amount of spatial and non spatial information stored as different theme layers in the database of the GIS provides the basis for a wide range of manipulations and analysis which vary greatly depending on the purpose of the application. In this context only the spatial analysis relevant to studies on landscape/land-cover and planning and management related will be reviewed. For a broader discussion on the themes of analysis and modelling with a GIS see Burrough (1986) and Dangermond (1991).

GIS allow data analysis through the application of spatial models. The capability of GIS of combining different types of spatial data within a modelling approach allows some of the direct and indirect impacts of policies and plans to be predicted and considered. Some of these models make an extensive use of weighting factors, both for different data layers or for the different features represented within a data layer (Quarmby et al. 1988; Janssen and Rietveld 1990). This permits the production of new alternatives whenever new policies and priorities have to be taken into account and allows a variety of proposals to be compared (Aspinall; 1993). The spatial modelling capabilities of GIS may be utilised to detect areas with competing land-uses or potential land-uses, assist in the location of countryside designation or ecologically sensitive areas, analyse patterns and examine relationships of spatial features to each other or to other elements of the landscape (Selman and Doar; 1992).

The shape of the landscape can be used in the form of a digital elevation model (DEM) and combined with other thematic or quantitative data to perform inter-site visibility analysis, to calculate gradient and aspect of slopes, to model the visible consequences of new roads or bridges (Burrough; 1988), to measure the scenic potentials in areas of high scenic values (Miller et al.; 1992) or to model the visual impact of a new development on the surrounding environment (Quarmby et al; 1988). In these studies perspective views of the terrain can be produced by specifying eyepoint and viewpoint coordinates taking into account the vantage point of a person at ground level.

The location, extent and rate of recent and current changes in land-use and landscape may be investigated by using spatial overlay analysis on different temporal datasets (Turner; 1990). The analysis may not only be concerned with resource information but may be addressed to the study of these changes in specific areas of countryside designations such as AONBs, National Parks. SSSIs (Healey et al. 1988; Taylor et al. 1991; Peccol et al. 1993). The impact of these designating areas can be therefore modelled with a GIS to assess their effectiveness.

In another application, the distance of all forest patches from a target forest patch (e.g. a seed source) was easily computed with a GIS (Dunn et al.; 1991b).

The ability of GIS to create a buffer zone around point, linear and area features may be used to quantify land-uses depending on their proximity to factors considered to be central to the analysis (Johnston et al. 1988; Harrison et al. 1991; Dunn et al. 1991b).

The examples just reviewed, show some of the potentials of GIS technology in investigating impacts of past and new land-use policies, monitoring landscape change, exploring future scenarios and improving the information base available to policy makers for guiding decision-making.

3.3.4 Data Output and Display

Among the various benefits of using GIS in land-use planning is the flexible form of the output, such as maps, graphs, summary tables, which can be tailored to meet the specific requirements of the user (DoE; 1987). These may be in digital form or hard copies which are easier to understand for decision makers and policy makers.

Colour electrostatic plotters can be used for map output with minimum loss of quality if compared with traditional litho printing (Budd; 1992). The digital format of the data allows the up-date of maps quite easily and the generation of new maps and tables with great flexibility in response to the different type of queries. For example the geographical distribution of landscape features may be shown separately or associated with other layers of the dataset; a selection may be done for specific categories of land-cover (e.g. map of woodland types), changes to a particular category (e.g all changes to agro-pastoral land) or changes from one specific category to another (e.g. agro-pastoral to industrial land-use). Furthermore GIS may enable the aggregation and disaggregation of data between administrative units at different scales (region, county, district, parish) or within the same level of administrative units (e.g. data of different parishes).

The choice of the colours and of the general layout (scale, legend, orientation indicator) is done interactively by the operator and may be adapted to convey clearly the information content of the map to the user.

3.3.5 Applications

Some of GIS applications in landscape and land-cover studies have been reviewed above while analysing GIS components. Other applications to be mentioned are:

"The Use of GIS in the Analysis of Countryside Data" carried out for the DoE to explore the potentials for the use of GIS in the analysis of countryside data and to assess users requirements for both data and operational procedures. Planning, Environmental Monitoring and National Demonstration projects were chosen within which a number of themes were addressed (Harrison et al.; 1991) such as application of GIS to investigate the pressures for development in the countryside, management of semi-natural vegetation in the Dartmoor National Park in relation to sheep stocking rates, woodland inventory and others. The conclusion of the project, drawn also on the basis of the positive reactions to the demonstrators, was that GIS has great potentials to assist policy makers in helping to address key policy issues (Harrison et al.; 1991).

A digital database of landscape maps for each National Park in England and Wales was produced within the MLCNP project, carried out by Silsoe College for the Countryside Commission. The project demonstrated the usefulness of GIS in providing the information required, up-dating it, adding new layers to the database and for creating a basis for comparing future changes in the National Parks (Taylor et al.; 1991).

The Countryside Information System (CIS) has been developed by the ITE for the DoE to provide policy makers with information about the countryside and to support the work of policy advisers concerned with issues at national and regional scales (Haines-Young; 1992). The CIS contains sample based information derived from the "Countryside Survey 1990" and includes estimates of change for the periods covered by the earlier ITE surveys of 1978-84 and 1984-90 within the Land Classes and for Great Britain as a whole. All the three surveys were conducted using the ITE Land Class System which uses samples of 1 Km square drawn from environmental strata. For each sample square, mapped data are stored as a series of thematic overlays: five field maps describe physical landscape features, agricultural and semi-natural vegetation, forestry, boundaries, and structures such as roads and buildings (Lane et al; 1992). Census type data held on the CIS include information on grid squares falling under one of the different statutory designations.

An example of broad scale GIS as a support for routine policy applications is the one developed within the CORINE Programme of the European Communities. The database holds a wide range of datasets such as land-cover, designated areas, biotopes, soil types etc. Although the project was successful, a series of fundamental problems emerged mainly as the result of poor coordination, a lack of primary surveys and inconsistency in the data collection in the member states (Briggs; 1991).

These examples show how GIS may combine both data inventory and modelling capabilities in a single package to deliver information that is relevant to decision makers at different scales. The development of a more integrated approach to land-use planning and management of rural resources is made possible by the use of this technology. Decision makers are provided with a powerful tool for improving the decision basis and understanding the possible effects of the strategies adopted.

4. STUDY AREA AND DATASETS RELEVANT TO THE PROJECT

4.1 Description of the Study Area

The landscape is typical of the lowlands, with its lack of dramatic features and a dominance of the land-cover over the land-form. Nevertheless there are areas of outstanding countryside, such as a small section of the Chilterns, AONB and AGLV which comprises also the National Nature Reserve and SSSI of Barton Hills. The landscape of the Chilterns is characterised by chalk hills, steep slopes, grass downlands and beech woods with a dominant agricultural land-use. The study area also includes a portion of the Green Sand Ridge, partly AGLV, prominent elevated area of lower greensand, which is predominantly wooded. In this natural region are included the Local Nature Reserve and SSSI of Cooper's Hill, an example of heathland not colonised by woodland (BNHS; 1980) and the SSSIs of Maulden Church Meadows, Maulden Woods/Pennyfathers Hill and Maulden Heath. Between the Greensand Ridge and the Chilterns there is the natural region of the Southern Clay Vale. Here, features like intensive agriculture and lack of woodland are dominant in shaping the landscape, but two SSSIs have been notified by English Nature: Flitwick Moor - the largest unreclaimed area of marshland in Bedfordshire - and Pulloxhill marsh (MBDC; 1989).

The major settlements in the study area are Flitwick and Ampthill, which have been subject to development pressure in the past, mainly due to their proximity to the M1 motorway and the line of the main Bedford-London railway. The Green Belt designation to prevent the coalescence of these two towns and the north part of the Luton-Dunstable Green Belt are included in the study area. Other relevant forms of development, are the A6 and A507 roads, which are part of the Strategic Highway Network, and several mineral workings, some of them now derelict.

The east part of the study area is covered by APA designation and partly is "white land", which means that no special designations are applied.

4.2 Location of the Study Area

The study area covers 96 Km^2 (8 Km x 12 Km) and it is placed astride the mid and south Bedfordshire Districts. Having an approximately rectangular shape, the location of the four corners, according to the OS National Projection is:

	East m	**North** m
Left Bottom	502000	228000
Left Top	502000	240000
Right Top	510000	240000
Right Bottom	510000	228000

4.3 Reasons for the Selection of the Study Area

The selection of a study area instead of the whole county was a choice required by restraints in time and the funds available, after an estimate of the project work required per Km^2. This choice was made with the awareness that carrying out the project for all the county of Bedfordshire would have produced more complete results.

The selection was influenced by the following main factors:

• The availability of the data sets relevant to the project.
The data sets that most conditioned the choice were the historic and contemporary series of aerial photographs. Indeed while no problem arose in the availability and provision of large scale topographic maps and/or plans, it was necessary, by checking the flight plans, to ensure the coverage of the whole study area with the set of photographs for each of the three dates. The choice of the location of the area and of the dates was a compromise to satisfy this requirement.

• The presence of different countryside designations.
This was considered another essential condition given the aims of the project. The study was mainly to focus on rural land changes and therefore the presence of a dominant portion of countryside land was an essential prerequisite. From the bibliographical review and a consultation of the County Structure Plan it was clear that north Bedfordshire was mainly characterised by intensive agricultural areas lacking in countryside designations. South Bedfordshire, given the presence of the industrial city of Luton with its airport, the neighbouring cities of Dunstable and Houghton Regis and several quarries in use or derelict, was characterised by too high a presence of developed land.

4.4 Availability and Description of the Data Sets Relevant to the Project

A description of the data sets which provided significant or supplementary information in this project will follow.

4.4.1 Ordnance Survey (OS) Maps

These topographical maps were derived by the OS with a combination of aerial and ground survey methods (Harley; 1975). The national projection for these maps is a modified form of the Transverse Mercator or Gauss Conformal and it is the one adopted in this project.

• **OS 1:100,000 scale.**

Bedfordshire and Hertfordshire Administrative Map. Part of the 1:100,000 administrative areas map series, it shows the boundaries of the county, districts and civil parishes as notified to 1/10/1991. It provided the administrative boundary of the county.

• **OS 1:10,000 scale series.**

The sheets comprising the study area are:

TL02NE: surveyed at 1:2,500 scale in 1975-79 and revised for significant changes in 1980;
TL02NW: surveyed at 1:2,500 scale in 1975-79 and revised for significant changes in 1980;
TL03SE: surveyed at 1:2,500 scale in 1975-77 and revised for significant changes in 1981;
TL03SW: surveyed at 1:2,500 scale in 1976-83 and revised for significant changes in 1988;
TL03NE: surveyed at 1:2,500 scale in 1970-74 and revised for significant changes in 1978;
TL03NW surveyed at 1:2,500 scale in 1970-71 and revised for significant changes in 1976.

The sheets are part of the Regular Series of 1:10,000 OS maps, and they have been derived from 1:2,500 scale National Grid sheets. Each sheet represents an area of 5 x 5 Km and forms a quarter of a 10 Km square. National Grid lines are drawn on the 1:10,000 sheets at 1 Km intervals and, in the project, they provided the frame for the photointerpretation of linear and point feature per Km^2. These maps were also used to supply a common projection and scale for the land-cover data, derived from aerial photographs, and the countryside designations areas, derived from the local plans. These maps were used as a reference for drawing the boundaries of the land-cover areas. The boundaries derived from the photographs and those on the maps did not always correspond given the different dates of the two sources of information. The 1:10,000 scale maps were also used as supporting data to verify the location and nature of some of the features derived from the aerial photographs (e.g. location of reservoirs, ponds, quarries, pits, industrial estates, communication systems, electricity transmission lines etc.)

The maps were also utilised as a basis onto which to draw the boundaries of the countryside designations at a common scale.

4.4.2 OS 1:50,000 Scale Height Data - Digital Terrain Model (DTM)

The DTM consists of height values at each intersection of a 50 m horizontal grid. The values have been mathematically interpolated from the contours in the 1:50,000 scale Landranger maps. Height values are rounded to the nearest metre. Heights are listed reading south-north from the south-west corner of a 20 Km square. The accuracy in the DTM depends on the nature of the ground, ranging from 2 m in a hilly rural area to 3 m in an urban lowlands area.

The information provided by the OS DTM was used in the project to produce the elevation, slope and aspect maps.

Part of the tile TL02 has been used in this project.

4.4.3 Aerial Photographs

Three different series of aerial photographs, flown for the Bedfordshire County Council were used to carry out the aerial photographic interpretation (API). The sets date back to 1968, 1981 and 1991 and they have been the source of the linear landscape features, point landscape features and land-cover data.

The following points, related with the use of the aerial photographs, will be discussed :

- **dates of the photographs**
- **coverage of the study area**
- **quality of the photographs.**

4.4.3.1 Dates of the Photographs

The selection of the dates of the photographs was a compromise between the requirements of the project and the sets of photographs already available. Nevertheless other factors influenced this choice. The selection of three different dates was useful to detect possible trends of land-cover and landscape changes in a broad range of years. The coverage of the whole study area by the three sets of photographs was considered an important factor in ensuring the consistency of the API. The choice of the difference in terms of years between each set of photographs was also taken into consideration. This depends on the time over which changes in the land occur which varies depending on the object of the observation. For example the rate of change in farmed land between different crops can be annual, while other processes like conversion from cropland to woodland appears evident only over a longer period. A range of approximately 10 years between the dates of the photographs was considered suitable to the aims of this project. The most recent set of photographs available when the project started in 1992, was from 1991 and it was chosen to provide an up-dated picture of the land-cover and landscape as close as possible to the present. Two historic sets of photographs were chosen, the oldest dating back to 1968 and an intermediate to 1981. The 1968 flight was the first to be commissioned by the County Council to provide the complete coverage of the county, after that of 1947, flown by the RAF. The selection of the 1968 set was also influenced by the awareness that most countryside designations started in the 1960s or later.

4.4.3.2 Coverage of the Study Area

Detail on the coverage of the study area by the aerial photographs and their scale are given in Tables 2, 3, 4 and Figures 2, 3, 4.

4.4.3.3 Quality of the Photographs

The quality resulting from the combination of detail, contrast and overall density, together with the type and scale of the photograph, influences the visibility of objects and therefore the extent to which they can be detected (Vink; 1964).

The photographs available for the study area were generally of good quality. In all the sets, stereo coverage was available and there was no cloud cover. The photographs had a scale of 1:10,000 and 1:12,000 which seemed to be a good compromise between the need of a synoptic view and a sufficient detail for features like fences or trees. The scale of 1:10,000 facilitated the tracing of the boundaries of land parcels onto map overlays because it matched with the scale of the OS maps used as a basis for all the data compilation.

The 1991 photographs were colour and were clear and consistent. The quality of the print was good. The general absence of shadows and a flattening effect depending on the time of acquisition and on the vertical format of the shot, may have caused misinterpretation between isolated trees and bushes.

Table 2: List of Photographs Covering the Study Area for 1991.

Run	Film N°	Date	Scale
9	5272 to 5286	7/09/1991	1:10,000
10	5218 to 5232	7/09/1991	1:10,000
11	5106 to 5120	7/09/1991	1:10,000
12	1671 to 1684	21/08/1991	1:10,000
13	1621 to 1635	20/08/1991	1:10,000

Table 3: List of Photographs Covering the Study Area for 1981.

Run	Film N°	Date	Scale
11	9235 to 9249	22/06/1981	1:10,000
12	9285 to 9298	22/06/1981	1:10,000
13	9373 to 9386	22/06/1981	1:10,000
14	9479 to 9483	22/06/1981	1:10,000
15	9535 to 9548	22/06/1981	1:10,000

Table 4: List of Photographs Covering the Study Area for 1968.

Run	Film N°	Date	Scale
8	3208 to 3224	1/07/1968	1:12,000
9	7389 to 7405	8/04/1969	1:12,000
10	7468 to 7482	8/04/1969	1:12,000
11	5995 to 6009	14/10/1968	1:12,000

The 1981 photographs were in black and white panchromatic film and of good quality. The flight was performed in a complete absence of haze and in a good stage of the cycle of the agro-pastoral classes to allow their discrimination. An enhanced stereoscopic effect in comparison with the 1991 images led to the need to accommodate changes in the appearance of the features between the 1:10,000 scale photographs (1991 and 1981) and 12,000 scale ones (1968).

The 1968 photographs were also in black and white panchromatic film but were characterised by the lowest quality. This made the API the most time consuming. The photographs were acquired in different months (July, April and October) which caused some difficulties in maintaining consistency of interpretation across the study area. This is especially valid for the photographs acquired in April, because all the broadleaved vegetation was bare and some crops (wheat and barley) were easily confused with grassland. Furthermore there was a general low contrast with very similar tones of grey between different elements .

4.4.4 Plans

As previously seen, the statutory planning system comprises two levels of plans:

The Structure Plan and the more detailed **Local Plans**

which complement the former.

Together they form the **County Development Plan**, which provides the planning context for a rural county. Structure Plans set out policies and proposals of "structural" importance, providing a strategic framework for development control and local plans. They take into account the national and regional policies as they affect the physical and environmental planning of an area. They do not show the precise boundaries of areas where particular policies are to be applied. Local Plans develop and apply the provisions of the Structure Plan in greater detail, they are prepared by District Councils as a specific basis for the development of those areas.

• **Bedfordshire County Structure Plan:**

The Bedfordshire County Structure Plan forms part of the new County Development Plan, being produced by the County and District Councils under Part II of the Town and Country Planning Act 1971 (BCC; 1980). The Plan was first submitted to the Secretary of State for the Environment in April 1977, was approved with modifications in January 1980 and became operative from 8 February 1980. Subsequently, the County Council submitted three alterations to the Structure Plan (Alteration N.1 and N.2 in 1984 and Alteration N.3 in 1990) two of which (Alteration N.1 and N.3) were approved.

The main functions of the plan are so stated by the Bedfordshire County Council (BCC; 1980):

> 1) "to justify to the Government and the public its policy and general proposals, and thus provide guidance to development agencies on matters which affect the key issues of housing, employment, transportation and the environment,
> 2) to interpret national and regional policies, including those pertaining to the economic planning and development of the South East region,
> 3) to provide the framework and statutory basis for local plans. These will be prepared largely by the District Planning Authorities in accordance with the Development Plan Scheme now being drawn up by the County Council in conjunction with the District Councils."

This Plan covers the period from 1981 to 1996 and, with its subsequent Alterations, it consists of a written statement and key diagrams. The former sets out general policies and proposals for the County; in particular, in Chapter III Section 3.4, Policies from 48 to 92 define the strategy of the County Council for the preservation and improvement of the physical environment. These policies are grouped into main issues such as agriculture, landscape, wildlife and area of scientific interest, mineral extraction, recreation, urban conservation, pollution. waste disposal. The Key Diagram 4 shows the main areas of settlement growth, the main lines of communication, the areas where the conservation has precedence over development and other items such as mineral works.

In this project, data have not been directly derived from the County Structure Plan, due to the general nature of the issues treated and of the Key Diagram, which shows only the broadest frameworks. Yet, prior to selecting the study area, a consultation of the Key Diagrams of the Structure Plan and the written statement was necessary to get a general overview of the issues related to the county as a whole, especially the environmental and countryside issues. The Key Diagram provided preliminary and broad information on the approximate location of the main countryside designations.

The Local Plans apply the provisions of the Structure Plan in greater detail and relate them to precise areas of land or to specific locations. They consist of a written statement formulating proposals for the development or change in other land-use of the land in their area, a map showing those proposals and diagrams plus illustrations or other descriptive matter. These plans and the maps enclosed, define in detail the boundaries of the countryside designations and therefore have been adopted as a source of data in this project. A Local Plan Scheme prepared by the Bedfordshire County Council in 1991 (BCC; 1991) sets out a programme for preparing statutory local plans in the County. It emerges from its consultation that there are no adopted district-wide statutory Local Plans in the four districts to the present.

- **Mid Bedfordshire Local Plan**

This is a district-wide plan, extending up to 1996, to develop the policies and general proposals of the County Structure Plan and to relate them to precise areas of land or to specific locations. It was placed for public consultation in 1989 but has not yet formally been adopted. It comprises a written statement and a "Proposals Map"; The written statement describes and analyses conditions in existence in relation to land-uses, social and economic factors. The Proposals Map shows those parts of the District for which new specific policies have been proposed and which can be indicated on the map. The Proposals Map is 1:50,000 scale with insets of specific areas at 1:2,500 scale. Although the District Plan has not been adopted, it was the only source available to provide detailed boundaries of the policy areas for the Mid Bedfordshire District, although some of these boundaries are still provisional and subject to modifications.

- **South Bedfordshire Rural Area Local Plan**

This provides the complete coverage of the District apart from the town of Dunstable and it was formally adopted in 1990. This plan is going to be incorporated in the South Bedfordshire District Plan whose preparation is still in progress. Its aims are similar to those mentioned for the Mid Bedfordshire District Plan, but it places major emphasis on development control in the rural area. It comprises a written statement with the policies described, a 1:25,000 scale Proposals map and 1:2,500 scale Insets Maps. This plan provided the boundaries of the policy areas for the South Bedfordshire District.

5. AERIAL PHOTOGRAPHIC INTERPRETATION (API)

The API work was the key process to derive the landscape and land-cover data from the three sets of aerial photographs and record them in a format suitable to be processed with computer based technologies. Together with the GIS work it formed the bulk of this project.

5.1 Preparatory Work

The conventional photointerpretation was preceded by preparatory work including:

- **A desk study**

This involved a review of the relevant publications on landscape and land-use in Bedfordshire to get an overall idea of their characteristics and of the existing conflicts in the area. This work was complementary to a first rapid analysis of the photographs and of the maps. Furthermore the study of the crop calendar for the south of England proved to be very useful given the different climatic conditions and agriculture normally experienced by the photointerpreter. The information provided by the crop calendar however was treated with some flexibility: particular agricultural operations, exceptional climatic conditions, the adoption of special varieties of crops can influence the cycle of the vegetation and make the crop calendar ineffective.

- **A field survey of the study area**

This was performed, after the desk study, mainly to provide a training aid for the development of the classification scheme and information for the subsequent correct identification of landscape features. It included driving through the study area to gain an overall impression of the landscape and some stops in the area, where the main features could be identified. For interpreters without experience of the area the comparison of the features seen on the ground and their appearance on the photograph is of great help.

- **The preparation of a preliminary and provisional classification scheme**

- **A test of the methodology of API on a small portion of the study area**

This trial was carried out on 6 Km^2 out of 96 Km^2. Its main aims were:

to train in the methodology of API as it was carried out for the project "Monitoring Landscape Change in the National Parks of England and Wales" (MLCNP) and to test it in the study area to see if some adaptations were necessary.

to test the suitability of the provisional classification scheme in relation to the photographs and apply possible adjustments.

to access the problems arising during the API stage from the quality of the aerial photographs.

to estimate the total amount of time necessary to carry out the API in the whole study area;

- to test the suitability of the results of API for the requirements of the subsequent digitising stage.

5.2 Classification Scheme

The preparation of a classification scheme is a basic part of the process of API. In designing the scheme it is important to check if the definition of the classes allows them to be consistently interpreted. For example it is necessary to verify if the information provided by the photographs is compatible with the level of detail of the scheme. When the classification is derived from an already existing classification scheme, this test is not essential provided that the purposes and the conditions of its application are compatible with the criteria adopted for its development (e.g. the same classification may not be suitable for any scale of photographs).

In this project the classification scheme is not new, but it was adapted from an already existing and tested classification.

The selection of the landscape categories in the classification is highly influenced by the possibility of deriving them from the aerial photography, although aesthetic and ecological factors are taken into consideration.

5.2.1 Source of the Classification Scheme

The original form of the classification scheme proposed for this project was derived, with some adjustments, from the scheme used in the project "Monitoring Landscape Change in the National Parks of England and Wales" (MLCNP) carried out by Silsoe College (Taylor et al.; 1991)[1]. This classification was developed for mapping the landscape of the National Parks from aerial photography. Its structure is characterised by a broad range of detailed classes which therefore may be grouped in main categories, going from the particular to the general depending on the detail of the analysis required. The range of classes was quite wide because they aimed to represent the different landscapes of each of the National Parks. The detail in the definition of the classes was satisfactory in relation to the scale and quality of the photographs available for this project, and was able to guarantee a good level of consistency while carrying out the API.

5.2.2 Form of Landscape Features

The landscape classes can be represented by three main groups of features:

- **area features**
- **linear features**
- **point features**

as in the original classification scheme.

They may include non natural elements which are related to the appearance or the history of the landscape (e.g. fences and pylons).

[1] The full classification of landscape features used in the MLCNP project is in Appendix 1

The landscape area features represent the land-cover; indeed it is recognised that land-cover is an essential part of the landscape. These features are represented by polygons whose boundaries enclose an area more than 0.25 ha.

The landscape features developing in a dominant direction were represented by lines. If they are more than 20 m wide they are represented as area features. The linear features often overlap with the boundaries of land-cover areas. Hedgerows, rows of trees, fences are all elements which correspond to linear features.

Landscape elements that occupy a very limited space on the ground (less than 0.25 ha) and do not have a dominant direction are represented as point features. In their spatial relationship with linear features they may be inside or outside (e.g. individual trees inside or outside hedgerows).

5.2.3 Full Classification Landscape Features

- **Area Features (land-cover)**

(A) WOOD AND FOREST LAND
- (A1) Broadleaved high forest
- (A2) Coniferous high forest
- (A3) Mixed high forest
- (A4) Scrub
- (A5) Clear felled/newly planted areas

(B) SEMI-NATURAL VEGETATION
- (B1) Lowland heath
- (B2) Chalk grassland

(C) AGRO-PASTORAL LAND
- (C1) Cultivated land
- (C2) Improved pasture
- (C3) Rough pasture
- (C4) Set Aside land

(D) DEVELOPED LAND
- (D1) Urban land
- (D2) Major transport routes
- (D3) Isolated Industrial estates
- (D4) Derelict land
- (D5) Isolated rural developments
- (D6) Quarries, mineral works, pits
- (D7) Parkland

WATER (E)
- (E1) Inland water (> 0.25 ha)

- **Linear Features**
  - (G1) Hedgerows
  - (G2) Double hedgerows
  - (G3) Strip woodland
  - (G4) Rows of trees
  - (G5) Woodland edge
  - (G6) Fences, ditches and other boundaries

• Point Features

(H1) Number of parcels
a) agricultural
b) non agricultural
(H2) Individual trees outside linear features
(H3) Groups of trees, all species
(H4) Individual trees in linear features
(H5) Inland water (< 0.25 ha)
(H6) Pylons

5.2.4 Definition of Landscape Categories

The definition of the majority of the classes in this project, as previously mentioned, is derived from the original classification scheme of the MLCNP project. It was important to keep continuously the following definitions as a reference to maintain the consistency during the API. The definition of landscape classes is in Appendix 2.

5.2.5 Adjustments of the MLCNP Classification Scheme to the Landscape of Bedfordshire

The choice of using an existing classification scheme saves time and work. However it is necessary to test the validity of its application within the different framework of a new project. Differences in the quality of the photographs (scale, resolution, type of film etc.), the characteristics of the study area, the level of detail required, the purposes and the timing of the study are all elements which may influence the feasibility of applying a tested classification scheme in a new context.

In this project most of the categories and their definitions were derived without changes from the original classification scheme. Yet some adjustments were introduced to adapt the original classification to the new framework of this piece of research. After a review of the original classification scheme the following modifications were brought:

- Inclusion of new classes.
- Exclusion of classes from the original classification scheme.
- Aggregation of different classes into one.
- Change in the codification system.

5.2.5.1 Inclusion of New Categories

The preliminary survey carried out in the countryside of Bedfordshire highlighted the presence of classes not represented in the original classification scheme. The list and the reasons for their inclusion were as follows:

• Area Features:

(B1) Lowland heath. Areas with greater than 80% cover of heather (*Calluna vulgaris* and *Erica spp.*).

(B2) Chalk grassland. Habitat typical of the Chilterns Hills whose solid geology is dominated by chalk (CC; 1992). It was included for its importance in characterising the landscape.

(C4) Set-Aside land. This scheme was introduced in 1988 and the effects were not visible from the most recent set of photographs, at the time the MLCNP project was carried out. Now this class is relevant to this project.

(D3) Isolated industrial estates. Many isolated industrial estates are present in the study area. For type and colour of buildings they may represent an intrusion in the landscape.

(D7) Parkland. It is linked to the growth in the county of great estates in the 19th century and it contributes to the character of the landscape of several areas.

- **Linear Features:**

(G2) Double hedgerows. Two close and parallel hedgerows may have a different visual impact on the landscape than a single one. Beside it is proven that the ecological value of a double hedgerow is higher than that of a single one (Selman and Doar; 1992).

(G4) Rows of trees. Features present in areas, such as Bedfordshire, where the action of man is dominant in shaping the landscape. A distinction should be made between hedgerows and rows of trees since the different size and silhouette of their canopies indicate the scale of an open landscape and influence its character.

- **Point Features:**

(H1) Number of parcels present per kilometre square. This provides information on the size of the fields and on possible processes of reorganisation of the land. The higher the number of parcels per kilometre square the smaller their size. This provided information on a possible process of enlargement of fields occurring since the 1960s'.

(H6) Pylons. They are recognised to be the consequence of the relatively recent process of urbanisation of the countryside. Their presence, with the related electrical cables, causes disturbance of the visual appearance in rural landscapes.

5.2.5.2 Exclusion of categories from the MLCNP classification scheme

Since the MLCNP classification scheme aimed to represent the landscapes of the National Parks which are considerably varied, it included many landscape categories which were not represented in the landscape of Bedfordshire. The categories not represented were excluded to simplify the structure of the new classification without influencing its effectiveness. The excluded classes were:

- **Area Features:**

  Upland heath
  Upland grass moor
  Bracken
  Unenclosed lowland area
  Upland mosaics

Eroded areas
Coastal heath
Open water, coastal
Wetland vegetation
Bare rock
Other coastal features
Unclassified land

- **Linear Features:**

Walls
Grips

5.2.5.3 Aggregation of Different Classes Into One

The three classes of the MLCNP classification scheme:

Fences and insubstantial field boundaries
Banks
Open ditches

were grouped into one class:

Fences, ditches and other boundaries.

The decision to aggregate the classes mainly depended on the difficulty faced, while testing the methodology, in identifying these different features with a satisfactory level of accuracy. This problem emerged mainly in the API of the 1968 black and white photographs.

5.2.5.4 Changes in the Codification System

The codification system is the complete set of codes associated with each class. Each code represents one landscape class and is assigned to each feature while carrying out the API. It links the feature with its definition and therefore provides a short annotation for it. As in the source classification, they are represented by a letter associated with a number (e.g. A1, A2, G6, H4); the letter corresponds to the main class (e.g. A=Woodland) and the numbers specify the minor classes of any given main class (e.g. A1= Broadleaved High Forest, A2= Conifer High Forest). There is no correspondence between the codes of the MLCNP and the Bedfordshire classification schemes.

5.3 Choice of the Grid Size

The API of linear and point features and the successive analysis of their quantitative data were referred to a surface unit of land in terms of density. The unit of reference allows comparisons between landscape features in different areas of land or changes in the same square overtime. The one kilometre square units provided by the grid traced on the OS 1:10,000 scale topographic maps were chosen for this purpose. The smaller the size of the grid, the better is the resolution; therefore the more fragmented and complex the landscape is the smaller should be the size of the grid. This rule is not strictly applied and this choice is often a compromise between the level of detail required and the availability of resources. In Bedfordshire fields generally have a large average size and a relative low density of landscape features; therefore a grid smaller than one kilometre square may have not brought significant improvements in the quality of the information; beside, since the "Modified Linear Intersect" method adopted for measuring the linear features as described in chapter 7 sect. 7.1.1 guaranteed reliability of the results only when a certain number of counts for each category was reached in each square, a smaller grid would have significantly lowered the number of counts per square, leading to unreliability of the results. A larger grid also means time saved in the phase of drawing the squares on the photo overlays and in measuring the landscape features for the smaller number of squares to process. Since each square unit was almost coincident (not exactly because of the distortion) with the correspondent one on the OS grid, it was easier to trace its corners and the relative coordinates on the photo overlay.

5.4 Methodology for API

5.4.1 Organisation of the Work

The API was carried out for each kilometre square for the three dates in the sequence: 1991, 1981 and 1968. This task started with the 1991 set because the photointerpretation was made easier by the information provided by the preliminary field survey of the study area. With the method adopted it was easy to single out possible changes in the landscape because of the experience gained during the API of the first date (1991). It also helped in adjusting mentally to the changes in the appearance of the features caused by the different quality of the sets of photographs. The API was carried out for each flight run within the boundaries of the study area before moving to the next run. This approach was also convenient because the photographs needed only to be handled once to perform the data extraction. Initially a class was surveyed and completed in a square before starting another one. This method being quite systematic, guaranteed that none of the classes was missing during the API. This approach proved to be very time consuming because each zone of the kilometre square was examined as many times as the number of the classes. It proved quicker to survey the square, field by field, and record the land-cover and all the point and linear features at the same time for each field. A criterion adopted to avoid the omission of parcels was the selection of a portion of square delimited by very distinctive boundaries (e.g. roads, railways, woodlands) containing few parcels, and to carry out the survey of all of them, prior to starting another area.

Before starting the API it was necessary to find the correspondence between the photographs and each kilometre square of the study area, with the aim of having the square as much as possible in the centre of the photograph to minimise distortion. The 1991 set of photographs was used for this purpose. A square overlay of transparent acetate film was stuck onto each 1991 photograph. The same photograph was then used as a base for the overlays of the other two dates. The corners of the square as derived from the OS grid of the 1:10,000 scale map were traced onto the overlay. Due to distortion in the photographs the overlay grids were not square.

On each overlay the date of the flight, number of the run and photograph, length of the two diagonals of the square and the OS coordinates of each corner were recorded.

A preliminary comprehensive examination of the photograph with naked eye before and during the API was an useful operation to gain an overall idea of the landscape of each square (e.g. pattern of the fields, the dominance of some classes, particular crops or other distinctive elements).

The API work was carried out using two stereoscopes at the same time placed one beside the other. A 1991 stereo pair was fixed on the carriage of the first stereoscope and the API for land-cover and point and linear features was completed. Then the 1981 stereo pair corresponding to the same kilometre square was placed under the second stereoscope. While the API for 1981 was carried out, the changes were recorded on the second overlay to the 1991 photography (linear and point features) or on the overlay to the map (land-cover areas). This process required continuous movements between the two stereoscopes and the map. The 1968 stereo pair was then placed under the second stereoscope, on top of the 1981 photographs which remained available for quick checks. The features were recorded as described above, but on to new overlays. Although this method proved to be time consuming, the general accuracy of the results was improved by the stereoscopic effect of the view. Initially an attempt was made to use only one stereoscope. After the completion of the API for 1991, the picture with the overlays was left under one eyepiece and the corresponding 1981 photograph was placed under the other ocular. Then the changes were detected by comparison of the two photographs. Subsequently the same operation was performed replacing the 1981 picture with the 1968 one. This method proved to be quicker and more efficient in identifying the changes, especially for those features easy to miss (e.g.. isolated trees). However the lack of the stereoscopic effect led to a higher number of errors in the identification of some features.

Once the three overlays of a square were finished the API was started for the neighbouring square of the same run.

5.4.2 API for the Area Features

In the development of the procedure for the API for the land-cover features the requirements of the digitising stage had to be considered. The main issue was to avoid shifts between the boundary of the same parcel of land on different maps once the overlay analysis was performed within the GIS. This problem derived from the difficulty of tracing exactly by hand the boundary of the same parcel twice while drawing and digitising the map. Indeed although the land-cover of many parcels changed from one year to another, the corresponding boundaries did not. Therefore it was only necessary to digitise the boundaries of each parcel which did not change category once and reassign the new classes of land-cover. This approach also saved time and work in the API and digitising phases. The API for the area features implied the following operations:

- An overlay of stable, non distorting film of permatrace (a stable non distorting drafting film) was stuck onto the 1:10,000 OS map which covered the study area. The map, underlying the overlay, provided a reference scale to trace the landscape features and land-cover areas and to locate them spatially. The information in the maps was useful for the API of some of the features (covered reservoirs, derelict land, dairies, farms, quarries) whose identification on the aerial photographs was sometimes uncertain. All the parcels of land-cover (boundaries and code for each parcel) resulting from the API for 1991 were subsequently traced on this first overlay.

• A second overlay was stuck onto the first. While carrying out the API for 1981, only the parcels whose boundaries had changed from 1991 to 1981 were traced and assigned a new land-cover class.
• A third overlay was stuck onto the second and while carrying out the API for 1968, only the parcels whose boundaries had changed from 1981 to 1968 were traced and assigned a new land-cover class.

On each of the three overlays the following was recorded: the date of API, date of the sets of photographs, coordinates of the corners of the area covered, scale and the name of the photointerpreter.

5.4.3 API for the Linear and Point Landscape Features

The API for linear and point features required a different approach than the one used for the extraction of the land-cover features. Linear and point feature data were not entered in the GIS using a digitiser, but were processed with a spreadsheet. Therefore it was easier to trace them straightaway onto single transparent overlays to each photograph than onto maps. The features which remained unchanged over the three dates were recorded only once (on the first overlay) to avoid double tracing and measurements. The API for the linear and point features implied the following operations:

• The tracing of all the linear and point features for 1991 with non permanent pens of different colours (one for each class), into the frame provided by the one kilometre square on the overlay (as previously described). The linear features were marked with a full line alongside their correspondent on the photograph, the point features with a dot;

• The sticking of a second overlay onto the 1991 layer and, while carrying out the API for 1981, drawing only the features that changed between 1991 and 1981 maintaining the same colours for class. New features were added and traced with a normal line; losses were represented with a dotted line. If the feature remained but was changed to another class (e.g.hedgerow replaced by fence) it was traced with two parallel lines: the first, a dotted one, to indicate the loss from the class existing in 1991 and the second a normal line to indicate a gain of the other class in 1981. The new point features were indicated drawn with a "+" the losses with "-".

• The sticking of a third overlay onto the second (1981) and while carrying out the API for 1968, trace only the changes between 1981 and 1968. The procedure in recording these changes is the same than for the previous phase.

5.4.4 Criteria Adopted for API Work

Some criteria were extensively applied while carrying out the API work:

• The API was based on the information available from the bibliography on the study area and the changes that occurred in these last decades. Indeed the result of the photointerpretation does not depend only on the information provided by the photographs but it is an inductive process where the experience of the photointerpreter and the knowledge of the area are key factors in determining the results.

• Only the linear and point features included in countryside areas were traced and therefore measured. Those located in areas of developed land (except D5 and D7) were excluded on the basis that this project aimed to study the changes of the landscape in the countryside. This rule led to the treatment of features which were included in countryside areas in the historic sets of photographs and in developed areas in the most recent ones as losses. The feature on the boundaries between developed areas (D classes) and countryside areas (all the other land-cover classes except E1) were taken into account.

• Only the most dominant linear feature was recorded where two or more occurred together. This was done because it was often difficult to identify the feature that was covered. Here the linear features are listed in order of dominance:

(G5) Woodland edge
(G3) Strip woodland
(G4) Rows of trees
(G2) Double hedgerows
(G1) Hedgerows
(G6) Fences, ditches and other boundaries

For example if a woodland was surrounded by a fence, the boundary was registered as woodland edge.

The same rule was applied also to the other features (e.g. when ponds were covered by a group of trees only the latter was recorded).

• In order to simplify the level of detail provided by the photographs, it was decided that the class D2 should only include major transport routes. Therefore during the API the area covered by small roads was distributed in equal parts to the classes of the adjoining parcels.

• Isolated trees falling in scrub (A4) were not counted.

• All the vegetation (e.g. trees, rows of trees, hedgerows) whether dead or in bad conditions was recorded. This decision avoided potential sources of error depending on the fact that in the photographs of April 1969 the broadleaved vegetation could be confused with the dead vegetation because of the seasonal lack of leaves.

• The centroids of the parcels were located according to the following criteria:

• the presence of provisional electric fences for strip grazing in improved pasture was not considered as a boundary;

if two different well recognisable land-covers, such as cropland and pasture occurred in a parcel without apparent visible boundaries they were recorded as distinct;

if only a small part of a parcel was in the study area and the centroid fell outside it was not counted;

fields split into two or more parts for provisional works such as the positioning of pipelines or road works were counted as one;

if only part of the boundary remained between two fields with the same land-use and management, then they were counted as a single parcel.

5.5 General Problems Encountered During the API

5.5.1 Problems Deriving from the Position of the Square on the Overlay

• Squares falling astride two different runs.

The problem was overcame by splitting the square into two parts, one for each photograph of the two runs. These portions were placed near the edges of the picture, which caused time consuming API and a higher probability of errors.

• Presence of small gaps or overlapping zones between boundaries of two neighbouring squares.

This was due mainly to the distortion present on the photograph, more than to errors in tracing the frame of the square. The consequence was either to miss the feature or record twice those features falling in these areas. This problem was encountered also near the edges of the above mentioned split squares.

• In the 1968 photographs a whole line of squares fell astride two different runs flown in different dates: October 1968 and April 1969.

Consequently the appearance of the landscape classes within the same square was influenced by the different times in the annual cycle and not only by the changes that had occurred in the landscape. In the overlapping strips of the two years, a distinctive reference element, A6 road, was chosen and the API was carried out for 1969 west of the road and for 1968 east. This method allowed the assignment of a precise temporal reference to each field. It was necessary to work simultaneously with four different photographs under the stereoscope to have an overall view of the whole square. This lead to a more tiring and time consuming API.

• Sometimes the location of the square on the photograph was not central, but very close to the edge of the photograph.

In this case, to obtain a stereoscopic view of the whole square it was necessary to use both the preceding and the successive photographs of the same run. In this case the photograph onto which the overlay was stuck was part of two stereopairs. Therefore the API required the interpreter to work simultaneously with three photographs with a more difficult organisation of the work.

• The location of the four corners of the square on the photograph, as derived from the OS grid of the 1:10,000 scale map, was made by sight. When a lack of clear reference points such as roads, permanent boundaries, houses, etc. occurred in the area it was difficult to position them correctly.

5.5.2 Problems Deriving from the Quality of the Photographs

The quality of the photographs has already been discussed in chapter 4 sect. 4.4.3.3. Here are outlined its effects on the results of the API work.

1968/69 photographs:

• Identification of broadleaved vegetation in the photographs taken in April 1969. Trees and hedgerows were without leaves in that moment of the year and therefore API mas more difficult for the absence of their shadows. An easier recognisable element was the trunk of the trees.

• The detection of fences was arduous with the scale and quality provided by the pictures.

• The identification of ponds was often dubious because they were partially covered by vegetation. Consultation of the maps supplied complementary information which was useful for this purpose.

• Ditches unkept and covered by weeds appear flat and it was easy to confuse them with tracks or bridleways.

• Ditches just built had a very sharp shadow because of a lack of weeds; this could lead to misinterpretation with hedgerows due to the similar shadows.

• Difficulties in making a distinction between cereals, improved pastures and leys because of their similar appearance in the photographs dated April 1969. Cereals (mainly wheat and barley) were rising and the tram lines were not visible so that they could easily be misinterpreted with grassland. An element which helped to recognise them was the presence in the field of some areas where it was possible to catch a glimpse of the colour of the soil underneath. When the cereals were seeded earlier they were in a more advanced phase and other factors influenced their assignment to class C1 (cropland) such as the presence of tram lines, a very smooth texture or signs of agricultural operations (e.g. ploughing lines) visible at the edges of the fields. Sometimes other considerations made an inductive assessment necessary. For example some fields seemed to be improved pasture due to the presence of high grass but instead they were assigned to cropland on the grounds that hay cuts are not done in April in the area and it was likely that they were just covered by weeds between two crops' cycles.

1981 photographs:

• The stereoscopic effect was enhanced if compared with the sets of photographs of the other years. This required more concentration during the API to accommodate the changes in the appearance of the landscape features, especially trees and hedgerows.

1991 photographs:

• Lack of shadows of vertical features in some of the runs taken in 1991. This depended on the characteristics and the time the photographs were taken. It made distinction between trees and big bushes or the canopies of individual trees within thick hedgerows more difficult.

5.5.3 General Problems Specific to Landscape Features

Area Features

• The differentiation between improved pasture (C2) and leys (C1) after the first year was not possible. Leys, at the beginning of their cycle can be recognised by a smoother texture, a clearer tone of gray in B/W photographs or a clearer tone of green with a glimpse of soil underneath in the colour photographs. After the first year these distinctive elements were lost and leys were classified as improved pastures. Sometimes the distinction between these two classes was made on the grounds of other elements, related to the management of the farm. For example the large and regular shape of the fields in the surrounding intensively managed area and a dark tone of green which is a symptom of heavy fertilisation are factors which may be related to the presence of leys.

• Areas of grassland included in zones of urban fringe might be classified either as agro-pastoral classes (C2, C3, C4) or urban areas (D1) depending on their use. Sometimes the recreational purpose of these areas was not so evident leading them to be classified as pastures instead of urban land. To be more correct about their classification the context around these areas and the information provided by the map were taken into consideration.

• In the 1981 and 1968 B/W photographs it was difficult to make a distinction between areas of lowland heath (B1) and the low vegetation of bushes (A4) which was often mixed with them, because of the very similar texture and tone of grey. In the 1991 colour photographs heather was easy to detect because it was blossoming at the time of the flight.

• It was difficult to keep a consistency in deciding the point at which newly planted areas (A5) of conifers should be considered coniferous high forest (A2).

• The distinction between improved pasture (C2) and rough pasture (C3) was straightforward. Often rough pasture which was recently grazed or which had old drilling lines may appear similar to improved pasture. Improved pasture (C2) may appear as rough pasture (C3) with a rough surface because of the presence of weeds or high grass when it is close to the moment of cutting.

• It was difficult to trace the boundaries of some woodland areas when they were irregular and not present on the map.

Linear features

• Fences (G6) were difficult to recognise in a consistent way because their visibility varied greatly depending on the quality of the photographs.

• Low banks (G6) with a regular shape and covered with high grass/vegetation could be confused with hedgerows (G1).

• It was difficult to judge consistently the point at which high tree hedgerows should be considered rows of trees (G5) instead of hedgerows (G1).

• In 1981 there are some linear features with the appearance of fences or small hedgerows, being very thin and small. According to the classification both these elements should be included in class G6. Yet, from the API for 1968 and 1991 mature hedgerows (G1) were detected in the same places where in 1981 the linear features were classified as fences. Possibly after 1968 the hedgerows were removed and subsequently replanted near 1981. In this case the rigid application of the classification scheme led to a gap in the presence of hedges in favour of fences.

Point Features

• It was difficult to recognise consistently in the three sets of photographs mature trees (H2, H4) from big bushes or small trees (not recorded).

• The visibility of farm ponds was often obscured by the presence of vegetation all around and the ponds which were completely invisible were not recorded.

• Because of the slight oblique shot in some runs, close isolated trees might appear as group of trees, with joint canopies.

• Some problems were encountered in tracing the centroids of the parcels such as:

Difficulty in separating provisional tracks from permanent tracks. Indeed only the latter were considered as boundaries while counting the number of fields. In areas of intensive cropland, provisional tracks divided very big fields into smaller ones with different land uses and this might have led to errors in the counts. Factors like an independent access from the road or the shape and size may help in classifying a field as distinct. Therefore the information provided by the maps was not updated and could not be used for this purpose.

In very big and irregular parcels (e.g. woodland areas) the location of the centroid was not always easy to choose.

If a very big parcels was split between different squares (sometimes even four) and the location of its centroid falls very close to the edge of the squares there is the risk of tracing twice the centroid of the same parcel on different squares. To overcame this problem, it was necessary to work simultaneously with neighbouring squares to avoid double registrations.

5.6 Comments and Discussion of API Work

It is worth to note that while carrying out the API the experience of the photointerpreter and the knowledge of the area may greatly influence the quality of the results.

Some factors proved useful to improve the output of the work such as :

• to trust on the first visual impression, once some experience of the area had been gained. When the classification of a feature is uncertain often an increased amount of time is spent in this process which does not increase the quality of the work, but can arise further possible doubts in the interpretations due to an increase mental fatigue and loss in concentration;

• the comparison of the API for a feature whose identification is uncertain with that carried out for the same feature by a person with API experience and knowledge of the area is important to identify possible errors and make corrections;

• to carry out the API, when possible, during the day light hours. This is less tiresome for the eyes and allows to survey the photographs with conditions of constant illumination. Indeed the appearance of the features changed depending on natural or artificial light;

• a short break from the API work; it was helpful in avoiding loss of concentration and boredom.

The quality of the photographs and their influence on the output of the API have been already previously discussed.

Here some criteria adopted for the identification of landscape features and some specific observations on the study area will follow.

The identification of the landscape categories was mainly based on elements such as different colours or tones of grey in B/W photographs, texture, shape, general pattern of the features and other aspects of the agricultural management of the area.

Cereals and some other intensive crops can be distinguished by patterns, tramlines (lines visible in grown up crops left at regular distance by the machineries), height (in the last stage of the cycle); they are mainly present in fields of suitable size for machinery. These patterns are a useful element in recognising the horticultural crops, or allotment gardens, mainly organised in small fields, characterised by very different tone and texture, often with presence of greenhouses, usually located close to farms or villages.

Improved pastures are recognisable by tone and texture. Sometimes they are characterised by lines crossing the field left by drilling and fertilising operations. Improved pastures or leys recently cut, appear with bright clear tones (nearly white in B/W photographs) and windrows of hay may be seen.

The presence of animals or bales in the field are useful to make the distinction between pasture and cereals. The envelope pattern of the field is a distinctive element used to recognise improved pasture in the study area. This is given by the direction, maintained constant over the years, of the ploughing and harvesting operations. This pattern remains visible in the field even some years after it is not managed as pasture any more and depends on the different colour of the soil along the ploughing lines.

Coniferous forest is distinguished from broadleaved forest by its darker tone. Texture is smoother in the former and is influenced by the more compact structure of the trees. In newly planted areas, mainly of coniferous trees, the planting lines are very clear. **Hedgerows** are mainly recognised by their shape, tone and shadow. Distinction between trees and big bushes is mainly based on the height.

In the study area, **movements of features from one class to another** were noticed while carrying out the API: for example the death of some trees might have turned groups of trees (H3) or rows of trees into individual trees (H2 or H4).

In 1981 photographs **many dead trees** were observed and it may be due to a strong attack of Dutch Elm Disease that affected a high percentage of elms in Bedfordshire.

In 1991 photographs in the area of Wrest Park, the presence of crops with tone, texture and general characteristics different from the ones usually present in the study area was noticed. This factor caused some disorientation in classifying these parcels which are thought to be part of the **experimental schemes** of the Silsoe Research Institute (based in Wrest Park). In the same year (especially in Run 11) many fields were split by the positioning of a pipeline which, being temporary, was not considered as a boundary. Some fields changed from cultivated (C1) to newly planted areas (A5); they are still surrounded by hedgerows, their shape is unchanged and trees are very short; this might be interpreted as the new effect of the recent **Set-Aside Scheme** discussed in chapter 2.

From 1968 to 1991 some **reorganisations from small to larger fields** were observed in intensively cultivated areas. The effect was a loss of hedgerows or other permanent field boundaries and a decrease in the number of parcels per kilometre square. This effect was counterbalanced by the registration of an increase in the number of parcels stemming from the subdivision of improved pastures with fences for grazing purposes. The enlargement of the fields is in some way disguised by this last process which interfered in the understanding of the trends in their size. Only the number of fields with changes in permanent boundaries such as hedgerows or tracks should have been measured for this purpose considering that the mobility of the boundaries in grazed pastures is much higher and may interfere with the former. Also south of Harlington enlargements of the fields occurred from 1968 to 1981.

5.8 Duration of API Work

The API and the related works took approximately 3.5 months one person's full time work which means an average of 1.5 squares per day. The amount of time spent to carry out these tasks for each square was affected by several factors such as: the quality of the photographs, the pattern, density and quality of landscape features, the general organisation of the API work, the training of the photointerpreter in the classification scheme and in the API procedure and the tiredness which took place after many hours of work.

As a general rule the API was quicker for the 1991 photographs and became slower and slower moving to 1981 and 1968. The time required by the API of one square, including the tracing of the frame on the overlays, the extraction of land-cover areas and linear and point features varied from a minimum of half an hour to a maximum of 3 hours per overlay of each square. This time includes also the necessary breaks that need to be taken when the API gets more difficult and requires higher concentration.

The quality of the photographs was the main factor in influencing the speed of the work. Therefore the API for 1991 was the quickest and for 1968 the slowest. This had as a result a doubled time spent for the API of 1968 than for the API of 1981 or 1991. The characteristics of the landscape are also another factor affecting the speed of the work for each square. The type and density of features per square, their pattern given by the spatial relation between them, the context, and the changes occurring between two dates were the important factors to consider. For example the API of linear or point features per Km^2, generally was more time consuming than the API of the area features. Moreover a complex pattern of small parcels with a high rate of change in time, conditions often present in the urban fringe, made the API of these areas particularly slow. The high density of single trees in areas of parkland and the check of their changes in time were other factors that affected the speed of API.

5.9 Output of API Work and its Relationship with the Following Stages of the Project

The API, as described above, involved the identification of the land-cover types, linear and point features from the aerial photography at the three dates (1991, 1981, 1968).

The output for **area features** was :

map of land-cover types for 1991;
map of the changes in land-cover types between 1981 and 1991;
map of the changes in land-cover types between 1968 and 1981;

These maps were ready to be input in the GIS through the digitising phase that followed.

The result of API for **linear and point features** was for each kilometre square of the study area:

overlay to photograph of linear and point features for 1991;
overlay to photograph of the changes in linear and point features between 1981 and 1991;
overlay to photograph of the changes in linear and point features between 1968 and 1981;

The overlays so prepared were the input for the measurements and counts respectively of linear and point features. The measurement of linear features was carried out by using the "Modified Line Intersect Method" as described in chapter 7 sect. 7.1.1. The point features were simply counted by using a tally counter.

The results of API for area, linear and point features were also compared with ground survey data to estimate the overall accuracy of the interpretation and test the robustness of the classification scheme.

6. THE GROUND SURVEY

6.1 Background

The main objective for using API, as already stated in chapter 5, was the preparation of the land-cover maps for the three years and the extraction of linear and point landscape features. The presence of some problems which could have been a source of errors during the API, such as mistakes in tracing the boundaries, misidentification of parcels, lack of consistency during the API, wrong registration has already been discussed. Therefore once the API was finished there was a need to validate its results and to know the level of accuracy associated with the resulting maps. The importance of assessing the accuracy of land-use and land-cover classifications from remotely sensed data (including aerial photography) has been widely recognized and has been matter for research by different authors (Hord and Brooner 1976; Hay 1979; Arnoff 1982; ASPRS 1983; Congalton 1991; Stehman 1992). The accuracy tests may be performed on the overall map or on the individual categories (Stehman; 1992). However the accuracy assessment should be based upon reference data having a different source from that used in the preparation of the thematic map and corresponding in time with the remotely sensed data. Reference data have to be assumed to be accurate and form the standard for the comparison with the map to be tested. Therefore they should be provided by ground observations or at least by larger scale imagery.

Ideally the verification of the exact accuracy should be based upon the complete check of each parcel and feature classified (Van Genderen et al.; 1978) throughout the study area. This process allows one to determine if the thematic categories, as mapped, agree with the field identified categories. Due to time and cost constraints this is an impossible and pointless task and consequently a statistically valid sampling procedure based on field work is usually employed. If a correct sampling procedure is adopted the results obtained from the work carried out should be representative of the entire population. Whatever is the method adopted the main factors to be considered in its selection are: determination of the number of observations to be used; choice of the sampling pattern; the selection, for a given sampling pattern, of the proper spacing of observations from one another (Campbell; 1987). However the choice is performed, the most suitable method should avoid as far as possible bias. Different sampling designs may be used to test land-use map accuracy and a discussion of the main issues involved in their selection is provided by the existing literature (Van Genderen et al. 1978; Hay 1979; ASPRS 1983; Congalton 1988; Stehman 1992;).

Once the collection of the sample is completed it is used, together with the classified data, to construct error matrices or confusion matrices. The matrices are used to identify the overall accuracy of the classification technique, specific errors affecting individual categories and to measure the extent to which the interpretation technique over- or underestimates a particular category (Hay; 1988). They are constructed in a form of a table in which the rows indicate the land-cover categories determined by a classification technique, the columns indicate the same categories as identified by the ground survey, and the cell values indicate the number of observations allocated to each combination of categories (Story and Congalton 1986; Hay 1988). Diagonal elements of the matrix represent correct classification values.

Non diagonal elements of the matrix represent the categories where confusion has occurred. Those in the columns represent commission errors generated if an observation on the ground is classified on the map into a category to which it does not actually belong; the figures in the rows represent omission errors because the classification has omitted from the interpreted map true areas on the ground (Campbell 1987; Lillesand and Kiefer 1987).

A measure of agreement between classification and verification in assessing the overall accuracy and individual category accuracy is given by the Kappa coefficient of agreement. This method was first applied in remote sensing by Congalton at al. (1983) to improve the interpretation of the meaning of the error matrix and successively adopted in an increasing number of studies (Rosenfield and Fitzpatrick-Lins 1986; Hudson and Ramm 1987). Previously, one of the most widely used accuracy measures was the "Percentage Correct" representing the proportion of the observations that has been correctly classified. It is given by the sum of the diagonal entries (correct values) divided by the total number of observations in the matrix. Unlike the K coefficient, it does not provide convincing evidence of the real accuracy of the classification, because it examines only the correct values and not the values of the full matrix.

Within this project the Kappa coefficient of agreement was chosen and taken into consideration to assess the accuracy of the classification. Also the values of the Percentage Correct were calculated and then compared with the K coefficient.

6.2 Purpose of the Ground Survey

Although the maps produced within this project were not required to achieve a predetermined level of accuracy it was decided to carry out a ground survey to know how best to use the results. The main purpose of the ground survey was to enable a measurement of the accuracy of the API results on the overall maps.

6.3 Survey Design

As stated before, it was necessary to design the most suitable sampling procedure to verify the land-cover data and the landscape linear and point features.

6.3.1 Sampling Pattern

This specifies the arrangement of the sites to be visited in the field and statistical techniques were used for their location to avoid bias.

A simple random pattern was adopted for the collection of the ground data in this project. This method assured that all portions of the study area were equally subject to selection for the sample. In the case of map accuracy, simple random sampling is performed without replacement, which means that each unit can be selected only once.

Congalton (1988) after applying five sampling schemes in an agriculture, range and forest area summarised the results as follows: "simple random sampling always provides adequate estimates of the population parameters, provided the sample size is sufficient." Before selecting this method its limits were considered:

- it tends to undersample small but possibly very important areas unless the sample size is significantly increased;

- the location of the observations can be clustered (generating therefore spatial autocorrelation) or can be in places with very difficult access.

The experience of the area such as type of pattern, frequency of the classes, easy access to the sites, gained from the previous API work led to the decision that the results of the validation procedure would only be affected by these shortcomings within an acceptable limit.

6.3.2 Size of the Sample

The choice of the size of the sample is a balance between the statistical requirements and what is practically attainable depending on availability of time and resources.

Different authors recommend a minimum of 30 observations (Van Genderen et al.; 1978) for each vegetation or land-use category in the error matrix. Yet this number of observations for every category was recognised to be very difficult to achieve with the simple random sampling method unless a very high and therefore expensive number of observations was collected. This was due to the limited size of the study area and the low frequency of some classes. Therefore it was considered satisfactory, due to restraints in time, to have a significant number of observations in the categories of main interest which were recognised to be also the most frequent. It was decided that a number of units of chosen size should be surveyed. The sample fraction directly influences the accuracy of the results and a minimum of 2% of the entire area is considered satisfactory (Taylor et al.;1991). The choice of the size of the unit was a balance between the need to survey a sample fraction of more than 2% and a well distributed number of squares in the overall area. Finally 25 one quarter kilometre wide squares were selected, which covered the 6.5% of the study area. The squares were randomly selected. Their locations were traced within the grid provided by the 1:10,000 scale OS maps. The location of the squares within the study area is shown in Figure 5.

6.4 Preparation for Field Work

Some documents and other material were prepared before starting the field work the following were taken for the survey:

• 1:25,000 scale OS maps to provide a general overview of the area.
They were used both to study the best route to approach each square on the ground and to find the location of the existing footpaths in the area to be surveyed.

• The aerial photograph with the overlays.
The square marked on the overlays to the photography was very useful to locate accurately the area correspondent on the ground and in defining those boundaries not traced on the photocopy of the OS 1:10,000 map.

• A photocopy from the 1:10,000 scale OS map of the sample square.

• A series of colour fine fibre-tip pens to map the landscape features on the map.

• A detailed classification with the definition of the classes and the codification system.

6.5 Field Work

The sequence of the squares to be surveyed on a daily basis was decided using the framework with their locations as described in sect. 6.3.2. The location of the sample area on the ground did not cause too many problems as many reference points were visible both on the photographs and maps due to the absence of extensive areas of open countryside. These points were for example farms, roads and field boundaries. Once the sample area (one quarter kilometre square) was located, the starting point was chosen considering the location of the public footpaths, as resulted from the 1:25,000 OS maps and the pattern of the parcels within the square. In performing this task an attempt was made to survey as many parcels as possible using public right ways because the owners of the land had not been officially informed about the survey and its purposes. To allow a straight comparison between the two sets of data, all the features were mapped in the field within the selected squares with the same method and the same colours used during the API.

6.6 Accuracy Assessment

Within the squares the complete survey of all the features (area, linear and point) was performed in the field. Later, during the desk work, the extraction of the landscape features was performed by overlaying a grid [1] on the field surveyed square and on the data as resulting from API. Five points (four corners and the centre) of the grid were overlaid on the land-cover data respectively from ground survey and API and then compared giving a total of 125 observations. Linear and point data were extracted by using nine points of the same grid, the same five as for the land-cover plus the four between them. Due to their non areal distribution, only the linear and point feature closest to each point of the grid was selected for the comparison with the correspondent feature from the API. If no feature was present in the proximity of a point the number registered was 0. The total number of observations was 225 respectively for the linear and point features. The results for each square were recorded on a form shown in Appendix 4. The figures reported in the forms were used to fill the cells of the three matrices developed respectively for land-cover data, linear and point features as shown in Tables 5, 7and 9.

As reported by Campbell (1987) "K (kappa) is a measure of the difference between the observed agreement between the two maps (as reported by the diagonal entries in the error matrix) and the agreement that might be contributed solely by a chance matching of the two maps".

Its formula is:

$$K = (p_o - p_c)/(1 - p_c)$$

in which

[1] The grid is shown in Appendix 3

p_o = proportion of units which agree. In the matrix it corresponds to the sum of the diagonal entries divided by the total number of observations.
p_c = proportion of units for expected chance agreement. This value is calculated using the row and column totals (called marginals) in the matrix. It is found by the sum of the diagonal entries divided by the total of products of row and column marginals.

Thus the coefficient is zero for chance agreement, unity for perfect agreement and negative for less than chance agreement.

Tables 6, 8 and 10 show the products of the marginals, as described previously, to be used in the calculation of the K coefficient.

The values of K coefficient of agreement and percentage correct for the accuracy assessment of the overall interpretation of land-cover, linear and point features are shown in Table 11.

Table 11: Accuracy assessment of the photointerpretation.

	K coeff.	**PERCENTAGE CORRECT**
LAND-COVER	0.824	88.8%
LINEAR FEATURES	0.701	78.7%
POINT FEATURES	0.683	84.0%

Reported accuracies for land-use data vary greatly; generally values of the percentage correct of at least 85% are required for satisfactory land-use data (Campbell; 1987). The values of the K coefficient is represented by the subtraction of the estimated contribution of the chance agreement from the percentage correct and therefore they are smaller.

The K coefficient for land-cover data indicates a satisfactory level of accuracy for the classification. From an analysis of Table 5 it can be seen that the observations are concentrated in the categories more represented in the study area (C1, C2 and D1) and which cover some 78% of its surface. Confusion has occurred mainly between improved pasture (C2) and rough pasture (C3), Set-Aside land (C4) and cultivated land (C1) and between different categories of woodland.

Within the linear features confusion has occurred as seen from Table 7, mainly between hedgerows (G1) and fences (G6), and hedgerows (G1) and rows of trees (G4).

The analysis of point features in Table 9 shows that confusion has occurred mainly between trees (H2 and H4) and big bushes (unclassified). The high figure of unclassified in the diagonal is given by the number of observations where no feature was found both on the ground and on the photography and is due to the low density of these landscape elements in the sample.

6.7 Comments on the Ground Survey

It was possible to verify only the accuracy of the data of 1991 with this date being relatively close to the date of the ground survey (1993). Landscape data for

1981 and 1968 photographs were not assessed as there were no ground observations available for those sets.

Since the ground survey was carried out in 1993 (two years difference) some disagreement may have occurred between ground survey observations and API due to the landscape changes in the interim period. Big changes were not expected in those categories which were more stable such as woodland or urban land and although many changes had occurred within the different crops they were all classified in the category of cropland (C1).

The Set-Aside land (C4) category was the one which caused most of the problems of identification both during the API and the ground survey and was responsible for most of the changes that had occurred since 1991. Indeed under the definition of Set-Aside many types of land-covers may be found: rough pasture, improved pasture, woodland. Fields under set aside may be confused with crops if they were ploughed to bury the weeds. The identification of these parcels as Set-Aside was therefore possible with certainty only by other sources (e.g. by talking directly with the farmer). The confusion on the ground was generated also by fields initially cropped and later turned to set aside once very low yields were forecast. Indeed it emerged by talking with some farmers that the fields left under set aside were generally the least productive (e.g. for drainage problems or for the characteristics of the soils). During the ground survey a big increase in Set-Aside fields was also observed since 1991. These parcels, which were cultivated in 1991, were still registered as cropland in 1993 to avoid the combination of error and change occurring between these two dates. Near Pulloxhill and Houghton Park (Ampthill) some fields were found under the Countryside Premium scheme, part of the Set Aside Scheme, as described in chapter 2 sect. 2.4.7. Since 1991 changes have occurred also in other features such as hedgerows. Some of them have been removed and, by 1993, replaced with other features these were not recorded as change.

Some difficulties were found in defining on the ground the boundaries of categories such as woodland or semi-natural vegetation; in this case the consultation of the aerial photography was very useful. It was also noticed that during the API a common mistake was to include trees very close to the boundaries of woodland areas in the land-cover; once on the ground they were registered as isolated, resulting therefore as errors in the matrix. However trees proved to be the most difficult features to be classified in a consistent way as can be seen from the confusion matrix. While photointerpreting the trees the height and canopy (size and shape) were the main factors to be considered. Trees shorter than 4.5 m but with a large canopy had been registered while higher trees but with a thin canopy may have been missed. From the results of the ground survey it emerged that trees within hedgerows might be missed easier during API. Two trees which were very close and mixed their canopies have been counted as one.

Low banks with regular shape and covered with high grass sometimes were photointerpreted as low hedgerows.

Once the ground survey was finished it was realised that the introduction of a further two classes in the classification would have allowed a better accuracy in the API. These were:

a category between hedgerows and rows of trees including rows of small trees and high hedgerows. These features are very often present in Bedfordshire.

• many small woods such as spinneys and copses were found in the study area. Despite their size they are recognised to be an important element in the landscape. In the classification system they have been included in groups of trees, if smaller than 0.25 ha, and various categories of woodland if larger. Being recognised as typical elements of the landscape in Bedfordshire and being quite large in number they would have deserved a category apart.

The time required to carry out the ground work was four days, with an average of six squares per day. The desk work, involving preparation, comparison and processing of the data required roughly three days.

6.8 Output from the Ground Survey

The comparison of the results of the API with the ground survey data showed the agreements and disagreements between ground survey and API for land-cover types, linear and point features. The overall agreement between API and ground survey for land-cover data was 88.9 %, for linears 78.7 % and for point features 84 %, which, according to the reference values already discussed above, can be considered acceptable. The ground survey, by enabling the measurement of the accuracy of the API, provided information on the reliability of the results and the weak points of the classification scheme. Once the investigation on the accuracy of the results of API was completed, the next stage of the project, consisting of the computer work, was started.

7. COMPUTER WORK

The computer work involved the use of a spreadsheet to enter and process the linear and point data and a GIS to analyse the land-cover, countryside designation areas and land-form information. Linear and point data were input from the spreadsheet into the GIS in a later phase for their georeferencing and graphical display. The editing and processing of linear and point data were quicker and more flexible with a spreadsheet, as proven also by the results achieved in the MLCNP project, where a database was used for a similar purpose (Taylor et al.; 1991). The entering of the data of linear and point features through digitisation and their processing with the GIS would have been more complex and time consuming; furthermore the system proved to have some limits to perform the analysis required on this type of information.

Some preparatory work was necessary before converting all the data into digital form. It included :

- Measurements of linear features
- Counts of point features
- Compilation of countryside designation zones data.

7.1 Preparatory Work

7.1.1 Methodology for Measuring the Linear Features

The linear features were measured with the "Modified Line Intersect Method" developed by Marsh (1971) to determine the length of plant roots and tested later by Tennant (1975). This method was first applied with good results to quantify linear landscape features in the MLCNP project where it "proved to have the required advantages of speed and accuracy" (Taylor et al.; 1989). The estimation of the total length of lines is performed by placing a grid of known dimension randomly over them. The intersections of the underlying lines are then counted: the longer the feature the more intersections it makes with the lines of the grid. The conversion of the counts to length measurements is done using the following formula inclusive of the grid unit:

L = (Pi/4) . N . D (Taylor et al.; 1989)

Where :

L = Length of the linear feature under the area covered by the grid.
Pi = 3.14159....
N = Number of intersects with the grid.
D = Grid size in dimensions the same as L.

In the calculation of the value of L as it is on the ground, it was necessary to take into account that the linear features on the aerial photography overlays are subject to the effects of changes in the photo scale due to factors of distortion. Also the grid traced onto the overlay during the photointerpretation is distorted by scale variation. To correct this source of error, the average scale **(AS)** was calculated within each kilometre square of the National Grid as following:

AS = 1.41400 Km/Average Diagonal (Km)

where

1.41400 Km = size of the diagonal of one kilometre square on the ground.
Average Diagonal = average value of the two diagonals of the one kilometre square on the overlay to photograph.

The local equivalent dimension (D) of the grid used in counting the intersections with the linears (G) can then be calculated as following:

D = G . Average Scale of the photograph (AS)

where

G = size of the grid used in counting.

Its value is re-calculated for each grid square.
During the counting procedure it was important to adhere to the rules set for the MLCNP project to maintain a uniform technique.

- **Counts of one** were given to:
  - a feature crossing a line of the grid
  - a feature ending touching a line
  - a curved portion touching a line.
- **Counts of two** were allocated to:
  - a curved portion laying on or along a line;
  - features ending touching a vertex;
- **Counts of four** were given to :
  - lines crossing a vertex of the grid.

In particular, the correct interpretation of intercepts with curved linear features is relevant. The distinction between touching and partially or totally lying on or along intercept lines often depends on the operator. When a greater number of these decisions is required, for example when using a small grid size rather than large, changes in the intercept values are more likely to occur. The grid sizes selected for counting were 5 mm, 2.5 mm, 1 mm. A trial carried out by Taylor et al. (1989) proved that the size of the grid influences the overall precision of the method. The finer the grid the more precise and time consuming the measure. It also proved that the error in the measurements increased when the number of intersect counts, for a particular combination of grid size and length of linear become less than 50.

The count was carried out by type of feature: initially the larger grid (5 mm) was placed on the overlay to cover all the features of the same category; the grid was not moved until the counts of all the linears of the same category was finished. The counting was carried out in a systematic way, by traversing vertical and horizontal lines rather than following single lines. All counts for a category were accumulated on a tally counter. If the number of the counts was less than 50, the counting was repeated using a smaller grid. All the counts per category were recorded on a form (shown in Appendix 5) for each square kilometre of the study area.

Some problems emerged during the counting which were as follows:

- it was more difficult and time consuming to arrange split squares under the grid than the entire ones;
- in some cases there was uncertainty in understanding the way dotted lines (losses of linear features) touched the grid, especially when using a large grid;
- there could be uncertainty in defining where and how a feature touched the grid, when the smallest grid was used. This depended on the size of the stroke of the fibre pen used to trace the feature;
- a high density of features led to a higher probability of missing some;
- in many cases even using the smallest grid the significant number of 50 counts per category was not reached.

The count was started from the 1991 overlay, through the 1981 and the 1968 ones. Since only the features that changed were traced on the last two overlays, the difference (positive or negative) with the 1991 figure was calculated and the resulting value was recorded on the forms.

Once the counting of the intersections was finished and all the data were recorded on the appropriate forms, the figures were ready to be input into the speadsheet.

The method adopted of recording, counting and then processing the linears for each kilometre square led necessarily to a minimum spatial resolution for these elements of one kilometre square.

7.1.2 Counts of Point Features

The point features were counted per kilometre square. Therefore the minimum resolution for the point data was one kilometre square.

7.1.3 Compilation of Countryside Designation Zones Data

The countryside designation zones were derived from local plans. Since they were recorded on different plans at different scales, it was decided to trace their detailed boundaries onto overlays to 1:10,000 scale OS maps to simplify the subsequent digitisation work.

The countryside designation zones (CDZ) selected for the analysis were :

- Agricultural Priority Areas (APA)
- Areas of Great Landscape Value (AGLV)
- Areas of Outstanding Natural Beauty (AONB)
- Green Belt (GrBlt)

- Sites of Special Scientific Interest (SSSI)
- National Nature Reserve (NNR)

Several of these designations were overlapping to generate multi-designation areas as shown in Map 3.

The village development limits (VDL) were also traced on the overlays. They provided the information on the location and extent of possible further development.

7.2 Input of Linear and Point Features in the Spreadsheet

The software selected for this purpose was Quattro Pro which is characterised by good spreadsheet functions. The use of the spreadsheet made the processing and the editing of the data quicker and more flexible than the use of the GIS.

For the purpose of inputting the data into the spreadsheet, points and linears were managed in different files. The first column in the files contained a series of numbers to identify each square of the study area. The values for each category were assigned to the corresponding kilometre square through the appropriate number.

The length of linear features was calculated as Km/Km2 through the application of the formula mentioned in the previous paragraph.

The differences between different dates for categories of points and linears, as well as the totals for each category for each date were calculated. A sample of the tabulated output of linear data from the spreadsheet is given in Appendix 6.

Copies of these files with the values for each category and their differences for each date were edited and recorded in ASCII format for their inputting into the GIS.

7.3 GIS Work

The GIS work included the creation of the study area within which all the GIS operations were going to be performed. Then the data such as the OS DTM, maps, linear and point feature were input through digitising or other methods, depending on their format.

The data processing with the GIS included some preliminary operations aiming to enhance the quality of the data. Then the phase of analysis and modelling followed, which included mainly overlay analysis between the different data layers. Finally the results were displayed for presentation as maps, tables and graphs.

7.3.1 Description of the GIS

As any GIS it includes a software component, an hardware component and the data. These last ones were already discussed in the sections above. The description of the software and hardware will follow.

7.3.1.1 Software

The software selected was SPANS/OS2 V.5.2 by INTERA TYDAC Technologies Inc. SPANS runs under OS/2 using the Presentation Manager interface which acts as an umbrella operating system by integrating DOS, Windows and OS/2 applications (Intera Tydac; 1991). SPANS is characterised by strong data integration, analysis and modelling capabilities. It can process geographically-referenced data bases in vector, raster and quadtree data structures. The system is well suited for manipulating and analysing surfaces and thematic maps because of its strong grid modelling capabilities.

Within SPANS, data can easily be transferred between the various SPANS internal formats (quadtree, raster, vector, points and ASCII data). It is provided with a digitising package (TYDIG) to allow the input of cartographic data. Attribute data can be directly imported into SPANS in ASCII format or taken from databases, spreadsheets etc. SPANS is composed of different modules to input, convert, analyse, display spatial information (for further information see SPANS manual, Intera Tydac 1991).

7.3.1.2 Hardware

The hardware included some peripheral for the input and output of data and a processing unit.

A Summergraphics A.1 digitising table was used to input the mapped data into SPANS.

The configuration of the processing unit system was:
PC 386 - 33 MHZ IBM compatible;
mathcoprocessor
16 Mb of RAM memory;
250 Mb hard disk;
19" colour monitor;
640 x 480 VGA graphic card;
mouse.

A Hewlett Packard Paint Jet XL colour printer and a Tektronix Thermal Wax Printer were used for the graphic output of maps. Graphs and tables were printed with a laserprinter.

7.3.2 Creation of the Study Area within SPANS

SPANS requires the definition of a study area when a new GIS project is starting. The area identifies the geographical location of the project. Therefore all data layers, images, classification schemes, legends, titles, and other annotations will be referred to this area. The definition of a new area within this project required:

- the identification of a projection;
- the specification of the geographical extents;
- definition of a base map.

The projection selected for this project is the UK National Grid.

The extents of the study area define a rectangular region in the projection plane covering the whole of Bedfordshire and they were defined by entering the coordinates of the two diagonal corners of the rectangle demarcating the study area. They were:

	X	Y
Lower-left	486000	212000
Upper-right	528000	272000

The last step in the creation of the universe was the definition of a base map, which determined the boundaries of the region where the analyses were going to be performed. To this purpose a binary map (only with two classes) was created after importing the vector files created by digitising the boundaries of Bedfordshire with TYDIG (see sect. 7.3.3.2). All the analyses related to the whole study area of the project had the county map as a base map.

The processing required also the selection of a quadtree level which specifies the resolution of the map. A high quad level corresponds to a better resolution, yet it has higher storage and processing requirements. The quadtree level chosen to process the map was 14 (then maintained in all the processing performed) which corresponds to 10.01 m cell size on the ground. The relation between quad level and cell size is influenced by the size of the study area.

7.3.3 Data input in the GIS

7.3.3.1 OS DTM

The DTM provided by the OS as described in chapter 4 sect. 4.4.2 was already in digital format. Yet it was necessary to convert the data in a format compatible with SPANS. A programme developed by Geodata Institute was utilised for this purpose. The OS data were the input for the programme which produced a raster file of elevation data compatible with SPANS.

7.3.3.2 Digitising

The digitising was performed with the TYDIG module of SPANS, an arc-node digitising package developed to capture data from paper maps or aerial photographs and store it in a topological vector format. TYDIG is provided with editing capabilities to correct errors during digitising and to build attribute databases. The data, once digitised, were exported with TYDIG to produce *.VEH/*.VEC files in ASCII format. The *.VEH file describes the global parameters of the *.VEC (data) file, as well as the data itself. The *.VEC file consists of one or more data sections, which are described by corresponding header records in the *.VEH file. These data sections may contain data for nodes, points, arcs or areas. Each section consists of records which occur on a separate line.

The land-cover maps and the countryside designation zones map were composed of six map sheets each of which in this phase were digitised and treated separately.

TYDIG was used to digitise the following data:

• the boundary of the County of Bedfordshire from 1:100,000 scale OS Bedfordshire and Hertfordshire Administrative Map;

• the 1:10,000 scale Countryside Designations Zones map derived from the local plans;

• the map of land-cover types for 1991, the map of the changes from 1981 and 1991 and the map of the changes from 1968 to1981 as they resulted from API.

• the frame of each map sheet (six in total), used later to create a map used to "cut" precisely the edge of the above mentioned maps. This step was necessary to avoid gaps while joining the six maps in a further stage.

The digitising of the land-cover maps required the application of a special technique to avoid possible shifts in the boundaries of the same parcel, once the maps of two different dates were overlaid. To this purpose it was necessary to digitise the boundaries of a parcel only once, even if this was present in all the three dates. This requirement has already been considered in the previous stage of API when, after producing the map for land-cover of 1991, only the changes between 1981-1991 and 1968-1981 were recorded. In the digitising stage the same process was applied, after reversing the order of the dates. The work was started with the map of the changes 1968-1981. Once it was finished, the digitising of the following layer of the 1981-1991 changes consisted of adding the new parcels to the files previously produced and by reclassifying the parcels whose boundaries were already digitised. The same procedure was applied to digitise the map of the land-cover for 1991. The resulting vector files therefore represented the land-cover for 1991, the parcels that changed between 1968 and 1981 and between 1981 and 1991.

The vector files were subsequently translated by SPANS to vector datasets in binary format used by the system for all internal vector processing.

7.3.3.3 Input of Linear and Point Data

Quantitative data of linear and point features and their differences were imported from Quattro Pro into SPANS as tables of attribute data. The output from Quattro Pro was in ASCII format; before importing into SPANS it was necessary to edit the headers of the files which contained the description of the data. Once finished, the data were converted in binary format into SPANS and were ready for further processing.

7.3.4. Data Processing with the GIS

Following the input of the data into the computer and their conversion in a format readable by SPANS it was possible to start the processing. It included the following operations:

- preparatory
- analysis and modelling

7.3.4.1 Preparatory Processing

This included all those operations performed on the data to produce new information and turn data into a form which might be easily interpreted. In this project the analysis and modelling operations could be performed only once the final maps were finished. The processing carried out to this aim included:

• transformation of vectors into arc-node polygons and then the latter to quadtree maps. The generated maps are classified according to the class assignment to each polygon in the vector dataset (applied to all the vector files imported from TYDIG);

• the cut of the edges of the thematic maps by overlaying and imposing a one class binary map (cutter) onto them. This operation was performed to avoid possible gaps while subsequently joining the six sheets to form a single map (applied respectively on each of the six sheets of the land-cover maps for the three dates and of the Countryside Designation Zones map);

• creation of the complete land-cover maps for each sheet of 1968 and 1981. With an overlay and join procedure the digital 1991 map sheets were slipped beneath the 1968 and 1981 digital map sheets (representing only the parcels which changed) and the classes were merged to create new 1968 or 1981 maps representing the complete land-cover situation (parcels which changed and not) for those dates (applied on each 1968 and 1981 land-cover sheet);

• join the six sheets to create a single map (applied on 1968, 1981, 1991 land-cover and countryside designation zones sheets);

• editing titles and legends for each final map.

7.3.4.2 Analysis and Modelling

The operations of analysis and modelling are performed to extract new knowledge from the data. These analyses constituted the bulk of the GIS work with the output being new maps and a series of report files containing the data of the analyses performed in tabular format. They included:

• **reclassification of the CDZ map** (Map 3) with a template to create new single class maps representing each countryside designation. This operation was necessary to isolate the boundaries of each countryside designation since the original map contained areas where different ones were overlapping.

The new maps derived from the CDZ map were:

- Agricultural Priority Areas (APA)
- Areas of Great Landscape Value (AGLV)
- Areas of Outstanding Natural Beauty (AONB)
- Green Belt (GrBlt)
- Sites of Special Scientific Interest (SSSI)
- National Nature Reserve (NNR)
- Village Development Limits (VDL)
- Areas without designations (Blank)

and they represented the location and extent of each zone.

The same procedure was adopted to create a series of maps representing those areas excluded by each countryside designation and complementary in terms of area and extent to the former ones. The areas selected were:

- Outside Agricultural Priority Areas (APA)
- Outside Areas of Great Landscape Value (AGLV)
- Outside Areas of Outstanding Natural Beauty (AONB)
- Outside Green Belt (GrBlt)
- Outside Sites of Special Scientific Interest (SSSI)

• **Analysis on land-cover including:**
- Land-cover analysis on single maps.
- Land-cover analysis on two maps.

Land-cover analysis on single maps.

This analysis produced a statistical report containing the area of each class on a map. It was performed for the whole study area and for each countryside designation zone with the aim of analysing the type of land-cover which characterised each of these areas. The areas analysed are listed in Table 12.

Table 12: Land-cover analysis on single maps.

BASE MAP	1968	1981	1991
Whole study area	X	X	X
In APA	X	X	X
In AGLV	X	X	X
In AONB	X	X	X
In Gr Blt	X	X	X
In SSSI	X	X	X
In NNR	X	X	X
In VDL	X	X	X
In blank areas	X	X	X
Outside APA	X	X	X
Outside AGLV	X	X	X
Outside AONB	X	X	X
Outside Gr Blt	X	X	X
Outside SSSI	X	X	X

Land-cover analysis on two maps

This analysis produced an area cross tabulation report of two maps which contained the area of all overlapping combinations of classes of the two maps. It indicates the extent of correlation between two layers. It was used to analyse the change of land-cover through time. This analysis was applied to the whole study area and to each CDZ as results from Table 13.

• Analysis of linear and point features

The data on linear and point features and their differences through time were stored as attributes in different tables as described in sect. 7.3.3.3.

For analysing and displaying geographically this information with the GIS, it was necessary to create a grid map of 96 one kilometre squares based on the National Projection. The map was produced with SPANS by creating two maps (a projection X map and a projection Y map) and by overlaying them by using a matrix template.

The linears and points, having the minimum resolution of one kilometre square, were attached as attributes to the grid map. To perform this task, each kilometre square of the grid was assigned with the same number present in the first column of each table as an identifier of each record. This number represented therefore the link between the squares in the grid map and the records of the table.

The creation of the grid map was the prerequisite to perform two main operations:

• **the creation of the maps of linear and point features** and their differences in the study area;
• **the analysis of the distribution of selected linear and point features** in selected countryside designation zones.

Table 13: Land-cover analysis on two maps.

BASE MAP	1968x1981	1981x1991	1968x1991
Whole study area	X	X	X
In APA	X	X	X
In AGLV	X	X	X
In AONB	X	X	X
In Gr Blt	X	X	X
In SSSI	X	X	X
In NNR	X	X	X
In VDL	X	X	X
In blank areas	X	X	X
Outside APA	X	X	X
Outside AGLV	X	X	X
Outside AONB	X	X	X
Outside Gr Blt	X	X	X
Outside SSSI	X	X	X

Creation of the maps of linear and point features

The grid map was reclassified, by using a modelling procedure within SPANS, with the values of the attributes (linear and point landscape features) contained in the tables. The procedure required the grid map as input map and the tables with the attributes. After chosing the table, the field in the table was selected which represented the classes in the input map (the number of each square of the grid map). Then the field was selected in the table which represented the new values to be assigned to the classes in the input map (the values of the attributes; e.g. length of hedgerows for 1991).

The output was a series of new maps of the study area representing the density per kilometre square for each landscape category. An example is Map 5.

By applying the same procedure to the tables of the changes of landscape features through time, another series of maps representing the losses and the gains per kilometre square for each landscape category between different dates was created. An example is Map 6.

Analysis of the distribution of selected linear and point features in selected countryside designation zones

The total amount of selected linear and point features in selected countryside designations was produced through the use of an analysis procedure (Analyse\Maps\Attribute totals) in the GIS.

This required the following inputs:

- the map containing the areas on which the analysis was based (maps of each countryside designation);
- the map whose attribute values were to be totalled (grid map);
- the table containing the attribute values that were to be totalled (tables with the values for linear and point features) and the number of the field which identified the attribute table column that was to be totalled.

The output consisted of report files with the totals for each landscape category in the selected countryside designation zones. Table 14 lists the analyses that were carried out.

Table 14: Analysis of linear and point features in the countryside designations

BASE MAP	1968	1991	change 1968-1991
In APA	X	X	X
In AGLV	X	X	X
In AONB	X	X	X
In SSSI	X	X	X
In blank areas	X	X	X
Outside APA	X	X	X
Outside AGLV	X	X	X
Outside AONB	X	X	X
Outside Gr Blt	X	X	X
Outside SSSI	X	X	X

The features selected were :

- Hedgerows (G1)
- Woodland edge (G5)
- Fence, ditches and other boundaries (G6)

- Individual trees inside linear features (H2)
- Individual trees outside linear features (H4).

It is necessary to point out that the figures produced by this analysis are approximate due to the coarse resolution of the linear and point data (one kilometre square). Indeed to perform this analysis in the squares cut by the boundaries of the designation, the GIS assigned the value of the attribute in proportion to the area of the square included in the designation, which did not necessarily represent the situation on the ground.

- **Creation of the elevation, slope and aspect maps.**

The land-form may have a relevant impact in influencing the landscape and the distribution of the categories of land-cover. Therefore the inclusion of a DTM in studies on landscapes where land-form is dominant may produce relevant results. As already pointed out in Chapter 4 sect. 4.1 the land-form does not have a major impact on the landscape of Bedfordshire. Yet the study area includes a small part of the Chilterns Hills and of the Greensand Ridge. An analysis of the distribution of the categories of land-cover depending on elevation, slope and aspect was carried out on a test area to demonstrate the potentials of this type of approach in landscape studies.

The elevation map was derived from the elevation raster files produced after the conversion of the OS DTM in SPANS readable format. To this purpose the raster file was transformed into an elevation quadtree map after setting up a suitable classification scheme. The slope map was computed from the quadtree elevation map and expressed as a percent rise (%).

The computational algorithm is described in detail in SPANS V. 5.2 Reference manual (1991).

The aspect map is computed from the quadtree elevation map. The aspect is defined as "the orientation of the steepest slope with respect to North and is computed as an angle clockwise from North. A slope facing North has aspect of 0 degrees, facing East 90 degrees, facing South 180 degrees. If it is a flat surface (no slope) it has value 360 degrees (Intera Tydac; 1991).

7.3.5 Display and Presentation

Great flexibility in the presentation of the data was allowed by the use of the GIS. A selection of the results had to be made due to the large amount of data available.

The GIS was used to display the geographical output, while tables and charts were produced with a spreadsheet which proved to be more suitable for this purpose.

8. ANALYSIS OF THE RESULTS

The analysis of the results included the characterisation of the landscape in the study area and in the countryside designation zones. This was aimed at understanding the individual nature and the distinguishing qualities in terms of landscape of these areas resulting both from the combination of the different land-cover types and individual landscape elements such as hedgerows or trees.

Subsequently the land-form of the study area was examined in terms of its partition into classes of elevation, slope and aspect. The influence of the land-form on the distribution of the land-cover types in the study area has also been considered.

The dynamics of landscape change were examined in the study area and the countryside designation zones. The land-cover was analysed in terms of net change and gross change. The former provided information on the difference in area of land-cover types, the latter on the movements within the categories through time. The net change of selected landscape features was carried out to allow a complete characterisation of the trends.

The effectiveness of the countryside designations was finally assessed through the analysis and the comparison of the changes inside and outside selected designated areas.

8.1 Characterisation of the Landscape in the Study Area for 1968, 1981, 1991

8.1.1 Area Features

The landscape of the study area was mainly influenced by the interaction of man's activities with natural resources, as can be seen from the composition of the land-cover types in Table 15 and shown in Map 1. The area of the main categories (A, B, C, D, E) was not subject to drastic changes. The land-cover was dominated in all the three dates by agro-pastoral land (C) (from 74% to 79%) and developed land (D) (from 13% to 17%). The trends of these two main categories were opposite, with the former having its peak in 1968 and the latter in 1991. The agro-pastoral land was quite similar in proportion to that for the whole of England (73%) (CC; 1990) while the developed land (D) was higher if compared with 10% for England (CC; 1990). The amount of woodland (A) and semi-natural vegetation (B) was quite low, never rising above 9%. The presence of inland water was insignificant and was mainly concentrated in the estate of Wrest Park and Flitwick Moor.

Within the agro-pastoral category the cultivated land (C1) was dominant in all the three dates (56% to 62%). The lowest value was not surprisingly for 1991, when special schemes aimed at the reduction of agricultural production such as the Set-Aside Scheme or Farm Diversification Scheme were already in force; indeed for 1991 there was 2.3 % of Set-Aside land (C4) which was not present in the other dates. Given the possibility of misclassification of Set-Aside Land with other land-cover categories as discussed in chapter 6 sect. 6.7, it may be argued that this percentage compares favourably with the values of 2.7% for the same year for the whole of Bedfordshire (BCC; 1992). Land under the Set-Aside Scheme, might indeed have appeared also as newly planted areas (A5), improved pasture (C2) and rough pasture (C3). The maximum value for cultivated land (C1) was in 1981 with 62% of the study area which demonstrates the importance that intensive agriculture had as an economic activity in the County. Considering that agriculture and forestry were not subject to the controls of the planning system, then this figure might suggest that such an extensive presence of cultivated land might have had a close relationship with the changes in the landscape of the study area. Cultivated land (C1) had a significantly higher percentage in the study area than the corresponding value of 40% for the same period for England (CC; 1990).

Improved pasture (C2) was the second largest land-cover type within agro-pastoral land, varying from 10% to 13% followed by rough pasture (C3) with 3% to 4%. The figures for grassland confirm that agricultural activity in the study area was mainly characterised by intensive arable cultivation rather than husbandry or a combination of these two. Improved pasture (C2) had its maximum value in 1968, possibly related with a more prosperous husbandry. Rough pasture had its peak in 1991; this might be related as already discussed, with the effects of the Set-Aside Scheme.

Urban land (D1), composed mainly of the centres of Ampthill, Flitwick and Barton-le-Clay, constituted in 1991 10% out of the 17% of developed land (D). For the other dates, it remained the dominant category. However it is worth pointing out that, in 1968 urban land represented 8% out of the 13% of the total developed land and therefore the proportion between these two categories has not changed in time since they have a similar rate of growth.

Like urban land, other categories of developed land such as major transport routes (D2), isolated industrial estates (D3), derelict land (D4) and isolated rural development (D5), had their peak in 1991 which proves that an increase of population and related activities in the countryside was still in progress at that time. In particular derelict land (D4) increased its surface by a factor of 8 since 1968. During the photointerpretation it was clear that the presence of derelict land in the countryside mainly derived from disused quarries or mineral works (D6) which in 1991 had their smallest surface (0.4%). In 1968 parkland (D7), mainly deriving from the presence of the great estates in the 19th century, was the second largest land-cover type (1.5 Km^2) within developed land (12.2 Km^2), after urban land, while in 1991 it was only the fourth.

The semi-natural vegetation was composed of the lowlands heath (B1) near Ampthill and by the chalk grassland (B2) typical of the Chilterns Hills in the south of the study area. They both had their maximum values in 1968 with respectively 0.084 Km^2 and 0.584 Km^2. Although these land-cover types had a quite small surface if compared with the total of the study area (96 Km^2), they have an outstanding value in terms of landscape and ecology. However the study area is quite poor in both these categories (0.63 %) if compared with the whole England (8 %) (CC; 1990).

The main category of woodland (8 %) was dominated by broadleaved high forest (A1) (3 %) and mixed high forest (A3) (3%). The first with its highest value in 1968 (2.8 Km^2) and the second in 1991 (3.2 Km^2). By comparing the figures for 1981 with those for England in 1980 (CC; 1990) it appeared that the percentage of broadleaved high forest was higher (4.2%) and mixed forest lower (1%). In the study area scrub (A4), plantations (A5) and coniferous high forest (A2) followed. Plantations had their peak in 1991 (0.9 Km^2); indeed this might be related with the strategies adopted by the Bedfordshire County Council to increase the area of woodland. New plantations might also have increased under the effect of the Set-Aside Scheme.

The study area is more intensively managed and developed than England as a whole given its proximity to the city of London, its high percentage of high quality agricultural land according to the MAFF land classification system (MAFF; 1988)) and the presence of natural resources of national importance such as various minerals. The above analysis of the land-cover confirmed this, since agro-pastoral and developed land formed more than the 90% of the study area.

8.1.2 Linear and Point Features

The analysis of linear and point features in the study area is shown respectively in Tables 16 and 17 and Charts 1 and 2. These indicate that generally in 1968 the study area was richer in natural features and that these decreased to 1991. From Table 16, which shows the length of linear features it can be seen that the most represented feature in all the three dates was the category of hedgerows (G1) with the highest value in 1968 (479.5 Km). This gave evidence of the importance that hedgerows had in characterising the landscape of the study area where they survived as field boundaries from the period of the "enclosures" and they are still one of the most distinctive elements of the landscape. The density of hedgerows in 1991 is shown in Map 2. Other well represented categories were fences, ditches and other boundaries (G6) and woodland edge (G5). The first does not represent natural features, but it derives from man's activities on the land; its value in landscape and ecological terms is not high. Not surprisingly it had its peak in 1991 with 182.8 Km. Woodland edge (G5) varied from a minimum of 160.9 Km in 1981 to a maximum of 163.7 Km in 1991; this was in accordance with the figure of total woodland for land-cover which also had its peak in 1991.

Other natural features such as rows of trees (G4), double hedgerows (G2) and strip woodland (G3) in all the three dates were not as well represented as the previous ones. They all had their maximum values in 1968 respectively with 103.7 Km, 13.9 Km and 9.6 Km and their minimum ones in 1991. In particular rows of trees (G4) were much better represented in 1968 than in the other dates. Features such as hedgerows, double hedgerows, rows of trees and fences, during the photointerpretation were found mainly as field boundaries. All together their amount was larger in 1968 which might be a sign of a higher fragmentation of the land at that time.

The natural point features such as individual trees outside linears (H2), groups of trees (H3) and individual trees in linears (H4), all had their maximum values in 1968 and their minimum in 1991. The best represented category, as shown in Table 17, was individual trees in linear features (H4) varying from 2096 to 3019 with its maximum in 1968. This was followed by individual trees outside linear (H2) varying from 544 to 745 and groups of trees (H3). Inland water was mainly represented by farm ponds which in 1968 were larger in number than for the other dates. The number of parcels including agricultural and non agricultural (H1) had its maximum value in 1968 with 2036 and minimum in 1991 with 1893; this demonstrated that in 1968 the fragmentation of the land was higher. More than three quarters of the parcels were anycase agricultural as further evidence of the rural character of the area. The non agricultural parcels had their peak in 1991 with 347 units while the agricultural in 1968 with 1734 units. It might be argued that since in 1991 there was the lowest number in agricultural parcels and the highest in non agricultural the rural character of the area is not as strong as in the previous dates.

Finally there was the presence of 39 pylons in all the three dates, mainly concentrated in the South of the study area.

8.2 Characterisation of the Landscape in the Countryside Designation Zones

For the characterisation of the landscape in the countryside designation zones Tables 18, 19 and 20 will be discussed. Tables 18 and 19 show the characterisation of the land-cover respectively in Km^2 and % for all the countryside designation zones. The location of these areas is shown in Map 3. In the analysis, areas without particular designations, and therefore subject only to the statutory planning system, and the Village Development Limits (VDL) were also considered. The VDL are "the means of regulating the release of land in line with the likely scale of locally arising demand in the plan period" (MBDC; 1989). New development within the VDL is normally restricted to the strict policy of infilling. Therefore they include the existing village and the land most likely to be subject to further development.

From the analysis of Table 18 it can be seen that most of the study area was covered by one or more countryside designations and only 16 Km^2 out of the total 96 Km^2 were left only under the control of the statutory planning system.

8.2.1 Green Belt (Gr Blt)

The Green Belt (Gr Blt), part of the South Bedfordshire Green Belt, covered almost half of the study area with 45 Km^2 out of 96 Km^2. Within it the dominant category was cultivated land (C1) with 30 Km^2 out of the total 53.5 Km^2 of the study area, followed by improved pasture (C2) (4.6 Km^2) and broadleaved high forest (1.6 Km^2). Agro-pastoral and developed land main categories were the best represented in this area. Nonetheless the main purpose of the Gr Blt is to contain further development and can be seen that there is 1.4 Km^2 of urban land (D1) out of 9.7 Km^2 for the study area. From the analysis of some of the other categories of developed land it emerged that 0.57 Km^2 of derelict land (D4) out of a total of 0.60 Km^2 was concentrated within the areas of Gr Blt. Major transport routes and isolated industrial estates were present respectively with 1.03 Km^2 and 0.37 Km^2.

8.2.2 Areas of Great Landscape Value (AGLVs)

The Areas of Great Landscape Value (AGLVs) covered 26.5 Km^2 of the study area and were mainly concentrated in the Chiltern Hills, Greensand Ridge and Flitwick Moor. The largest land-cover type was cultivated land (C1) with 15.3 Km^2 followed by improved pasture (C2) (3.5 Km^2) and mixed high forest (A3) (2.1 Km^2); two thirds of the total (3.1 Km^2) of this last category are therefore concentrated in this designation. More than half (4.36Km^2) of the total woodland (A) of the study area (7.88 Km^2) was concentrated in these areas. AGLVs did not include lowland heath (B1) while they included the total of chalk grassland (B2) (0.56 Km^2). Isolated industrial estates (D3) were absent while, among the categories of developed land, the largest was urban land (D1) with 0.5 Km^2 followed by isolated rural developments (D5) (0.4 Km^2). Although AGLVs act to preserve the beauty of the landscape 0.013

Km^2 of derelict land (D4) and 0.069 Km^2 of quarries and mineral works (D6) can be found in these areas.

8.2.3 Areas of Outstanding Natural Beauty (AONBs)

The only Area of Outstanding Natural Beauty (AONB) in the study area was part of the larger AONB of the Chiltern Hills and it extended for 15.5 Km^2 in the Southern part of the project area. It was also included in the already mentioned AGLVs. Here, as in the AGLVs, the largest category was cultivated land (C1) (11.3 Km^2), followed by improved pasture (C2) (0.7 Km^2). Within woodland the dominant land-cover was scrub (A4) (0.67 Km^2) followed by broadleaved high forest (A1) (0.66 Km^2) while coniferous high forest (A2) was absent. The expected composition of woodland categories in the Chilterns would see broadleaved high forest (A1) as dominant whereas scrub proved to be dominant. All chalk grassland (B2) was included in this designation while lowland heath (B1) was not present. Within the land-cover types of developed, the most relevant was urban land (D1) (0.32 Km^2) followed by isolated rural developments (D5) (0.16 Km^2). As for the AGLVs isolated industrial estates (D3) were absent but derelict land (D4) and quarries/mineral works (D6) amounted respectively to 0.013 Km^2 and 0.069 Km^2.

8.2.4 Agricultural Priority Areas (APAs)

The Agricultural Priority Areas (APAs) covered 21.9 Km^2 of the total area. These areas do not aim to safeguard the landscape as much as the best agricultural land from development as already mentioned in chapter 2. Here, as expected, the dominant categories were cultivated land (C1) with 12.2 Km^2, improved pasture (C2) with 3.9 Km^2 and rough pasture (C3) with 1.5 Km^2. The main category of agro-pastoral land amounted therefore to 18.23 Km^2 out of 21.94 Km^2 of the total area of APAs and gave evidence of the strong agricultural character of these areas. Urban land (D1), among the categories of developed land, was the best represented (1 Km^2) followed by isolated rural developments (D5) (0.57 Km^2).

8.2.5 Sites of Secial Scientific Interest (SSSIs)

The Sites of Special Scientific Interest (SSSIs) extended for only 3.9 Km^2 of the total study area and with the Natural Nature Reserve of the Barton Hills which extended for 0.51 Km^2 they were the designations with the smallest area. However their importance did not lie in the extent of the area covered as much as in the quality of the natural and ecological features protected by these designations. The dominant land-cover types were represented by woodland and semi-natural vegetation. In SSSIs the largest categories were mixed high forest (A3) (1.3 Km^2), broadleaved high forest (A1) (0.76 Km^2) and scrub (A4) (0.61 Km^2). Almost half of the total surface of this category is concentrated in the SSSIs. All the area of lowland heath (B1) in the study area (0.048 Km^2) is protected by an SSSI designation and more than half of the chalk grassland (0.33 Km^2). In the NNR the largest category was chalk grassland (B2) with 0.24 Km^2 followed by broadleaved high forest (A1) (0.13 Km^2). Here significantly there was a total absence of developed land.

8.2.6 Others

In areas without designations the agro-pastoral categories were the best represented with 13.4 Km^2 out of 15.9 Km^2. Mixed high forest (A3) (0.72 Km^2) and urban land (D1) (0.51 Km^2) followed.

Within the Village Development Limits (VDL) urban land was, as expected, the largest category with 7 Km^2 out of the 9.7 Km^2 of the total study area. Categories of woodland and semi-natural vegetation within these areas are the least represented.

8.2.7 Relative Character of Designations

By analysing Tables 19 and 20 which show respectively the percentage of land-cover types and the density of selected linear and point features, it was possible to compare the character of the landscape in the different designations. From Table 19 it can be seen that the countryside designations, except SSSIs and NNR, and the areas with no designation were mostly occupied by agro-pastoral (C) land-cover types which varied from 74 % in AGLV to 83.8 % in areas without designation. In AONBs cultivated land (C1) was 72.8% as an evidence of the importance that this land-cover might have in influencing the landscape of these areas. On the other hand APAs, whose aim was to safeguard the best agricultural land from development, had the lowest value for this category (C1) (55.2 %) within these designations, following AONB (72.8 %), Gr Blt (66 %), AGLV (57.7 %) and even areas without designation (67.9 %). However improved pasture (C2) with 17.5 % and rough pasture (C3) with 6.5 % were well reresented in APAs. Since the presence of pastures may be related with the practice of husbandry it might be argued that in APAs this activity was more practiced than the aims of this designation might lead one think.

Developed land was dominant in the VDL, where it was mainly represented by urban land (D1) and isolated industrial estates (D3) respectively with 84.5 % and 3.8 % of their area. It was significant that further development in these areas will be carried out mainly at the expense of the categories of agro-pastoral land such as cultivated land (C1) (4.5 %), rough pasture (C3) (3.4 %) and improved pasture (C2) (1.4 %). However when the analysis of developed land was extended to the countryside designations it emerged that there was a higher presence of this land-cover in APAs and Gr Blt with 11.2 % and 10.5 % respectively. In particular urban land (D1) and quarries/mineral works (D6) showed their highest values within APAs with respectively 4.6 % and 1.1 %. In APAs there was also the highest relative value of isolated rural developments (D5) (2.6 %) if compared with the other designations. Urban land (D1) had a relatively high value in the Gr Blt (2.9 %) if compared with the other designations; major transport routes (D2) (2.3%) and derelict land (D4) (1.2 %) were the best represented here than in other areas, despite the aims of this designation.

SSSIs and the NNR had a quite different composition of land-cover when compared with the other designations. Here woodland (A) and semi-natural vegetation (B) were dominant, covering more than the 80 % of the area of these sites. In the SSSIs woodland was 72 % with 34.2 % being mixed high forest (A3) followed by broadleaved high forest (A1) (19.7 %) and scrub (A4) (15.8 %). 17 % of the area of SSSIs was agro-pastoral and rough pasture (C3) was the largest of this category with 8.6 %. This result was in accordance with the spirit of this designation which tends to encourage within its boundaries non intensive agricultural practices. The NNR was characterised by the highest proportion of chalk grassland (B2) (46.4 %) if compared with the other designations; woodland was also well represented with 33.3 % whose main part was composed of broadleaved high forest (A1) (25.6 %). Cultivated land (C1) was 18.7 % of the area of the NNR.

The proportion of woodland and semi-natural vegetation in the other designations was significantly lower than in SSSIs and NNR. In AGLVs and the AONB woodland is the second largest main category after agro-pastoral respectively with 16.5 % and 11.3 %. Yet the composition of woodland is different in these designations, with mixed (A3) and broadleaved (A1) high forest being better represented in AGLVs, while in AONBs this last category followed scrub (A4). However in AGLVs and AONBs woodland and semi-natural vegetation were present with higher proportions than in the study area where respectively they were 8.2 % and 0.6 % or the other areas such as Gr Blt, areas without designations and APAs.

8.2.8 Linear and Point Features by Designated Area

The density of selected linear and point features in the countryside designations and the study area for 1991 is shown in Table 20. The basic spatial unit is one kilometre square and its selection depended on the factors already discussed in chapter 5 sect 5.3. By comparing these figures for the study area with those for the whole of England in 1985 (CC; 1990) the same density can be seen for hedgerows (G1) (4.4 Km/Km^2) and woodland edge (1.7 Km/Km^2). SSSIs were the areas richest both in linear and point features. Here the density of natural features such as hedgerows (G1) (25.9 Km/Km^2) and woodland edge (G5) (22 Km/Km^2) were respectively five and ten times greater than in the study area and gave evidence of the importance that these features might have in characterising the landscape of these sites. Fences and others (G6) which represented artificial features are also more abundant in SSSIs (13.5 Km/Km^2) than in the study area (1.9 Km/Km^2). Since hedgerows and fences represented field boundaries, it might be argued that the landscape had a higher level of fragmentation within SSSIs. Also trees outside (H2) and trees in linear features (H4) had a much higher density in SSSIs with respectively 36 and 144 per Km^2. With regard to the other designations, including areas with no designation, the distribution of landscape features did not appear to be consistent with the designation itself. For example the highest density of hedgerows was shown in areas without designations (8.1 Km/Km^2) and in APAs (7.7 Km/Km^2). Surprisingly APAs were richer in natural landscape elements (apart from woodland edge (G5)) than AGLVs or AONBs. Also the density of fences and others (G6) is higher here than in other areas which might lead to the conclusion, supported also by the results of the land-cover analysis showing a higher percentage of pasture, that husbandry is more practiced here than in other designations. AGLVs appear richer in landscape elements than AONBs despite the fact that the importance of their landscape is recognised in a local context more than in a national context.

The characterisation of the landscape in the countryside designation zone shows that SSSIs and NNR were the only designations with remarkably different features from the other areas analysed. Indeed they show an extensive presence of woodland and semi-natural vegetation with the highest densities in linear and point features. In the other designations the influence of man's activities were more evident, confirmed by a dominance of categories of agro-pastoral and developed land and by a lower density of landscape elements if compared with SSSIs and NNR; furthermore the figures did not show a specific character of the landscape which could be easily related with the nature of the designation.

8.3 Relationship between Land-Cover and Terrain Characteristics

Land-form is an important component of the landscape not only since it influences its aesthetic appearance but also because it acts upon the distribution of the different land-cover types.

The land-form in the study area is characterised in Tables 21, 22 and 23 showing respectively elevation, slope and aspect as represented in Map 4. The figures for elevation in Table 21 confirmed that the study area belongs to the wider area of the so called "Lowlands", with an elevation between 40 m and 100 m for more than 80% of it.. There was no dominant category of elevation, with the largest area concentrated in the category 61-70 m with 20.43 Km^2 and the smallest in >161 m (0.43 Km^2). The analysis of Table 22 shows clearly that almost half of the study area (46.3%) was flat and more than the 80 % had a slope less than 8%. This might be related with the strong vocation for intensive agriculture of this area. The smallest areas are concentrated in the categories of steepest slope such as 30-40 % (0.35 %) and 40-50 % (0.06%). From Table 23 showing the distribution of aspect it can be seen that 7.2 % of the study area is flat; furthermore there is no dominant aspect.

Tables 24, 25 and 26 show the distribution of the land-cover types in relation to elevation, slope and aspect.

Since in the study area the elevation varied within a relatively narrow range with categories from 41-50 m to >161 m, a general analysis of Table 24 does not show a clear relationship between the distribution of the land-cover types and the elevation categories.

Lowland heath (B1) was almost all distributed between 90 m and 120 m. Most of the area of the categories of agro-pastoral C1, C2, C3, C4 was found to be concentrated between 50 m and 100 m.

The analysis of Table 25 shows a clear relationship between the land-cover types and the categories of slope. Indeed slope may influence greatly the mechanisation of some agricultural operation or the suitability of a site for new development. Within the categories of woodland, high forest (A1, A2, A3) and newly planted areas (A5) were mainly distributed on land with a slope under 6 %. More than 50 % of scrub (A4) colonised land steeper than 10% showing that this land-cover type might be found on land less suitable for other types of woodland.

Chalk grassland (B2) was concentrated mainly in the two categories of slope of 10-20 % and 20-30 % with respectively 47.9 % and 25.7 %. In the chalk hills of the Chilterns a major function of this land-cover is to prevent erosion as confirmed by the figures in the table. More than 50 % of cultivated land (C1) was in flat areas with almost 90 % under 6 %. The other categories of agro-pastoral land (C2, C3, C4) tended to be distributed mainly on land under 6 %. Developed land also was concentrated in the first two categories of slope. Only derelict land (D4) and quarries/mineral works (D6) had a more even distribution in categories with slope over 4 %.

The figures in Table 26, show the distribution of the land-cover depending on the aspect. This last factor may influence, for example, the distribution of land-cover -types according to the hours of sunshine or the influence of the dominant blowing winds on crops. However in this case the data did not show a clear relationship between the land-cover and categories of aspect and lead to the conclusion that aspect was not a major factor in influencing the distribution of the land-cover in the study area.

8.4 Landscape Change Dynamics

The landscape change for the land-cover was analysed in terms of net change and gross change (gross gain and loss).

The net change is the difference between the areas of a land-cover type for two different dates and may be represented by a negative (loss) or a positive (gain) figure.

The gross change represents the total amount of change into and out of a feature and is always a positive figure. It can be much larger than net change and where this occurs it is a valuable indicator of dynamic changes within the landscape which from net change might not appear so clearly. For example the gross change in category A between 1968 and 1991 was calculated as follows:

Gross = ABS (A1968 - Both) + ABS (A1991 - Both)

where

Both = area that was cover type A for both the dates
ABS = absolute value

The figures necessary to calculate net and gross change were extracted from the tables produced with SPANS during the area cross-tabulation analysis previously discussed in chapter 7 sect. 7.3.4.2.

However the tables selected for the discussion of the land-cover dynamics show only the gross change in terms of losses and gains. Reconsidering the example above, these are :

Losses = (A1968 - Both)
Gains = (A1991 - Both)

However these values allow to work out easily net and gross change as following:

Net change = Gains + Losses
Gross change = ABS(gains) + ABS(losses)

The gross losses and gains shown on the tables represented respectively the total amount of change out of and into a feature.

Linear and point features were represented as net change.

Charts allowed the identification of the nature of the losses and gains for each land-cover category and completed the information provided by the tables. Here the positive figures represented the gains and the negative ones the losses.

8.4.1 Landscape Change Dynamics in the Study Area

Landscape change dynamics in the study area are shown in Tables 27, 28 and 29 and in Charts 3, 4 and 5.

From an analysis of Table 27 it can be seen that in the whole period (1968-1991) the main categories of woodland (A) and developed land (D) had larger gains of land than losses, with respectively 1.82 Km^2 and -1.47 Km^2 for woodland and 4.66 Km^2 and -0.85 Km^2 for developed land; semi-natural vegetation (B) (0.013 Km^2 and -0.073 Km^2) and agro-pastoral land (C) (16.61 Km^2 and -20.734 Km^2) had trends opposite to the previous ones. If the two periods 1968-1981 and 1981-1991 are considered, these tendencies were respected, except for woodland. Here losses were larger than gains in 1968-1981 with an opposite trend in 1981-1991. This gives evidence of the positive result of the strategies undertaken by the Bedfordshire County Council to improve the area of woodland in the County. In the main category of woodland, in 1968-1991, it emerged that broadleaved high forest (A1) and scrub (A4) had a net loss while coniferous (A2) and mixed high forest (A3) and newly planted had a net gain; this was in accordance with the trends in the whole of England (CC; 1990) where the native forests of broadleaved species were replaced by coniferous species.

In agro-pastoral land the dynamics from 1968 to 1991 showed categories such as cultivated land (C1) and improved pasture (C2) which suffered a net loss of land. Gains were respectively 5.86 Km^2 and 5.9 Km^2 with losses of -11.23 Km^2 and -7.50 Km^2. On the contrary rough pasture (C3) and Set-Aside land (C4) had a net gain and this was in accordance with the possible effect that new strategies for a more extensive agriculture might have had. The dynamics in cultivated land in 1968-1991 are shown in Chart 3 and Map 5 where a high rate of interchange of this category with improved pasture (C2) can be seen. The gains (6 Km^2) and the losses from and to this last category were almost the same. The same happened with rough pasture (C3) although the amount of land interchanged was smaller (less than 2 Km^2). These effects might be related with the rotation of the land applied as a good agronomic practice to maintain the productivity of the land. Losses of cultivated land (C1) not compensated by any gain occurred in favour of newly planted areas (A5) and Set-Aside land (C4) likely as an effect of the application of the Set-Aside Scheme. From the same chart a loss emerged of more than 2 Km^2 of cultivated land to developed land: in this case these areas may be considered irretrievable to agro-pastoral use. The analysis of Chart 4, showing the changes in improved pasture (C2), in part confirmed what was already stated above for cultivated land. A loss to developed land (D), although smaller than for cultivated land was also shown.

The changes in 1968-1991 in developed land (D) in Table 27 and Map 6, showed that all the classes of this main category had larger gains than losses except for quarries/mineral works (D6) and parkland (D7). Almost all the loss of this last land-cover type happened in the period 1968-1981. In the same period urban land (D1) had its largest net growth shown by a gain of 1.94 Km^2 versus a loss of only 0.024 Km^2. Chart 5 shows the dynamics in developed land (D) (which here did not include parkland (D7)) for 1968-1991. Against no losses, gains occurred primarily from cultivated land (C1), followed in order by improved (C2) and rough pasture (C3), scrub (A4) and parkland (D7).

From the analysis of linear features for 1968-1991 a loss in all features except woodland edge (G5) and fences/ditches (G6) can be seen. Out of 51.42 Km of total loss of hedgerows, it emerged that 37.21 Km disappeared between 1981 and 1991 despite policies more conscious of the importance of landscape and environment being applied in this period. The same trend was registered for double hedgerows (G2) and strip woodland (G3) where in 1968-1981 there were gains followed by losses in 1981-1991. Rows of trees (G5) had their major loss in 1968-1981 with 30.98 Km out of the total loss of 38.48 Km for the period from 1968 to 1991. This confirms what was already noticed in the phase of photointerpretation, where a high number of trees were dead due to the attack of the Dutch Elm disease. Woodland edge (G5) had a net gain of 2.79 Km in 1981-1991, which exceeded the loss (1.49 Km) of the previous period. Fences/ditches (G6) had the largest increase in 1981-1991 with 30.52 Km against a loss of 9.8 Km in the previous decade. The changes in hedgerows (G1) and fences/ditches in this period might show that the former might have been replaced with the latter.

The analysis of point features in Table 29 showed losses for all the categories, except in non agricultural parcels (H1b). In particular trees in linears (H4) suffered the largest loss, which for the whole period was of 923 trees and mainly occurred between 1968 and 1981 (535). Loss from 1968 to 1991 is represented as density per Km^2 in Map 7. The trend for trees outside linears (H2) was similar with a loss of 201 units in 1968-1991 of which 154 were in 1968-1981. Also in groups of trees (H3) and inland water (H5) the major losses occurred in the first decade respectively with -64 and -15 units. The trend for the total parcels of land (H1) moved toward less fragmentation of the land, mainly dependent on the reduction in agricultural parcels (H1a) which for the total period decreased by 188 units and for 1968-1981 decreased by 117 as an evidence that a process of reorganisation of agricultural land characterised the first decade of the period analysed. On the contrary non agricultural parcels (H1b) had an increase of 45 units.

Concluding, the analysis of landscape change in the study area shows an evolution in the whole period towards a landscape poorer in natural landscape features and with a higher presence of man derived elements on the land. This resulted both from the analysis of linear and point features and of the land-cover. Natural linear features had the most relevant losses in the second decade mainly for non natural causes. Hedgerows were the features most subject to this trend, with an increase of artificial features such as fences/ditches as evidence of the influence of man's activities on the land. The increase of woodland edge was mainly related to the increase of plantation which, although it contributs to the increase of wooded areas, cannot be considered part of the natural heritage of the area. Most of the loss of trees, occurred in the first decade mainly as the consequence of Dutch Elm disease. Semi-natural land-cover types were partially lost, while developed land increased mainly at the expens of agro-pastoral land. Within the agro-pastoral categories there was a trend towards a less intensive use of the land shown by a decrease of cultivated land and an increase in rough pasture and Set-Aside land.

8.4.2 Landscape Change Dynamics in the Countryside Designation Zones

8.4.2.1 Areas of Great Landscape Value (AGLV)

Changes in land-cover in AGLV are shown in Table 30 and Charts 6 and 7. Table 36 shows changes in selected linear and point features. In AGLV the trends for the whole period were similar to those in the study area. Woodland (A) and developed land (D) had larger gains than losses, while semi-natural vegetation and agro-pastoral land had reversed trends. The categories of woodland subject to net gain were coniferous forest (A2) (0.042 Km^2 gain versus 0.008 Km^2 loss), mixed high forest (A3) (0.262 Km^2 gain versus 0.130 Km^2 loss) and plantations (A5) (0.282 Km^2 gain versus 0.174 Km^2 loss). The change in high forest in 1968-1991 is shown in chart N.6. The highest gains and losses resulted, as expected from and to plantations: this indicated that part of the forest in AGLV was likely managed for timber production. A smaller rate of interchange resulted also with scrub (A4), rough pasture (C3) and parkland (D7). A small gain was shown from cultivated land (C1). The trends described in Table 30 for the categories of woodland and agro-pastoral land reflected those in the study area. In discussing the trends in the category of developed land it is worth remembering that although AGLV designation does not have any statutory power itself, it is supposed to strengthen the power of the statutory planning system. The designation was enacted in Bedfordshire in the late 50s' and therefore its effect covered the whole period analysed. In AGLV, from 1968 to 1991, there was a gain in developed land (D) of 0.304 Km^2 versus a loss of 0.198 Km^2, this last totally represented by parkland (D7). It was significant that major transport routes (D2) were characterised by the highest gain (0.132 Km^2), followed by urban land (D1) (0.078 Km^2) and isolated rural developments (D5)(0.076 Km^2). Transport routes are developments to which these designation are likely to be sacrificed for the national interest, as already pointed out in chapter 2 sect. 2.4.3. Chart 7 shows that development occurred mainly at the expenses of cultivated land (C1), followed in order by improved pasture (C2), scrub (A4), parkland (D7) and rough pasture (C3). Since the figures in Table 30 express gross change, which is an indicator of dynamic changes, the absence of dynamics for the categories of developed land, in particular for isolated industrial estates (D3), derelict land (D4) and quarries/mineral works (D6), possibly relate to the effect of the designation.

From 1968 to 1991 losses of natural features such as hedgerows (-0.98 Km/Km^2) and trees in (H4) (-12/Km^2) and outside (H2)(-4 /Km^2) linear occurred in these areas. On the contrary woodland edge (G5) and fences/ditches (G6) had an increase respectively of 0.043 Km/Km^2 and 0.266 Km/Km^2.

8.4.2.2 Areas of Outstanding Natural Beauty (AONB)

The only AONB in the study area, being designated in 1964, was effective throughout nearly the whole period analysed. As for AGLV it did not add any additional power to the statutory planning system and mainly strengthened its controls over new development. The changes for land-cover are shown in Table 31 while Table 36 shows the changes for some linear and point features. The trends in the main categories of land-cover showed that in woodland (A), semi-natural vegetation (B) and agro-pastoral land (C) losses were larger than gains. Only developed land had a net gain of 0.168 Km^2 mainly due to major transport routes (D2). Since the AONB is included in AGLV the dynamics in this category were generated by the same events. In woodland (A) mixed high forest was the only type with a net gain (0.073 Km^2); the gains and losses in newly planted areas were almost equal which proved that this category did not contribute to increase the total area of woodland. Improved pasture (C2) was the only type of agro-pastoral that decreased, having a loss of 1.237 Km^2 versus a gain of 0.512 Km^2. The dynamics in the types of developed land (D) were practically absent.

The analysis of linear and point features shows losses for all the natural elements of the landscape between 1968 and 1991 except for trees outside linear (H2). Hedgerows (G1) lost 0.71 Km/Km^2 and woodland edge 0.105 Km/Km^2. Fences/ditches (G6) gained 0.198 Km/Km^2 being the only feature to increase in this period.

8.4.2.3 Agricultural Priority Areas (APA)

APA were designated in Bedfordshire in the 1980s with the aim of preserving the best agricultural land from development. Therefore they do not aim to protect the landscape and from the definition of the designation itself a more intensive agriculture is expected.

The analysis of the changes in land-cover showed however that for 1981-1991 cultivated land (C1) had a net loss since the losses (-3.34 Km^2) were larger than the gains (0.42 Km^2). The opposite trend was seen for improved pasture (C2), rough pasture (C3) and Set-Aside land (C4) and this might lead to the conclusion of a trend towards extensification of agriculture in these areas. The increase of woodland (A) (0.469 Km^2) from 1968 to 1991 was mainly due to plantations (A5) as to confirm the increased presence of managed woods in these areas. Developed land (D) had a gain of 0.930 Km^2 versus a loss of -0.106 Km^2. Urban land (D1) and transport routes (D2) were the categories with the largest growth, followed by quarries/mineral works (D6), isolated rural developments (D5) and isolated industrial estates (D3). In 1981-1991 there was a net gain in quarries/mineral works (D6) of 0.169 Km^2.

Regarding the change in linear and point features from 1968 to 1991, Table 36 shows a loss in natural features such as hedgerows (G1) (-0.71 Km/Km^2), trees outside linear (H2) (-2 $/Km^2$) and trees in linear (-10 $/Km^2$). Woodland edge (G5) increased by 0.186 Km/Km^2, mainly related with the increase of plantations, and also fences/ditches (G6) (0.568 Km/Km^2).

8.4.2.4 Green Belt (Gr Blt)

The South Bedfordshire Green Belt was designated in the 1960s as a tool to control new development and the merging of neighbouring towns.

The changes in these areas are shown in Table 33 and Charts 8 and 9. From 1968 to 1991 there was a gain in developed land (D) of 1.582 Km^2 versus a loss of -0.496 Km^2. The increase was mainly given by derelict land (D4) (0.556 Km^2), urban land (D1) (0.416 Km^2) and transport routes (D2) (0.259 Km^2). This last category had its major expansion from 1981 to 1991 with 0.234 Km^2. Chart N.9 shows that development in the Green Belt occurred mainly at the expenses of cultivated land (C1), followed by scrub (A4), improved pasture (C2), rough pasture (C3) and parkland (D7). In woodland (A), the gross change showed some dynamics although the resulting net change was zero. In agro-pastoral land (C) from 1968 to 1991 there was a net loss of more than 1 Km^2 (7.526 Km^2 of gain and -8.562 Km^2 of loss) mainly caused by a decrease in improved pasture (C2) (-4.2 Km^2 loss and 2.344 Km^2 gain). Chart 8 shows the changes in cultivated land (C1) from 1968-1991 in Green Belt. Gains and losses mainly occurred with improved pasture (C2): however the amount of gains was of almost 1 Km^2 higher than the losses which in part might be the reason for the decrease of improved pasture (C2) shown in Table 33. There was a small interchange of land also with rough pasture (C3), while losses occurred to Set-Aside land (C4) and developed land.

8.4.2.5 Sites of Special Scientific Interest (SSSI)

The SSSIs were given increased protection only after 1981 when under the Wildlife and Countryside Act a renotification programme reviewed all the existing sites. Land-cover change in SSSIs is shown in Table 34 and Charts 10 and 11. If the whole period is considered, there was a net gain in woodland (A) (0.325 Km^2 gain versus 0.233 Km^2 loss) mainly due to broadleaved forest (A1) and scrub (A4). High forest interchanged with newly planted areas as shown in Chart 10 as a evidence that in SSSIs part of the forest was managed and not left in natural conditions. A smaller amount of land was exchanged also with rough pasture (C3), while gains were at the expenses of scrub (A4) and semi-natural vegetation (B). Table 34 shows that semi-natural vegetation (B) had a net loss of -0.052 Km^2 occurring mainly in the first decade of the total period. Chart 11 illustrates this loss mainly in favour of scrub (A4) and high forest (A123). Indeed already in the phase of photointerpretation it was observed that areas of lowlands heath and chalk grassland evolved towards scrub which might be interpreted as a loss of the identity of the sites due to the degradation of their original characteristics. Agro-pastoral land (C) suffered losses (-0.337 Km^2) larger than gains (0.293 Km^2). However rough pasture (C3) and set-aside land (C4) had a net increase to confirm that there was a process of extensification of agriculture in these sites. Gains in developed land were negligible and figures in these categories show the absence of dynamics of these land-covers in SSSIs.

Despite these designations a tighter control over operations damaging the characteristics of the sites was expected Table 36 shows a loss in natural features such as hedgerows(G1) (-3.301 Km/Km^2) and trees in linear (H4) (-54 $/Km^2$). An increase in woodland edge (G5) (0.044 Km/Km^2) and fences/ditches (G6) (2.103 Km/Km^2) was also noticed.

8.4.2.6 Areas without Countryside Designations

In areas without countryside designations only the statutory planning system is responsible for control of the use of the land. From the analysis of Table 35 it can be seen that developed land (D) was the only main category characterised by gains (0.216 Km^2) larger than losses (-0.004 Km^2). All the categories of developed gained land except parkland (D7). In particular urban land (D1) with 0.105 Km^2 covered almost half of the total gain in developed land. In the categories of agro-pastoral land (C) cultivated land (C1) and improved pasture (C2) had losses higher than gains with respectively -1.541 Km^2 and 0.942 Km^2 and -1.195 Km^2 and 0.422 Km^2. Rough pasture (C3) and Set-Aside land had net gains respectively of 0.237 Km^2 (0.369 Km^2 and -0.132 Km^2) and 0.945 Km^2. Woodland (A) had losses larger than gains with the former being -0.471 Km2 and the latter 0.418 Km2. The losses were mainly represented by broadleaved forest (A1) and plantations (A5). Table 36 shows losses for all the natural landscape features, while the only feature to increase was fences/ditches (G6).

8.4.2.7 Summary

Generally the trends of the land-cover in the countryside designations were similar to those in the study area as a whole indicating that the presence of these areas did not influence the changes in the landscape in an evident way.

In almost all the designations there was a growth in those categories of woodland related with the action of man such as plantations or the derived mixed and coniferous forests. Unlike the study area as a whole in some designations such as AONBs and Green Belt there was a global loss of woodland. Trends in the categories of agro-pastoral showed that as a general rule there was an increase in rough pasture and set-aside and a loss in cultivated and improved pasture both in the study area and the countryside designations. It was also clear that losses in cultivated land (C1) were higher in the second decade, probably related with the application of schemes aimed to promote a less intensive agriculture. Losses of semi-natural vegetation have occurred in all the designations as well as in the study area. The trend for developed land saw an increase in all the categories except parkland without a specific pattern concerning the distribution in the two decades except for urban land, which increased mainly in the first decade.

Also from the analysis of the changes of linear and point features in Table 36 there was no clear trend related to the character of the different designations. For example the highest losses of hedgerows and trees in linear occurred just in the SSSIs respectively with -3.301 Km/Km^2 and -54 $/Km^2$. The amount of losses and gains for the other features could not be related in any way with the aims of each designation.

8.5 Effectiveness of the Countryside Designations

For the assessment of the effectiveness of the designations, a comparison was carried out between the changes in the land-cover types and selected linear and point features respectively inside and outside each designation area. The results are shown in Tables 37, 38 and 39. The figures are expressed in percentage to allow the comparison between zones (inside and outside) characterised by different areas.

8.5.1 Green Belt

The analysis of net change respectively inside and outside the Green Belt for 1968-1991, in Table 37, showed that inside the Green Belt the losses in agro-pastoral land (C) (-2.27 %) were smaller than outside (-6.11 %) as were the gains in developed land (D) (2.38 % and 5.39 %). Losses in agro-pastoral inside the Green Belt were dominated by improved pasture (-4.07 %) and outside by cultivated land (C1) (-10.75 %). The urban land (D1) increased 0.87 % in the designation and 4.27 % outside which gives evidence that urban growth in some way was restrained by the presence of the designation. The gross changes showed that the dynamics were generally higher outside the Green Belt. This was true in particular for the categories of agro-pastoral and developed land where respectively 42.13 % and 6.81 % was subject to change versus the corresponding values of 35.31 % and 4.56 % inside the Green Belt.

8.5.2 Areas of Great Landscape Value

The analysis of the changes inside and outside AGLVs, in Table 37, showed that inside AGLVs the trends in land-cover tend to maintain the agro-pastoral character of the areas. Indeed from the net change a loss of 0.87 % emerged of agro-pastoral land (C) inside AGLV versus a corresponding value of 5.59 % outside. In particular cultivated land (C1) lost only 1.34 % inside AGLVs if compared with the 7.21 % of outside; furthermore inside the increase of set-aside land (C4) (0.69 %) was lower, leading to the conclusion that possibly agriculture in the AGLVs tend to be more intensive than outside. Woodland (A) increased by 0.59 % in AGLVs versus 0.28 % outside AGLVs, mainly due to coniferous (A2) and mixed (A3) high forests. The trend for developed land (D) showed an increase of 0.4 % in AGLVs versus 5.32 % outside AGLVs which demonstrated a possible influence of this designation on the expansion of this land-cover, shown in particular with a difference in the increase of urban land (D1) which inside AGLVs was 0.30 % versus 3.56 % outside. From the values of the gross change the agro-pastoral land (C) had for both inside and outside AGLVs the highest dynamics respectively with 37.63 % and 39.37 %. The gross change for developed land (D) showed higher dynamics outside AGLV with 7.21 % versus 1.9 % inside as evidence of a lower mobility of the categories of developed in this last area.

The analysis of linear and point features, in Table 39, did not show a particular trend which could give evidence of an influence of the designation on landscape change.

The changes, represented mainly by losses in all the features except woodland edge (G5) and fences/ditches (G6), had similar trends inside and outside AGLV. A higher loss of hedgerows (G1) resulted inside AGLV with 0.989 Km/Km^2 versus a loss of 0.689 Km/Km^2 outside.

8.5.3 Areas of Outstanding Natural Beauty

The changes inside and outside AONB from 1968 to 1991 are shown in Table 38 for the land-cover and Table 39 for linear and point features. As for AGLV the net loss in agro-pastoral (C) was lower inside (0.84 %) than outside (4.95 %) the designation. Cultivated land (C1) had a gain of 1.28 % inside AONB versus a loss of 6.91 % outside AONB. On the contrary improved pasture decreased by 4.68 % in AONB and 0.99 % outside AONB. Also set-aside land had a larger increase outside the designated areas. As in AGLV developed land showed a net increase of 1.09 % in AONB, larger than the one occurring outside (4.52 %). This difference was mainly originated by a higher growth of urban land (D1) outside AONB. Woodland showed a small loss inside AONB (-0.05 %), mainly due to a decrease in scrub (A4), while plantations (A5) showed an increase of 0.49 % only outside AONB. Dynamics in land-cover were generally higher outside AONB as evidence of a greater mobility within the categories. In particular these differences are more evident for agro-pastoral types (C) with 27.31 % inside AONB and 41.12 % outside and developed land (D) with 1.09 % inside and 9.13 % outside the designation.

Linear and point feature changes from 1968 to 1991, in Table 39, show that the presence of the designation did not influence the trends, being generally negative for natural landscape features both inside and outside AONB. Losses of hedgerows were higher inside the designation (0.71 Km/Km^2), possibly related with the consequences of the presence of a more intensive agriculture; also woodland edge (G5) showed a loss of -0.105 Km/Km^2 inside the designation versus a gain of 0.046 Km/Km^2 outside it.

8.5.4 Sites of Special Scientific Interest

The comparison between areas inside and outside SSSIs showed trends quite similar to those already discussed in the other designations. The net increase of woodland was higher in SSSIs (2.37 %) if compared with the areas outside (0.28 %) and mainly given by broadleaved forest (A1) and scrub (A4). Losses in semi-natural vegetation (B) of 1.35 % occurred in SSSIs: these included almost all the areas of these categories of the study area and therefore a comparison with the areas outside these designations did not have meaning. Net losses of agro-pastoral were larger outside SSSIs being -4.42 % versus -1.14 % of those occurring inside. The trend of the categories inside this main class did not give a clear evidence of the influence of this designation on changes of agriculture towards more extensive practices. Net change in developed land (D) was 4.12 % outside SSSIs versus 0.13 % inside as an evidence of a lower growth of this category in the designation.

Changes in linear and point features from 1968 to 1991, in Table 39, showed significantly higher losses of hedgerows (G1) (-3.31 Km/Km^2) and trees in linear (H4) (-54/Km^2) inside SSSIs. On the contrary a growth of 2.103 Km/Km^2 in fences/ditches (G6) resulted higher in SSSIs than outside (0.225 Km/Km^2) as an evidence of an increase of artificial landscape features in these areas.

8.5.5.Summary

The comparison of the changes of the landscape inside and outside the designations analysed showed clearly a lower growth of developed land in the designated areas. Indeed Green Belt, AGLV and AONB, as already discussed in chapter 2, do not add statutory powers to the conventional planning but just strengthen the application of the latter over new development. Regarding this aspect the designation might be considered effective as shown by the results. The decrease of agro-pastoral land was generally smaller inside the designations than outside as an evidence that the strong agricultural character of these areas tends to persist.

However as regards the protection and conservation of landscape these designation are not provided with adequate tools to prevent loss of landscape elements as proved by the fact that no significant differences were found inside and outside the designated areas. SSSI was the only designation where, due to the possibility of applying the management agreements to safeguard the natural features of the sites a trend different from those of the previous designations was expected. The results, however, did not show a trend clearly different from those of the areas outside SSSIs and on the contrary losses in landscape features occurred more heavily inside the sites than outside.

9. CONCLUSIONS

9.1 Effectiveness of Photointerpretation

The incorporation of policies and proposals for landscape conservation into local plans requires the availability of land-use and landscape data.

This project has demonstrated the suitability of large scale aerial photography for studying land-cover categories and landscape features. In particular aerial photography proved to be unrivalled for the detection of minor elements such as trees or fences otherwise impossible with other remote sensing techniques. However the use of aerial photographic interpretation in this context proved that this technique is more suitable in landscape studies at local level for its characteristics of being costly and time consuming.

Landscape mapping carried out through API provided a dataset which, if extended on a wider basis, could form the baseline against which future or past changes can be measured and represent the input for the application of some methods of landscape assessment or for the development of landscape plans on a local basis.

The ground survey and the accuracy assessment work have demonstrated the level of accuracy in the identification of landscape features and provided information on the reliability of the results of API. It outlined also the weak points of the classification scheme and possible future improvements. Field survey, in combination with aerial photographic interpretation has proved to be vital in the monitoring process not only for checking the accuracy of the interpretation but also for providing preliminary information for the development of the classification scheme.

9.2 Use of GIS Technology

GIS technology and the software adopted proved to be suitable for the creation of a database of landscape features and for performing all the analysis required both in the study area and the countryside designation zones.

Therefore, one of the main aims of this project, consisting of the compilation of a database of detailed landscape features for a study area in Bedfordshire has been achieved. The data exist in digital format and the GIS offers flexibility for data retrieval, for adding new information or for performing complex database operations. Indeed the results reported in this thesis are only a selected range of all the information archived in the database. In addition, new data may be produced as new queries arise both in the form of maps and tables. For example, the database could be extended to the whole county of Bedfordshire, if required, or new countryside designation areas may be added as new land-use policies are developed.

This project has also given an example, by linking different sets of data in a GIS environment, of the potentials of this relatively new technology to combine and manipulate information for assisting decision-makers in the land-use planning process.

Indeed it is the first application of GIS for analysing land-use and landscape changes in such a wide range of countryside designations zones. The use of GIS overlay techniques lead to the production of new information from combinations of varied data layers for investigating the effectiveness of land-use planning policies. The GIS allowed the comparison of the different characters of the designations in quantitative terms and the monitoring of the changes in relation with the influence of the countryside designations. This provides the basis upon which new conservation strategies can be based or the existing policies can be more effectively addressed.

This GIS application is therefore a contribution to the evolution of a more integrated apporach to land use planning based on a more comprehensive understanding of the rural environment in its complex.

Moreover the effectiveness of GIS for landscape mapping, in integration with data on land-form has demonstrated the feasibility of the use of GIS in the application of those methods for landscape assessment based on the utilisation of these datasets.

9.3 Landscape Change and Effectiveness of the Countryside Designation Zones

The use of GIS has allowed the characterisation of the study area and of the countryside designations in terms of proportion of categories of land cover and landscape elements.

The new aspect of this GIS application lies in the possibility of carrying out an extensive investigation of landscape changes in the CDZs based on quantitative data for the first time. The changes in land cover were analysed not only in terms of difference between two different dates, but also in terms of total amount of change into and out of a feature so that the rate of interchange within categories is also analysed.

These data together with those on the density of landscape features allowed a complete analysis of the evolution of the landscape and land-use in these areas in the last decades.

The characterisation of the areas outside the CDZs and of the "white land" (areas without designations) was useful to outline possible differences with the designated areas in the evolution of the landscape.

From the complete census of landscape features and their changes in the study area analysed for 1968, 1981, 1991, an intensive management pattern emerged given that agro-pastoral and developed land formed more than 90% of its area. The intensive character of agriculture is shown by the dominance of cultivated land within the agro-pastoral categories. The minor elements of landscape are dominated by hedgerows and trees in linears, still surviving in the area as an inheritance of the past rural economies.

All the countryside designations, except SSSIs and NNR showed a strong agro-pastoral character since they were dominated by cultivated land and pastures. This fact is confirmed also by a lower presence of developed land in the designations than in the study area. SSSIs and NNR on the contrary showed an extensive presence of woodland and semi-natural vegetation, associated with a higher density of landscape features as an evidence of a landscape less influenced by man's activities.

The changes in the landscape of the study area moved towards a more intensive management of the area resulting in an increase of categories of developed land which occurred mainly at the expense of agro-pastoral cover types. Losses in heather and chalk grassland confirmed this trend. Woodland increased, but changed its composition since the more traditional broadleaved forest decreased in favour of plantations, mainly of conifers and mixed forest. The effect of the Set-Aside Scheme and other schemes for extensification of agricultural practices may be partially responsible for the increase of plantations as they are for the changes in agro-pastoral categories, shown as a decrease of cultivated land and an increase of set-aside land and rough pasture.

Trends in the minor landscape elements showed a loss in the traditional elements of landscape such as hedgerows or trees in linears in favour of fences, ditches and other boundaries. The increase of woodland edge was mainly related to the areas of new plantations.

The trends of the land-cover in the countryside designations were generally similar to those reported above for the study area except for the growth of categories of developed land, which in the designations were significantly lower. Changes in linear and point features did not show a clear trend related to the character of the designations.

The comparison of the changes of landscape outside and inside the CDZs showed that the latter proved to be effective in preventing the sprawl of developed land. However as regards minor landscape elements lossess occurred with a similar pace independent of the presence of designations which may lead to the conclusion that the powers related with these designations are not sufficient to made them effective.

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CRANFIELD UNIVERSITY
SILSOE COLLEGE

M. Phil THESIS

ACADEMIC YEAR 1992 - 1993

ELISABETTA PECCOL

A GIS BASED DATASET TO ASSESS THE INFLUENCE OF COUNTRYSIDE PLANNING POLICIES ON LANDSCAPE CHANGE IN BEDFORDSHIRE

VOLUME 2

SUPERVISOR: Dr. CHRIS A. BIRD

February 1994

THIS THESIS IS SUBMITTED IN FULFILLMENT OF THE
REQUIREMENTS
FOR THE DEGREE OF MASTER PHILOSOPHY

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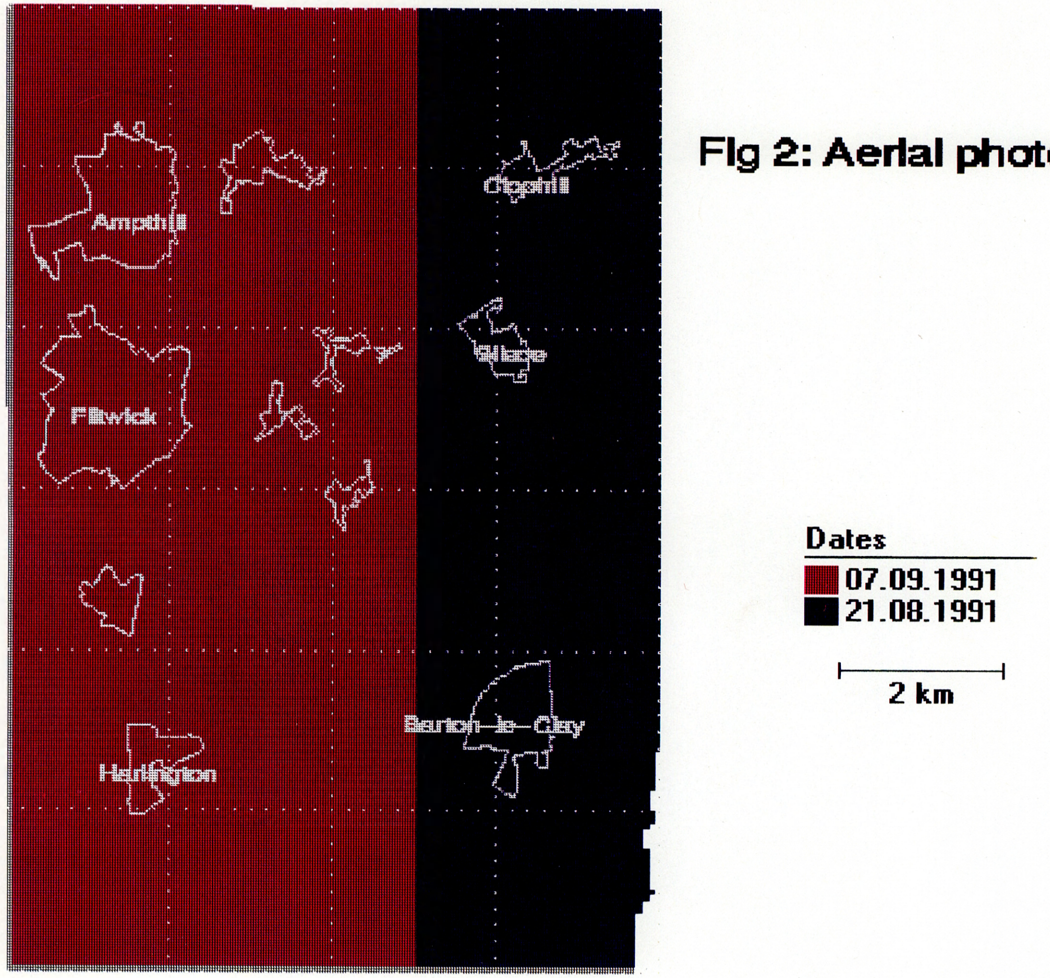
LIST OF ACRONIMS:

APA	Agricultural Priority Area
API	Aerial photographic interpretation
AGLV	Area of Great Landscape Value
AONB	Area of Outstanding Natural Beauty
ASPRS	American Society for Photogrammetry and Remote Sensing
BCC	Bedfordshire County Council
BNHS	Bedfordshire Natural History Society
CAP	Common Agricultural Policy
CC	Countryside Commission
CDZ	Countryside Designation Zone
CIS	Countryside Information System
CPO	Compulsory Purchase Order
CPS	Countryside Premium Scheme
CSC	Chilterns Standing Conference
DEM	Digital Elevation Model
DTM	Digital Terrain Model
DoE	Department of Environment
ECLUC	Ecological Consequences of Land-Use Change
EN	English Nature
ESAMP	Environmentally Sensitive Areas Monitoring Programme
FDS	Farm Diversification Scheme
FWS	Farm Woodland Scheme
GIS	Geographical Information System
Gr Blt	Green Belt
ITE	Institute of Terrestrial Ecology
LNR	Local Nature Reserve
LUC	Land Use Consultants
MAFF	Ministry of Agriculture Fishery and Food
MBDC	Mid Bedfordshire District Council
MLC	Monitoring Landscape Change
MLCNP	Monitoring Landscape Change in the National Parks
MLURI	Macaulay Land Use Research Institute
NC	Nature Conservancy
NCC	Nature Conservancy Council
NCMS	National Countryside Monitoring Scheme
NCO	Nature Conservation Order
NNR	National Nature Reserve
OS	Ordnance Survey
RAF	Royal Aerial Force
SAS	Set-Aside Scheme
SBDC	South Bedfordshire District Council
SSSI	Site of Special Scientific Interest
TPO	Tree preservation Order
VDL	Village Develpment Limits
WGS	Woodland Grant Scheme

FIGURES

Fig 2: Aerial photography coverage



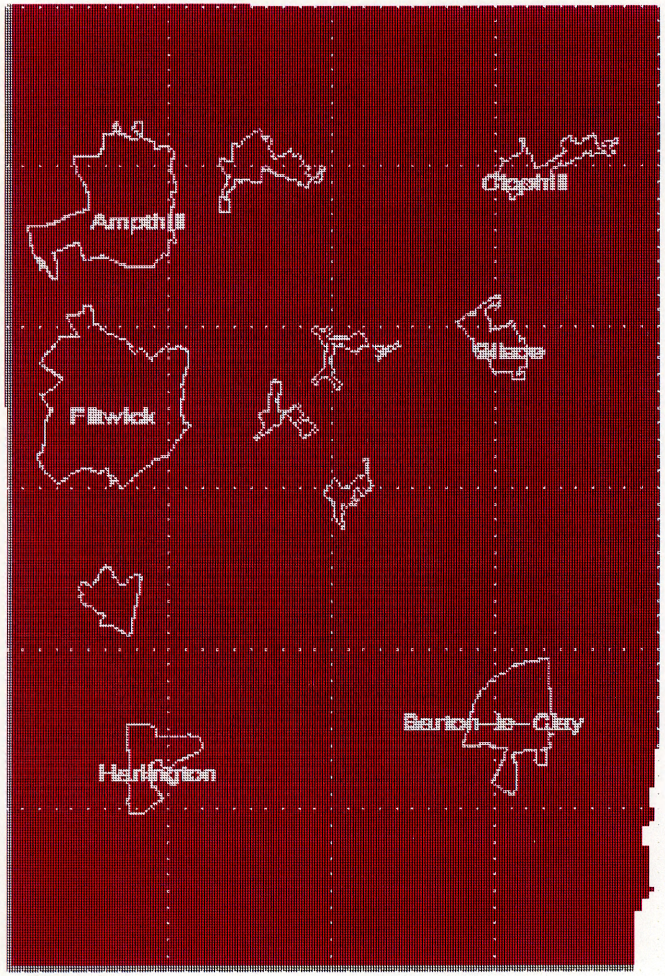
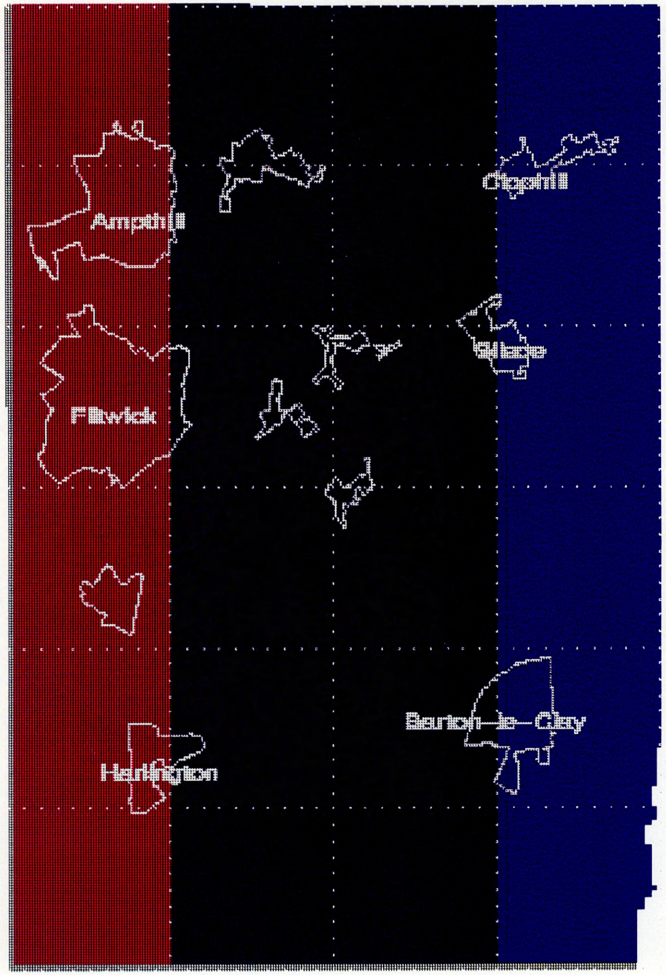


Fig. 3: Aerial photography coverage

Fig. 4: Aerial photography coverage



Dates
01.07.1968
08.04.1969
14.10.1968

2 km

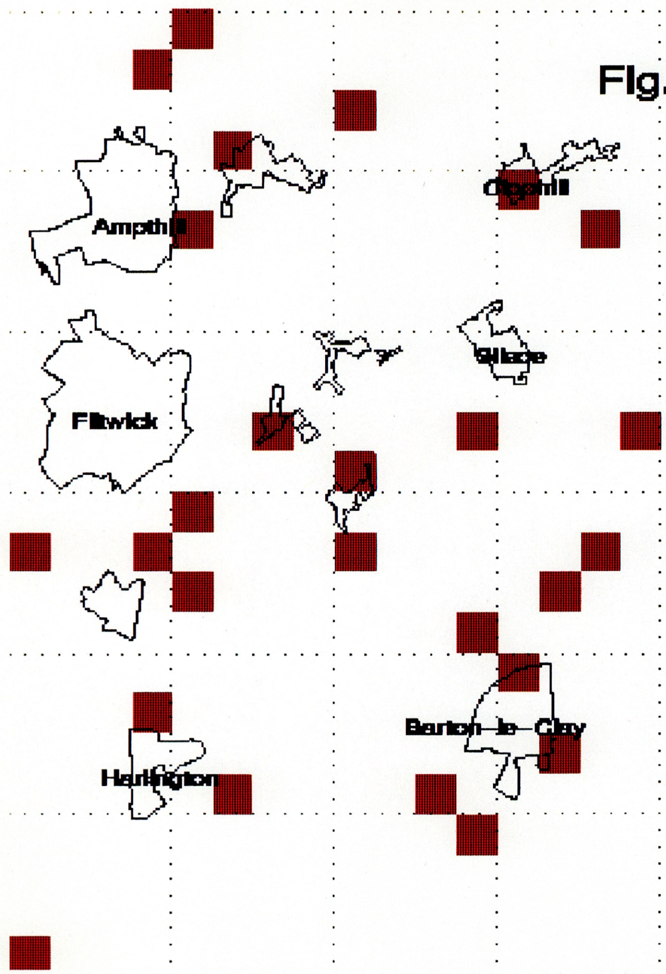
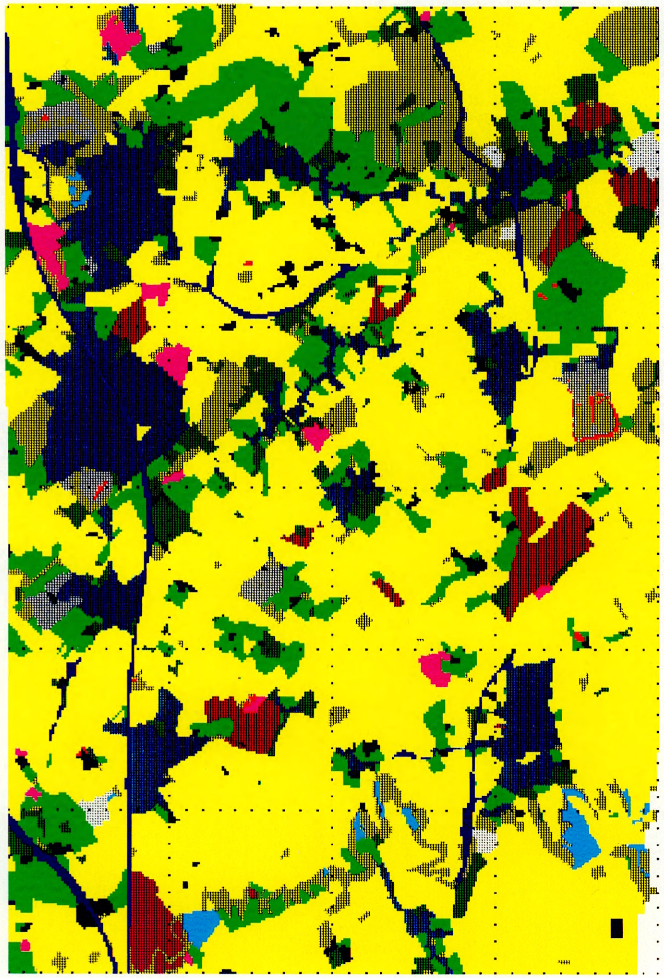


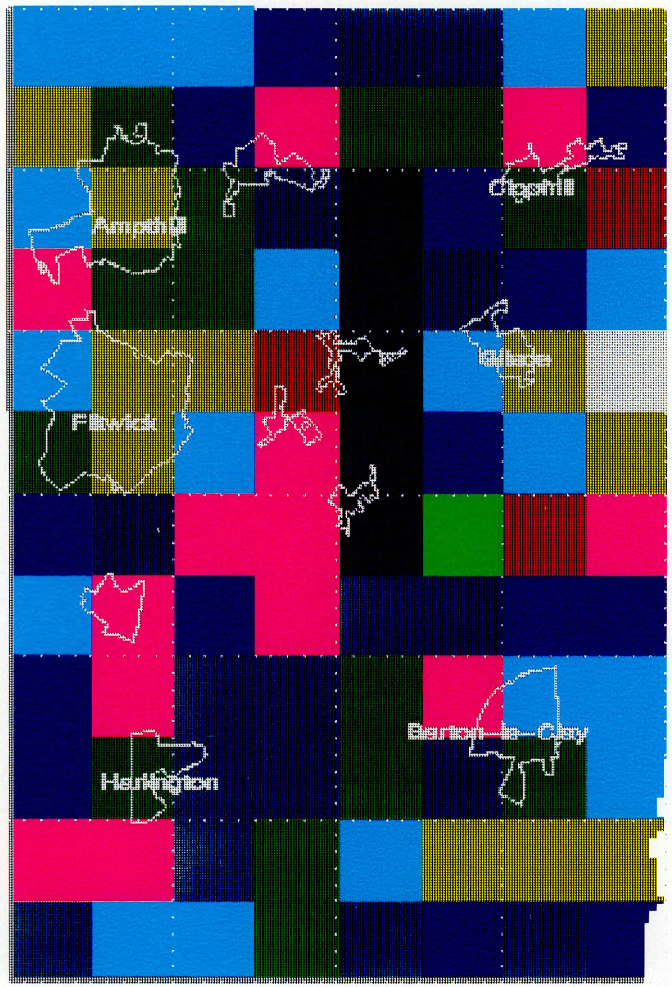
Fig. 5: Location of ground survey sites

MAPS

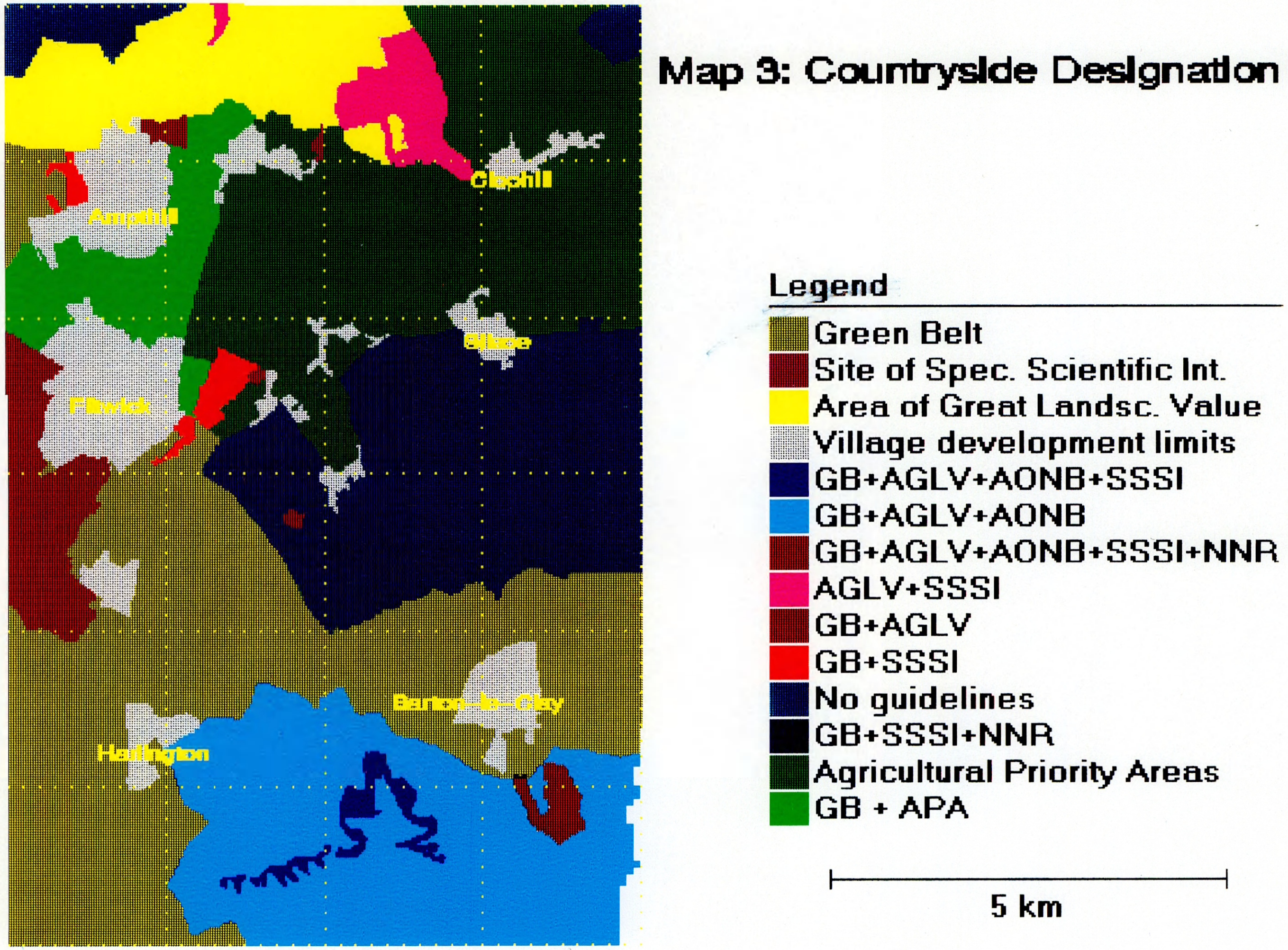


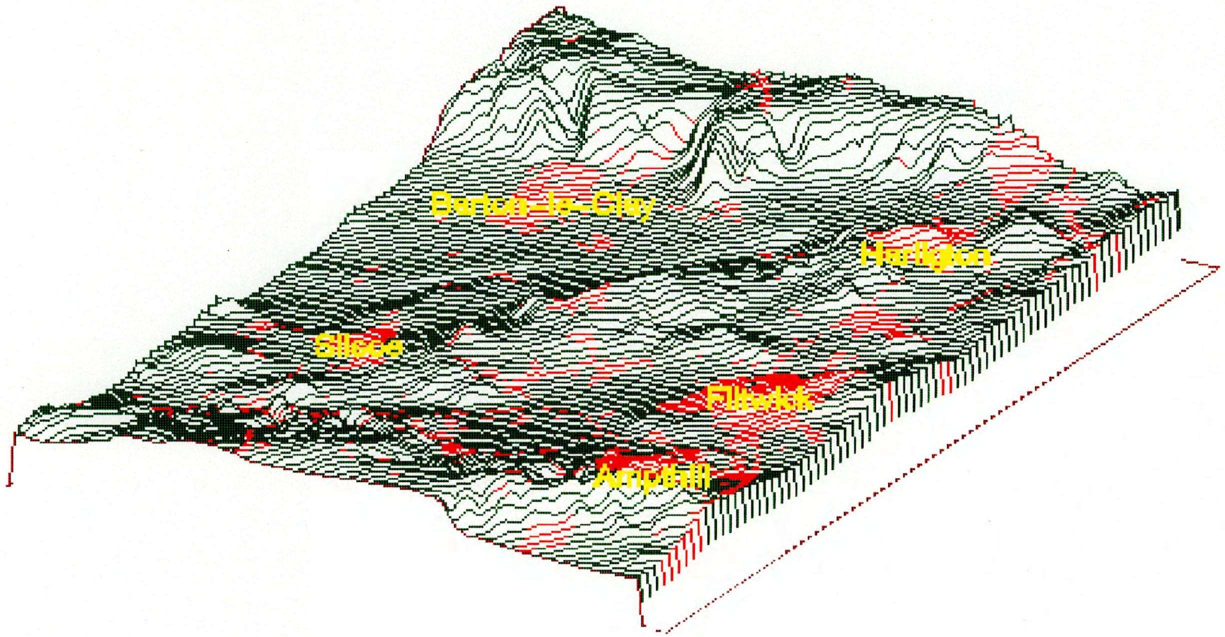
Map 1: Study area – Land cover 1991

Map 2: Study area – Hedgerows 1991



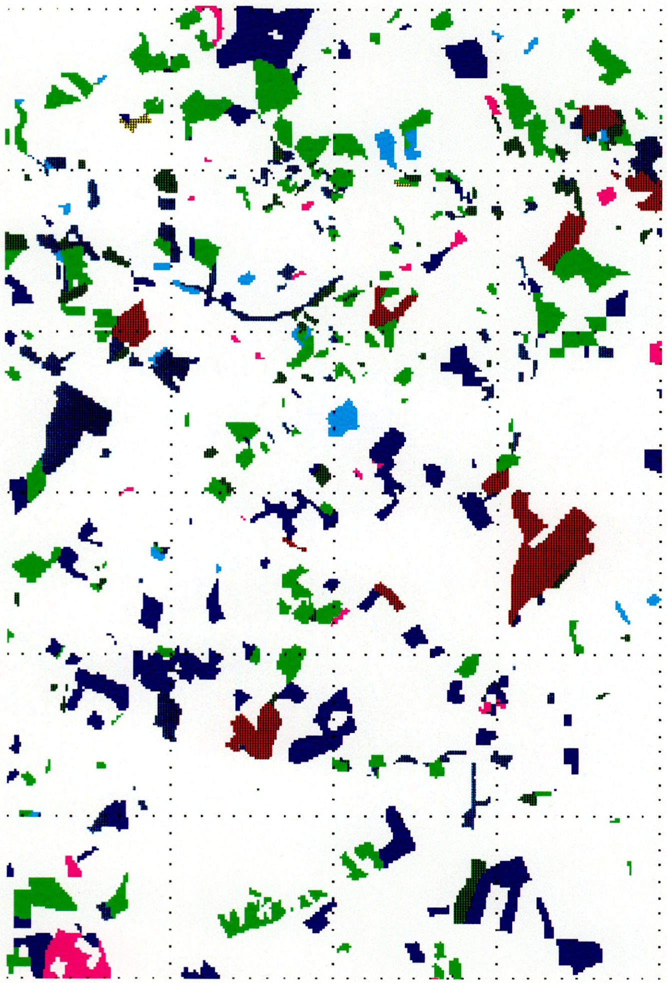
Map 3: Countryside Designation Zones





Map 4 : DTM of the study area

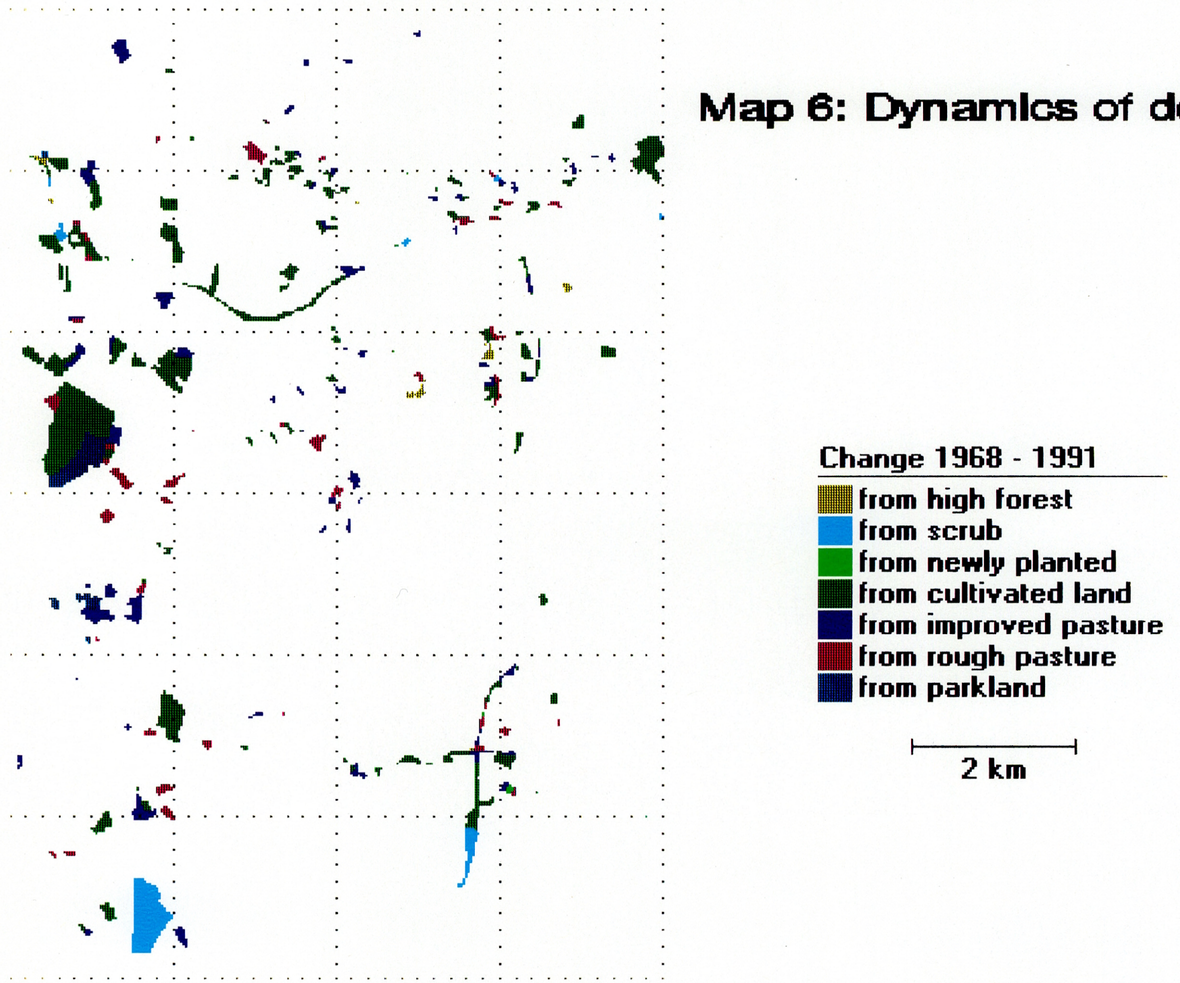
Map 5: Dynamics of cultivated land



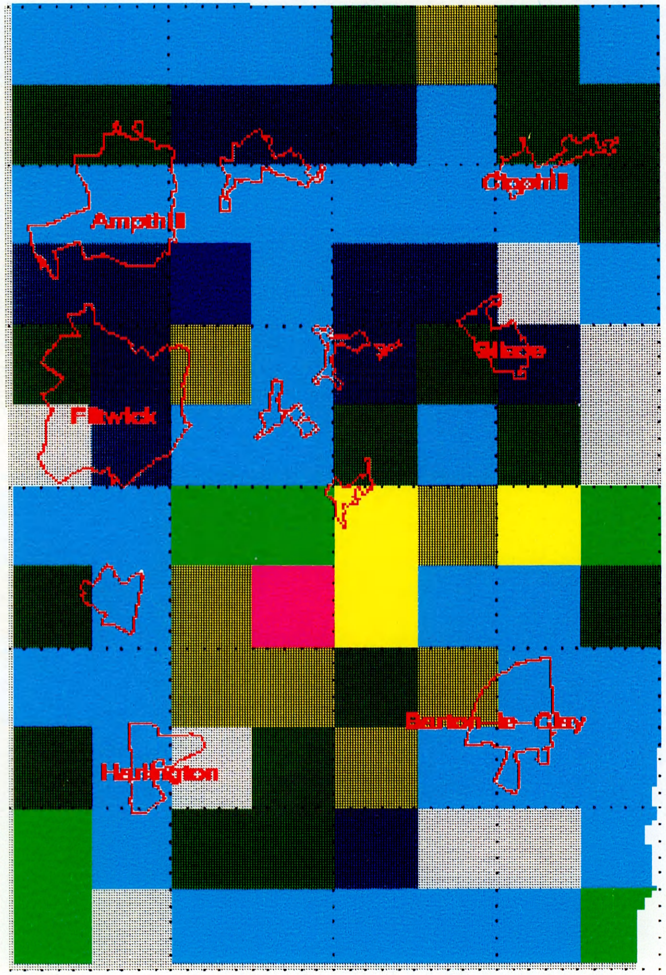
Change 1968 - 1991
- to high forest
- to newly planted
- to improved pasture
- to rough pasture
- to Set-Aside
- to developed land
- from improved pasture
- from rough pasture

2 km

Map 6: Dynamics of developed land



Map 7: Trees in linear features



Change 1968 - 1991 N./Km2

- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 0
- no change
- 0 - 10
- 10 - 20
- 20 - 30

2 km

TABLES

PHOTOINTERPRETATION Landscape Class		GROUND SURVEY																			
		A1	A2	A3	A4	A5	B1	B2	C1	C2	C3	C4	D1	D2	D3	D4	D5	D6	D7	E1	T
Broadleaved High Forest	A1	1			1																2
Coniferous High Forest	A2																				
Mixed High Forest	A3	2	2																		4
Scrub	A4	1			1																2
Clear Felled, Newly Planted	A5					2															2
Lowland Heath	B1																				
Chalk Grassland	B2																				
Cultivated Land	C1								70			2									72
Improved Pasture	C2								1	18											19
Rough Pasture	C3									3	2										5
Set-Aside	C4											2									2
Urban Land	D1												11								11
Major Transport Routes	D2													2							2
Isolated Industrial Estates	D3																				
Derelict Land	D4																				
Isolated Rural Developments	D5																2				2
Quarries, Mineral Works, Pit	D6															2					2
Parkland	D7																				
Inland Water	E1																				
Total	T	4	2		2	2			71	21	2	4	11	2		2	2				125

Tab. 5. Confusion matrix showing the comparison of observations by photointerpretation (rows) and ground survey (columns) for land cover categories.

PHOTOINTERPRETATION Landscape Class		GROUND SURVEY																			
		A1	A2	A3	A4	A5	B1	B2	C1	C2	C3	C4	D1	D2	D3	D4	D5	D6	D7	E1	T
Broadleaved High Forest	A1	8	4		4	4			142	42	4	8	22	4		4	4				250
Coniferous High Forest	A2																				
Mixed High Forest	A3	16	8		8	8			284	84	8	16	44	8		8	8				500
Scrub	A4	8	4		4	4			142	42	4	8	22	4		4	4				250
Clear Felled, Newly Planted	A5	8	4		4	4			142	42	4	8	22	4		4	4				250
Lowland Heath	B1																				
Chalk Grassland	B2																				
Cultivated Land	C1	288	144		144	144			5112	1512	144	288	792	144		144	144				9000
Improved Pasture	C2	76	38		38	38			1349	399	38	76	209	38		38	38				2375
Rough Pasture	C3	20	10		10	10			355	105	10	20	55	10		10	10				625
Set-Aside	C4	8	4		4	4			142	42	4	8	22	4		4	4				250
Urban Land	D1	44	22		22	22			781	231	22	44	121	22		22	22				1375
Major Transport Routes	D2	8	4		4	4			142	42	4	8	22	4		4	4				250
Isolated Industrial Estates	D3																				
Derelict Land	D4																				
Isolated Rural Developments	D5	8	4		4	4			142	42	4	8	22	4		4	4				250
Quarries, Mineral Works, Pit	D6	8	4		4	4			142	42	4	8	22	4		4	4				250
Parkland	D7																				
Inland Water	E1																				
Total	**T**	**500**	**250**		**250**	**250**			**8875**	**2625**	**250**	**500**	**1375**	**250**		**250**	**250**				**15625**

Tab. 6. Confusion matrix showing the products of the marginals in Tab. 5 for the land cover categories.

PHOTOINTERPRETATION Landscape Class		GROUND SURVEY G1	G2	G3	G4	G5	G6	U	TOTAL
Hedgerows	G1	97			2		4	1	**104**
Double Hedgerows	G2	1	1						**2**
Strip Woodland	G3								**4**
Rows of Trees	G4			4	9				**9**
Woodland Edge	G5					32			**32**
Fences, Ditches and other b.	G6	5					34	1	**40**
Unclassified	U							34	**34**
Total	**T**	**103**	**1**	**4**	**11**	**32**	**38**	**36**	**225**

Tab. 7. Confusion matrix showing the comparison of observations by photointerpretation (rows) and ground survey (columns) for linear features.

PHOTOINTERPRETATION Landscape Class		GROUND SURVEY G1	G2	G3	G4	G5	G6	U	TOTAL
Hedgerows	G1	10712	104	416	1144	3328	3952	3744	**23400**
Double Hedgerows	G2	206	2	8	22	64	76	72	**450**
Strip Woodland	G3	412	4	16	44	128	152	144	**900**
Rows of Trees	G4	927	9	36	99	288	342	324	**2025**
Woodland Edge	G5	3296	32	128	352	1024	1216	1152	**7200**
Fences, Ditches and other b.	G6	4120	40	160	440	1280	1520	1440	**9000**
Unclassified	U	3502	34	136	374	1088	1292	1224	**7650**
Total	**T**	**23175**	**225**	**900**	**2475**	**7200**	**8550**	**8100**	**50625**

Tab. 8. Confusion matrix showing the product of the marginals in Tab. 7 for linear features.

PHOTOINTERPRETATION Landscape Class		GROUND SURVEY						
		H2	H3	H4	H5	H6	U	TOTAL
Single Trees Outside Linears	H2	4	1					**5**
Groups of Trees	H3		5					**5**
Single Trees Inside Linears	H4	1	1	46			13	**61**
Inland Water	H5				4			**4**
Pylons	H6					1		**1**
Unclassified	U	3	1	16			129	**149**
Total	**T**	**8**	**8**	**62**	**4**	**1**	**142**	**225**

Tab. 9. Confusion matrix showing the comparison of observations by photo-interpretation (rows) and ground survey (columns) for point features.

PHOTOINTERPRETATION Landscape Class		GROUND SURVEY						
		H2	H3	H4	H5	H6	U	TOTAL
Single Trees Outside Linears	H2	40	40	310	20	5	710	**1125**
Groups of Trees	H3	40	40	310	20	5	710	**1125**
Single Trees Inside Linears	H4	488	488	3782	244	61	8662	**13725**
Inland Water	H5	32	32	248	16	4	568	**900**
Pylons	H6	8	8	62	4	1	142	**225**
Unclassified	U	1192	1192	9238	596	149	21158	**33525**
Total	**T**	**1800**	**1800**	**13950**	**900**	**225**	**31950**	**50625**

Tab. 10. Confusion matrix showing the product of the marginals in Tab. 9 for point features.

Landscape Class		1968	1968	1981	1981	1991	1991
		Km2	%	Km2	%	Km2	%
Broadleaved High Forest	A1	2.766	2.890	2.603	2.720	2.511	2.630
Coniferous High Forest	A2	0.037	0.040	0.064	0.070	0.072	0.080
Mixed High Forest	A3	2.725	2.850	2.775	2.900	3.076	3.220
Scrub	A4	1.568	1.640	1.373	1.440	1.350	1.410
Clear Felled, Newly Planted	A5	0.438	0.460	0.662	0.690	0.878	0.920
Total Woodland	**A**	**7.535**	**7.880**	**7.477**	**7.820**	**7.887**	**8.260**
Lowland Heath	B1	0.084	0.090	0.062	0.060	0.049	0.050
Chalk Grassland	B2	0.584	0.610	0.547	0.570	0.559	0.580
Total Semi-Natural Veget.	**B**	**0.668**	**0.700**	**0.608**	**0.630**	**0.607**	**0.630**
Cultivated Land	C1	58.951	61.660	59.205	61.930	53.581	56.040
Improved Pasture	C2	12.843	13.430	9.975	10.430	11.320	11.840
Rough Pasture	C3	3.297	3.450	3.615	3.780	3.860	4.040
Set-Aside	C4	0.000	0.000	0.000	0.000	2.211	2.310
Total Agro-Pastoral	**C**	**75.092**	**78.540**	**72.795**	**76.140**	**70.972**	**74.230**
Urban Land	D1	7.182	7.510	9.100	9.520	9.735	10.180
Major Transport Routes	D2	1.126	1.180	1.222	1.280	1.636	1.710
Isolated Industrial Estates	D3	0.577	0.600	0.820	0.860	0.927	0.970
Derelict Land	D4	0.075	0.080	0.270	0.280	0.603	0.630
Isolated Rural Developments	D5	1.306	1.370	1.502	1.570	1.644	1.720
Quarries, Mineral Works, Pits	D6	0.461	0.480	0.656	0.690	0.411	0.430
Parkland	D7	1.480	1.550	1.050	1.100	1.057	1.110
Total Developed Land	**D**	**12.206**	**12.770**	**14.620**	**15.300**	**16.013**	**16.750**
Inland Water	E1	0.106	0.110	0.106	0.110	0.127	0.130
Total Inland Water	**E**	**0.106**	**0.110**	**0.106**	**0.110**	**0.127**	**0.130**
Total Area	T	**95.607**	**100.000**	**95.607**	**100.000**	**95.607**	**100.000**

Tab. 15. Study area : area of the land cover classes (Km2) and % for 1968, 1981, 1991.

Landscape Class		1968	1981	1991
		Km	Km	Km
Hedgerows	G1	479.466	465.256	428.041
Double Hedgerows	G2	13.994	14.980	13.167
Strip Woodland	G3	9.652	9.737	8.233
Rows of Trees	G4	103.733	72.744	65.243
Woodland Edge	G5	162.457	160.966	163.760
Fences, Ditches and other boun.	G6	162.106	152.288	182.808

Tab. 16. Study area: length of linear features for 1968, 1981, 1991.

Landscape Class		1968	1981	1991
		Number	Number	Number
Agricultural Parcels	H1a	1734	1617	1546
Non Agricultural Parcels	H1b	302	327	347
Total Parcels	**H1**	**2036**	**1944**	**1893**
Single Trees Outside Linears	H2	745	591	544
Groups of Trees	H3	310	246	238
Single Trees Inside Linears	H4	3019	2484	2096
Inland Water	H5	101	86	90
Pylons	H6	39	39	39

Tab. 17. Study area: number of point features for 1968, 1981, 1991.

Landscape Class		None	Gr Blt	AGLV	AONB	APA	SSSI	NNR	VDL
		Km2	Km2	Km2	Km2	Km2	Km2	Km2	Km2
Broadleaved High Forest	A1	0.445	1.517	1.132	0.659	0.312	0.760	0.132	0.022
Coniferous High Forest	A2	0.000	0.056	0.071	0.000	0.000	0.000	0.000	0.001
Mixed High Forest	A3	0.718	0.511	2.075	0.353	0.431	1.321	0.000	0.003
Scrub	A4	0.076	1.092	0.795	0.669	0.155	0.610	0.040	0.004
Clear Felled, Newly Planted	A5	0.133	0.265	0.296	0.067	0.334	0.085	0.000	0.016
Total Woodland	**A**	**1.373**	**3.441**	**4.368**	**1.749**	**1.231**	**2.775**	**0.172**	**0.046**
Lowland Heath	B1	0.000	0.049	0.000	0.000	0.000	0.048	0.000	0.000
Chalk Grassland	B2	0.000	0.567	0.559	0.559	0.000	0.331	0.240	0.000
Total Semi-Natural Veget.	**B**	**0.000**	**0.615**	**0.559**	**0.559**	**0.000**	**0.380**	**0.240**	**0.000**
Cultivated Land	C1	10.851	30.069	15.269	11.285	12.118	0.152	0.096	0.372
Improved Pasture	C2	1.201	4.570	3.474	0.709	3.855	0.136	0.000	0.119
Rough Pasture	C3	0.408	1.497	0.688	0.302	1.428	0.330	0.008	0.285
Set-Aside	C4	0.945	0.564	0.183	0.183	0.839	0.036	0.000	0.001
Total Agro-Pastoral	**C**	**13.404**	**36.700**	**19.614**	**12.480**	**18.239**	**0.653**	**0.104**	**0.776**
Urban Land	D1	0.506	1.350	0.513	0.323	1.005	0.009	0.000	7.038
Major Transport Routes	D2	0.053	1.031	0.252	0.141	0.395	0.024	0.000	0.121
Isolated Industrial Estates	D3	0.142	0.378	0.000	0.000	0.206	0.001	0.000	0.317
Derelict Land	D4	0.005	0.571	0.013	0.013	0.023	0.000	0.000	0.008
Isolated Rural Developments	D5	0.196	0.735	0.441	0.161	0.570	0.014	0.000	0.021
Quarries, Mineral Works, Pits	D6	0.000	0.169	0.069	0.069	0.242	0.000	0.000	0.000
Parkland	D7	0.240	0.540	0.624	0.000	0.017	0.000	0.000	0.002
Total Developed Land	**D**	**1.142**	**4.773**	**1.913**	**0.706**	**2.458**	**0.048**	**0.000**	**7.508**
Inland Water	E1	0.065	0.037	0.022	0.003	0.017	0.000	0.000	0.000
Total Inland Water	**E**	**0.065**	**0.037**	**0.022**	**0.003**	**0.017**	**0.000**	**0.000**	**0.000**
Total Area	**T**	**15.983**	**45.567**	**26.476**	**15.496**	**21.946**	**3.856**	**0.517**	**8.330**

Tab. 18. Countryside designation zones:1991 land cover characterisation (Km2).

Landscape Class		None	Gr Blt	AGLV	AONB	APA	SSSI	NNR	VDL
		%	%	%	%	%	%	%	%
Broadleaved High Forest	A1	2.79	3.33	4.27	4.25	1.42	19.70	25.58	0.26
Coniferous High Forest	A2	0.00	0.12	0.27	0.00	0.00	0.00	0.00	0.02
Mixed High Forest	A3	4.49	1.12	7.84	2.28	1.96	34.25	0.00	0.04
Scrub	A4	0.48	2.40	3.00	4.32	0.71	15.82	7.75	0.05
Clear Felled, Newly Planted	A5	0.83	0.58	1.12	0.43	1.52	2.20	0.00	0.19
Total Woodland	**A**	**8.59**	**7.55**	**16.50**	**11.28**	**5.61**	**71.97**	**33.33**	**0.56**
Lowland Heath	B1	0.00	0.11	0.00	0.00	0.00	1.25	0.00	0.00
Chalk Grassland	B2	0.00	1.24	2.11	3.61	0.00	8.60	46.43	0.00
Total Semi-Natural Veget.	**B**	**0.00**	**1.35**	**2.11**	**3.61**	**0.00**	**9.85**	**46.43**	**0.00**
Cultivated Land	C1	67.89	65.99	57.67	72.83	55.22	3.94	18.67	4.46
Improved Pasture	C2	7.52	10.03	13.12	4.58	17.56	3.53	0.00	1.42
Rough Pasture	C3	2.55	3.29	2.60	1.95	6.51	8.55	1.57	3.42
Set-Aside	C4	5.91	1.24	0.69	1.18	3.82	0.92	0.00	0.01
Total Agro-Pastoral	**C**	**83.87**	**80.55**	**74.08**	**80.54**	**83.11**	**16.94**	**20.24**	**9.31**
Urban Land	D1	3.17	2.96	1.94	2.08	4.58	0.24	0.00	84.50
Major Transport Routes	D2	0.33	2.26	0.95	0.91	1.80	0.63	0.00	1.46
Isolated Industrial Estates	D3	0.89	0.83	0.00	0.00	0.94	0.01	0.00	3.81
Derelict Land	D4	0.03	1.25	0.05	0.09	0.11	0.00	0.00	0.09
Isolated Rural Developments	D5	1.23	1.61	1.67	1.04	2.60	0.36	0.00	0.26
Quarries, Mineral Works, Pits	D6	0.00	0.37	0.26	0.44	1.10	0.00	0.00	0.00
Parkland	D7	1.50	1.18	2.36	0.00	0.08	0.00	0.00	0.02
Total Developed Land	**D**	**7.15**	**10.46**	**7.23**	**4.56**	**11.21**	**1.24**	**0.00**	**90.14**
Inland Water	E1	0.40	0.08	0.08	0.02	0.08	0.00	0.00	0.00
Total Inland Water	**E**	**0.40**	**0.08**	**0.08**	**0.02**	**0.08**	**0.00**	**0.00**	**0.00**
Total Area	**T**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Tab. 19. Countryside designation zones:1991 land cover characterisation (%).

Landscape Class		Study Area	None	AGLV	AONB	APA	SSSI
Linear Features		Km/Km2	Km/Km2	Km/Km2	Km/Km2	Km/Km2	Km/Km2
Hedgerows	G1	4.477	8.126	6.378	4.910	7.765	25.931
Woodland Edge	G5	1.713	2.162	3.879	3.387	3.049	21.994
Fences, Ditches and other boun.	G6	1.912	3.765	2.421	1.367	4.309	13.514
Point Features		Num/Km2	Num/Km2	Num/Km2	Num/Km2	Num/Km2	Num/Km2
Single Trees Outside Linears	H2	6	10	10	2	10	36
Single Trees Inside Linears	H4	22	31	31	25	47	144

Tab. 20. Density of selected linear and point features for 1991 in the study area and selected countryside designation zones.

Elevation m	Area (%)	Area Km2
41 - 50	1.15	1.099
51 - 60	16.63	15.902
61 - 70	21.37	20.433
71 - 80	18.29	17.482
81 - 90	13.58	12.979
91 - 100	10.14	9.694
101- 120	9.69	9.266
121 - 140	3.07	2.939
141 - 160	5.62	5.376
> 161	0.46	0.437
Total	**100.00**	**95.607**

Tab. 21. Distribution of elevation in the study area

Slope %	Area (%)	Area Km2
0 - 2	46.33	44.299
2 - 4	27.53	26.322
4 - 6	11.42	10.914
6 - 8	5.76	5.509
8 - 10	3.06	2.929
10 - 20	4.67	4.462
20 - 30	0.82	0.779
30 - 40	0.35	0.338
40 - 50	0.06	0.055
Total	**100.00**	**95.607**

Tab. 22. Distribution of slope in the study area

Aspect degrees	Area (%)	Area Km2
0 - 45	13.45	12.858
45 - 90	11.63	11.121
90 - 135	13.25	12.670
135 - 180	14.92	14.263
180 - 225	7.46	7.136
225 - 270	7.54	7.207
270 - 315	8.78	8.391
315 - 360	15.71	15.022
Flat areas	7.26	6.940
Total	**100.00**	**95.607**

Tab. 23. Distribution of aspect in the study area in degrees clockwise from North

Landscape Class		41-50 m	51-60 m	61-70 m	71-80 m	81-90 m	91-100 m	101-120 m	121-140 m	141-160 m	>161 m
		%	%	%	%	%	%	%	%	%	%
Broadleaved High Forest	A1	0.03	18.41	16.30	8.75	7.01	14.97	20.21	6.80	7.51	0.00
Coniferous High Forest	A2	0.00	0.00	43.56	0.14	0.00	42.30	14.01	0.00	0.00	0.00
Mixed High Forest	A3	1.33	12.83	9.32	14.03	18.08	13.83	24.43	3.84	2.31	0.00
Scrub	A4	0.00	4.14	16.96	4.22	4.13	12.15	34.40	21.28	2.71	0.00
Clear Felled, Newly Planted	A5	7.16	13.22	17.37	21.49	14.17	15.72	6.28	1.03	0.86	2.70
Lowland Heath	B1	0.00	0.00	0.00	0.00	0.63	51.26	48.12	0.00	0.00	0.00
Chalk Grassland	B2	0.00	0.00	0.00	0.00	0.73	2.90	25.96	41.01	28.41	0.98
Cultivated Land	C1	0.80	17.02	23.33	17.55	13.83	8.25	7.58	2.67	8.31	0.65
Improved Pasture	C2	0.55	15.72	16.56	16.40	18.13	15.06	13.23	2.57	1.74	0.05
Rough Pasture	C3	2.91	24.67	21.02	21.33	11.87	7.45	4.80	4.14	1.20	0.62
Set-Aside	C4	10.62	48.36	16.37	17.77	2.34	3.19	1.34	0.00	0.00	0.00
Urban Land	D1	0.50	9.87	26.24	29.37	13.37	12.53	5.97	0.49	1.67	0.00
Major Transport Routes	D2	0.01	13.96	19.83	20.27	21.84	17.69	6.12	0.27	0.00	0.00
Isolated Industrial Estates	D3	0.00	8.97	48.78	29.91	8.28	1.42	1.30	1.24	0.09	0.00
Derelict Land	D4	0.00	0.10	3.82	1.19	0.00	17.57	53.67	23.53	0.12	0.00
Isolated Rural Developments	D5	0.65	17.13	18.66	17.51	15.69	11.64	11.95	1.68	3.21	1.89
Quarries, Mineral Works, Pits	D6	23.65	18.64	9.88	6.12	0.91	5.19	33.83	1.78	0.00	0.00
Parkland	D7	0.00	22.67	5.01	28.67	8.45	17.55	17.19	0.46	0.00	0.00
Inland Water	E1	0.08	62.71	15.78	12.75	1.99	6.69	0.00	0.00	0.00	0.00

Tab. 24. Study area : distribution of 1991 land cover (% of each category) in relation to the elevation (m).

Landscape Class		0 - 2 %	2 - 4 %	4 - 6 %	6 - 8 %	8 - 10 %	10 - 20 %	20 - 30 %	30 - 40 %	> 40 %
		%	%	%	%	%	%	%	%	%
Broadleaved High Forest	A1	36.46	19.87	8.58	5.98	4.31	13.8	5.66	4.52	0.84
Coniferous High Forest	A2	63.17	18.07	6.02	0	4.2	8.54	0	0	0
Mixed High Forest	A3	27.47	26.92	15.03	10.22	6.6	10.96	2.51	0.29	0
Scrub	A4	23.15	7.52	7.45	4.71	4.1	26.07	15.36	9.48	2.17
Clear Felled, Newly Planted	A5	43.19	26.47	13.09	5.03	5.05	6.75	0.24	0.18	0
Lowland Heath	B1	38.7	17.99	17.36	19.46	6.49	0	0	0	0
Chalk Grassland	B2	0.67	1.31	2.6	4.52	8.04	47.98	25.27	8.79	0.82
Cultivated Land	C1	51.94	27.41	10.31	4.67	2.38	3.02	0.26	0.02	0
Improved Pasture	C2	37.82	27.62	13.13	8.25	5.34	7.52	0.31	0.01	0
Rough Pasture	C3	44.23	26.03	12.13	7.23	4.56	5.66	0.14	0.02	0
Set-Aside	C4	63.25	22.04	6.94	3.85	1.61	2.32	0	0	0
Urban Land	D1	40.37	34.8	15.49	6.55	1.76	1.03	0	0	0
Major Transport Routes	D2	50.98	26.49	10.26	5.14	1.54	3.65	0.82	1.12	0
Isolated Industrial Estates	D3	44.36	38.78	9.46	4.99	1.19	1.23	0	0	0
Derelict Land	D4	21.21	34.54	22.33	12.16	3.62	5.58	0.55	0	0
Isolated Rural Developments	D5	41.92	31.8	13.2	6.22	3.65	3.21	0	0	0
Quarries, Mineral Works, Pits	D6	29.7	27.46	13.14	12.67	6.27	6.74	3.31	0.72	0
Parkland	D7	34.15	26.33	17.27	9.9	5.62	6.56	0.15	0	0
Inland Water	E1	69.16	19.44	8.53	1.99	0.88	0	0	0	0

Tab. 25. Study area : distribution of 1991 land cover (% of each category) in relation to the slope (%) .

Landscape Class		0 - 45	45-90	90-135	135-180	180-225	225-270	270-315	315-360	Flat Areas
		%	%	%	%	%	%	%	%	%
Broadleaved High Forest	A1	16.89	10.05	9.94	11.64	6.15	7.68	9.24	21.29	7.12
Coniferous High Forest	A2	24.65	35.99	6.72	7.14	0.14	0.00	0.56	13.17	11.62
Mixed High Forest	A3	9.35	10.27	19.87	24.26	12.52	9.37	4.24	7.04	3.09
Scrub	A4	20.08	8.26	9.91	9.52	3.88	10.29	18.82	14.09	5.15
Clear Felled, Newly Planted	A5	11.69	6.65	12.96	16.80	12.99	8.66	2.23	15.34	12.69
Lowland Heath	B1	6.28	15.27	49.16	10.67	0.00	1.88	3.97	12.76	0.00
Chalk Grassland	B2	9.77	6.45	2.61	3.25	9.11	16.05	30.94	21.75	0.07
Cultivated Land	C1	15.09	12.96	12.38	13.83	6.49	6.53	8.47	16.15	8.10
Improved Pasture	C2	11.63	10.31	12.10	14.81	10.46	11.06	9.11	14.84	5.70
Rough Pasture	C3	11.00	8.26	15.37	15.42	8.97	9.05	8.57	13.91	9.46
Set-Aside	C4	6.77	13.60	23.90	10.50	2.41	3.64	8.72	14.41	16.05
Urban Land	D1	10.86	10.59	16.89	21.02	7.57	6.75	5.46	17.06	3.80
Major Transport Routes	D2	12.25	11.55	13.39	14.29	7.72	5.58	14.98	11.51	8.73
Isolated Industrial Estates	D3	15.08	8.74	10.53	11.50	8.97	12.48	5.41	21.45	5.83
Derelict Land	D4	3.94	0.42	0.00	0.81	2.09	4.27	48.60	39.25	0.62
Isolated Rural Developments	D5	11.57	11.62	13.65	17.08	11.27	6.23	10.05	11.83	6.70
Quarries, Mineral Works, Pits	D6	9.38	15.19	18.07	27.16	5.41	1.33	10.77	8.35	4.35
Parkland	D7	4.99	1.15	10.75	18.56	13.13	22.11	13.95	9.09	6.28
Inland Water	E1	14.26	12.11	16.02	18.96	9.16	8.29	6.14	7.49	7.57

Tab. 26. Study area : distribution of 1991 land cover (% of each category) in relation to the aspect (degrees clockwise from North) .

Landscape Class		1968-81	1968-81	1981-91	1981-91	1968-91	1968-91
		Losses	Gains	Losses	Gains	Losses	Gains
		Km2	Km2	Km2	Km2	Km2	Km2
Broadleaved High Forest	A1	-0.326	0.163	-0.129	0.037	-0.413	0.157
Coniferous High Forest	A2	0.000	0.027	-0.008	0.016	-0.008	0.043
Mixed High Forest	A3	-0.379	0.430	-0.109	0.410	-0.141	0.493
Scrub	A4	-0.431	0.236	-0.120	0.097	-0.495	0.276
Clear Felled, Newly Planted	A5	-0.398	0.622	-0.431	0.647	-0.420	0.859
Total Woodland	**A**	**-1.535**	**1.477**	**-0.796**	**1.206**	**-1.475**	**1.828**
Lowland Heath	B1	-0.023	0.000	-0.013	0.000	-0.036	0.000
Chalk Grassland	B2	-0.038	0.000	0.000	0.012	-0.038	0.012
Total Semi-Natural Veget.	**B**	**-0.060**	**0.000**	**-0.013**	**0.012**	**-0.073**	**0.013**
Cultivated Land	C1	-5.690	5.944	-8.221	2.597	-11.233	5.863
Improved Pasture	C2	-7.136	4.268	-3.373	4.718	-7.504	5.981
Rough Pasture	C3	-1.647	1.964	-1.236	1.481	-1.997	2.560
Set-Aside	C4	0.000	0.000	0.000	2.211	0.000	2.211
Total Agro-Pastoral	**C**	**-14.473**	**12.176**	**-12.830**	**11.007**	**-20.734**	**16.614**
Urban Land	D1	-0.024	1.942	-0.037	0.672	-0.046	2.599
Major Transport Routes	D2	0.000	0.096	-0.002	0.416	0.000	0.510
Isolated Industrial Estates	D3	-0.017	0.261	-0.010	0.117	-0.025	0.376
Derelict Land	D4	-0.013	0.208	-0.192	0.525	-0.056	0.584
Isolated Rural Developments	D5	-0.029	0.225	-0.007	0.148	-0.024	0.362
Quarries, Mineral Works, Pits	D6	-0.129	0.324	-0.514	0.269	-0.259	0.209
Parkland	D7	-0.447	0.017	0.000	0.008	-0.446	0.024
Total Developed Land	**D**	**-0.658**	**3.073**	**-0.762**	**2.155**	**-0.856**	**4.663**
Inland Water	E1	0.000	0.000	0.000	0.021	0.000	0.021
Total Inland Water	**E**	**0.000**	**0.000**	**0.000**	**0.021**	**0.000**	**0.021**
Total Area	**T**	**-16.725**	**16.725**	**-14.401**	**14.401**	**-23.138**	**23.138**

Tab. 27. Study area : gross changes in land cover (Km2).

Landscape Class		1968-81 Km	1981-91 Km	1968-91 Km
Hedgerows	G1	-14.210	-37.215	-51.425
Double Hedgerows	G2	0.986	-1.813	-0.807
Strip Woodland	G3	0.085	-1.504	-1.419
Rows of Trees	G4	-30.988	-7.501	-38.489
Woodland Edge	G5	-1.490	2.794	1.304
Fences, Ditches and other boun.	G6	-9.818	30.521	20.702

Tab. 28. Study area: net change in the length of linear features .

Landscape Class		1968-81 Number	1981-91 Number	1968-91 Number
Agricultural Parcels	H1a	-117	-71	-188
Non Agricultural Parcels	H1b	25	20	45
Total Parcels	**H1**	**-92**	**-51**	**-143**
Single Trees Outside Linears	H2	-154	-47	-201
Groups of Trees	H3	-64	-8	-72
Single Trees Inside Linears	H4	-535	-388	-923
Inland Water	H5	-15	4	-11
Pylons	H6	0	0	0

Tab. 29. Study area: net change in the number of point features.

Landscape Class		1968-81	1968-81	1981-91	1981-91	1968-91	1968-91
		Losses	Gains	Losses	Gains	Losses	Gains
		Km2	Km2	Km2	Km2	Km2	Km2
Broadleaved High Forest	A1	-0.066	0.012	-0.025	0.004	-0.089	0.015
Coniferous High Forest	A2	0.000	0.027	-0.008	0.015	-0.008	0.042
Mixed High Forest	A3	-0.162	0.149	-0.103	0.249	-0.130	0.262
Scrub	A4	-0.068	0.090	-0.077	0.012	-0.118	0.074
Clear Felled, Newly Planted	A5	-0.106	0.235	-0.266	0.245	-0.174	0.282
Total Woodland	**A**	**-0.403**	**0.513**	**-0.480**	**0.524**	**-0.519**	**0.674**
Chalk Grassland	B2	-0.038	0.000	0.000	0.004	-0.038	0.004
Total Semi-Natural Veget.	**B**	**-0.038**	**0.000**	**0.000**	**0.004**	**-0.038**	**0.004**
Cultivated Land	C1	-1.042	2.141	-1.840	0.386	-2.401	2.046
Improved Pasture	C2	-2.395	1.136	-0.568	1.560	-2.385	2.119
Rough Pasture	C3	-0.218	0.355	-0.273	0.343	-0.311	0.519
Set-Aside	C4	0.000	0.000	0.000	0.183	0.000	0.183
Total Agro-Pastoral	**C**	**-3.655**	**3.632**	**-2.681**	**2.473**	**-5.097**	**4.866**
Urban Land	D1	0.000	0.070	-0.001	0.009	0.000	0.078
Major Transport Routes	D2	0.000	0.008	0.000	0.124	0.000	0.132
Isolated Industrial Estates	D3	0.000	0.000	0.000	0.000	0.000	0.000
Derelict Land	D4	0.000	0.000	0.000	0.001	0.000	0.001
Isolated Rural Developments	D5	-0.009	0.063	-0.002	0.023	0.000	0.076
Quarries, Mineral Works, Pits	D6	0.000	0.001	-0.001	0.000	0.000	0.000
Parkland	D7	-0.199	0.016	0.000	0.002	-0.198	0.017
Total Developed Land	**D**	**-0.208**	**0.158**	**-0.004**	**0.159**	**-0.198**	**0.304**
Inland Water	E1	0.000	0.000	0.000	0.003	0.000	0.003
Total Inland Water	**E**	**0.000**	**0.000**	**0.000**	**0.003**	**0.000**	**0.003**
Total Area	**T**	**-4.303**	**4.303**	**-3.164**	**3.163**	**-5.851**	**5.851**

Tab. 30. Areas of Great Landscape Value : gross changes in land cover (Km2).

Landscape Class		1968-81	1968-81	1981-91	1981-91	1968-91	1968-91
		Losses	Gains	Losses	Gains	Losses	Gains
		Km2	Km2	Km2	Km2	Km2	Km2
Broadleaved High Forest	A1	-0.017	0.012	-0.025	0.002	-0.041	0.014
Mixed High Forest	A3	0.000	0.007	0.000	0.067	0.000	0.073
Scrub	A4	-0.027	0.018	-0.050	0.006	-0.077	0.023
Clear Felled, Newly Planted	A5	0.000	0.037	-0.068	0.031	-0.068	0.067
Total Woodland	**A**	**-0.044**	**0.073**	**-0.143**	**0.105**	**-0.186**	**0.177**
Chalk Grassland	B2	-0.038	0.000	0.000	0.004	-0.038	0.004
Total Semi-Natural Veget.	**B**	**-0.038**	**0.000**	**0.000**	**0.004**	**-0.038**	**0.004**
Cultivated Land	C1	-0.452	0.985	-0.602	0.268	-0.911	1.110
Improved Pasture	C2	-1.082	0.345	-0.346	0.357	-1.237	0.512
Rough Pasture	C3	-0.022	0.199	-0.152	0.189	-0.032	0.246
Set-Aside	C4	0.000	0.000	0.000	0.183	0.000	0.183
Total Agro-Pastoral	**C**	**-1.557**	**1.529**	**-1.099**	**0.998**	**-2.181**	**2.051**
Urban Land	D1	0.000	0.022	0.000	0.006	0.000	0.027
Major Transport Routes	D2	0.000	0.008	0.000	0.123	0.000	0.131
Derelict Land	D4	0.000	0.000	0.000	0.001	0.000	0.001
Isolated Rural Developments	D5	0.000	0.006	-0.001	0.004	0.000	0.009
Quarries, Mineral Works, Pits	D6	0.000	0.001	-0.001	0.000	0.000	0.000
Total Developed Land	**D**	**0.000**	**0.037**	**-0.002**	**0.134**	**0.000**	**0.168**
Inland Water	E1	0.000	0.000	0.000	0.003	0.000	0.003
Total Inland Water	**E**	**0.000**	**0.000**	**0.000**	**0.003**	**0.000**	**0.003**
Total Area	**T**	**-1.638**	**1.638**	**-1.244**	**1.244**	**-2.404**	**2.404**

Tab. 31. Areas of Outstanding Natural Beauty : gross changes in land cover (Km2).

Landscape Class		1968-81	1968-81	1981-91	1981-91	1968-91	1968-91
		Losses	Gains	Losses	Gains	Losses	Gains
		Km2	Km2	Km2	Km2	Km2	Km2
Broadleaved High Forest	A1	-0.046	0.037	-0.008	0.003	-0.054	0.040
Mixed High Forest	A3	0.000	0.014	-0.005	0.008	0.000	0.017
Scrub	A4	-0.019	0.042	-0.011	0.047	-0.024	0.083
Clear Felled, Newly Planted	A5	-0.021	0.027	0.000	0.302	-0.021	0.329
Total Woodland	**A**	**-0.086**	**0.120**	**-0.024**	**0.361**	**-0.099**	**0.469**
Cultivated Land	C1	-1.518	0.901	-3.347	0.423	-4.310	0.769
Improved Pasture	C2	-0.996	1.173	-0.650	1.683	-1.063	2.273
Rough Pasture	C3	-0.377	0.475	-0.262	0.452	-0.453	0.742
Set-Aside	C4	0.000	0.000	0.000	0.839	0.000	0.839
Total Agro-Pastoral	**C**	**-2.891**	**2.549**	**-4.259**	**3.396**	**-5.827**	**4.622**
Urban Land	D1	-0.018	0.159	-0.025	0.115	-0.040	0.271
Major Transport Routes	D2	0.000	0.037	-0.001	0.167	0.000	0.203
Isolated Industrial Estates	D3	-0.008	0.050	-0.009	0.058	-0.017	0.107
Derelict Land	D4	0.000	0.027	-0.046	0.000	-0.035	0.016
Isolated Rural Developments	D5	-0.011	0.076	-0.003	0.087	-0.011	0.159
Quarries, Mineral Works, Pits	D6	-0.004	0.000	0.000	0.169	-0.004	0.169
Parkland	D7	0.000	0.000	0.000	0.005	0.000	0.005
Total Developed Land	**D**	**-0.041**	**0.349**	**-0.084**	**0.599**	**-0.106**	**0.930**
Inland Water	E1	0.000	0.000	0.000	0.010	0.000	0.010
Total Inland Water	**E**	**0.000**	**0.000**	**0.000**	**0.010**	**0.000**	**0.010**
Total Area	**T**	**-3.018**	**3.018**	**-4.367**	**4.367**	**-6.032**	**6.031**

Tab. 32. Agricultural Priority Areas : gross changes in land cover (Km2).

Landscape Class		1968-81	1968-81	1981-91	1981-91	1968-91	1968-91
		Losses	Gains	Losses	Gains	Losses	Gains
		Km2	Km2	Km2	Km2	Km2	Km2
Broadleaved High Forest	A1	-0.082	0.118	-0.075	0.021	-0.141	0.124
Coniferous High Forest	A2	0.000	0.027	-0.008	0.000	-0.008	0.027
Mixed High Forest	A3	-0.005	0.046	-0.006	0.068	-0.005	0.108
Scrub	A4	-0.375	0.149	-0.076	0.035	-0.433	0.166
Clear Felled, Newly Planted	A5	-0.034	0.128	-0.072	0.140	-0.102	0.265
Total Woodland	**A**	**-0.496**	**0.468**	**-0.236**	**0.264**	**-0.690**	**0.689**
Lowland Heath	B1	-0.022	0.000	-0.013	0.000	-0.035	0.000
Chalk Grassland	B2	-0.038	0.000	0.000	0.012	-0.038	0.012
Total Semi-Natural Veget.	**B**	**-0.060**	**0.000**	**-0.013**	**0.012**	**-0.073**	**0.013**
Cultivated Land	C1	-2.079	3.320	-2.440	1.251	-3.423	3.476
Improved Pasture	C2	-3.970	1.897	-1.501	1.718	-4.200	2.344
Rough Pasture	C3	-0.753	0.946	-0.583	0.594	-0.938	1.143
Set-Aside	C4	0.000	0.000	0.000	0.564	0.000	0.564
Total Agro-Pastoral	**C**	**-6.801**	**6.163**	**-4.523**	**4.126**	**-8.562**	**7.526**
Urban Land	D1	0.000	0.363	-0.022	0.055	-0.020	0.416
Major Transport Routes	D2	0.000	0.026	0.000	0.234	0.000	0.259
Isolated Industrial Estates	D3	-0.008	0.089	-0.001	0.040	-0.008	0.128
Derelict Land	D4	-0.013	0.165	-0.130	0.513	-0.021	0.556
Isolated Rural Developments	D5	-0.016	0.082	-0.002	0.081	-0.016	0.161
Quarries, Mineral Works, Pits	D6	-0.112	0.324	-0.514	0.101	-0.242	0.040
Parkland	D7	-0.190	0.017	0.000	0.006	-0.189	0.022
Total Developed Land	**D**	**-0.339**	**1.066**	**-0.670**	**1.029**	**-0.496**	**1.582**
Inland Water	E1	0.000	0.000	0.000	0.011	0.000	0.011
Total Inland Water	**E**	**0.000**	**0.000**	**0.000**	**0.011**	**0.000**	**0.011**
Total Area	**T**	**-7.696**	**7.696**	**-5.442**	**5.442**	**-9.821**	**9.821**

Tab. 33. Green Belt : gross changes in land cover (Km2).

Landscape Class		1968-81	1968-81	1981-91	1981-91	1968-91	1968-91
		Losses	Gains	Losses	Gains	Losses	Gains
		Km2	Km2	Km2	Km2	Km2	Km2
Broadleaved High Forest	A1	0.000	0.046	-0.007	0.012	-0.005	0.057
Mixed High Forest	A3	-0.162	0.073	-0.102	0.159	-0.129	0.098
Scrub	A4	-0.018	0.106	-0.034	0.018	-0.027	0.099
Clear Felled, Newly Planted	A5	-0.072	0.165	-0.165	0.071	-0.072	0.070
Total Woodland	**A**	**-0.252**	**0.390**	**-0.307**	**0.261**	**-0.233**	**0.325**
Lowland Heath	B1	-0.022	0.000	-0.013	0.000	-0.035	0.000
Chalk Grassland	B2	-0.017	0.000	0.000	0.000	-0.017	0.000
Total Semi-Natural Veget.	**B**	**-0.039**	**0.000**	**-0.013**	**0.000**	**-0.052**	**0.000**
Cultivated Land	C1	-0.081	0.003	-0.031	0.007	-0.110	0.008
Improved Pasture	C2	-0.005	0.071	-0.129	0.035	-0.128	0.101
Rough Pasture	C3	-0.101	0.011	-0.009	0.149	-0.099	0.149
Set-Aside	C4	0.000	0.000	0.000	0.036	0.000	0.036
Total Agro-Pastoral	**C**	**-0.187**	**0.085**	**-0.169**	**0.227**	**-0.337**	**0.293**
Urban Land	D1	0.000	0.003	0.000	0.001	0.000	0.004
Major Transport Routes	D2	0.000	0.000	0.000	0.001	0.000	0.001
Isolated Industrial Estates	D3	0.000	0.001	0.000	0.000	0.000	0.001
Isolated Rural Developments	D5	0.000	0.000	0.000	0.000	0.000	0.000
Total Developed Land	**D**	**0.000**	**0.003**	**0.000**	**0.002**	**0.000**	**0.005**
Total Area	**T**	**-0.478**	**0.478**	**-0.489**	**0.489**	**-0.623**	**0.623**

Tab. 34. Sites of Special Scientific Interest : gross changes in land cover (Km2).

Landscape Class		1968-81	1968-81	1981-91	1981-91	1968-91	1968-91
		Losses	Gains	Losses	Gains	Losses	Gains
		Km2	Km2	Km2	Km2	Km2	Km2
Broadleaved High Forest	A1	-0.205	0.015	-0.025	0.013	-0.203	0.001
Mixed High Forest	A3	-0.211	0.262	0.000	0.207	-0.005	0.263
Scrub	A4	0.000	0.025	-0.012	0.008	0.000	0.021
Clear Felled, Newly Planted	A5	-0.262	0.286	-0.206	0.054	-0.262	0.133
Total Woodland	**A**	**-0.679**	**0.588**	**-0.244**	**0.281**	**-0.471**	**0.418**
Cultivated Land	C1	-0.875	0.647	-1.327	0.987	-1.541	0.972
Improved Pasture	C2	-0.869	0.836	-1.090	0.350	-1.195	0.422
Rough Pasture	C3	-0.117	0.328	-0.136	0.163	-0.132	0.369
Set-Aside	C4	0.000	0.000	0.000	0.945	0.000	0.945
Total Agro-Pastoral	**C**	**-1.861**	**1.811**	**-2.553**	**2.444**	**-2.867**	**2.707**
Urban Land	D1	-0.004	0.033	0.000	0.073	-0.004	0.105
Major Transport Routes	D2	0.000	0.034	-0.001	0.000	0.000	0.033
Isolated Industrial Estates	D3	0.000	0.041	0.000	0.000	0.000	0.041
Derelict Land	D4	0.000	0.004	-0.004	0.005	0.000	0.005
Isolated Rural Developments	D5	0.000	0.033	-0.001	0.001	0.000	0.033
Parkland	D7	0.000	0.000	0.000	0.000	0.000	0.000
Total Developed Land	**D**	**-0.004**	**0.144**	**-0.006**	**0.079**	**-0.004**	**0.216**
Inland Water	E1	0.000	0.000	0.000	0.000	0.000	0.000
Total Inland Water	**E**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Total Area	**T**	**-2.543**	**2.543**	**-2.803**	**2.803**	**-3.341**	**3.341**

Tab. 35. Area without countryside designations : gross changes in land cover (Km2).

Landscape Class		Study Area	None	AGLV	AONB	APA	SSSI
Linear Features		**Km/Km2**	**Km/Km2**	**Km/Km2**	**Km/Km2**	**Km/Km2**	**Km/Km2**
Hedgerows	G1	-0.538	-0.242	-0.989	-0.710	-0.977	-3.301
Woodland Edge	G5	0.014	-0.122	0.043	-0.105	0.186	0.044
Fences, Ditches and other boun.	G6	0.217	0.059	0.266	0.198	0.568	2.103
Point Features		**Num/Km2**	**Num/Km2**	**Num/Km2**	**Num/Km2**	**Num/Km2**	**Num/Km2**
Single Trees Outside Linears	H2	-2	-5	-4	0	-2	1
Single Trees Inside Linears	H4	-10	-22	-12	-11	-10	-54

Tab. 36. Density of selected linear and point features: difference between 1968 and 1991 in the study area and selected countryside designation zones.

Landscape Class		Inside				Outside			
		Green Belt		AGLV		Green Belt		AGLV	
		Net	Gross	Net	Gross	Net	Gross	Net	Gross
		%	%	%	%	%	%	%	%
Broadleaved High Forest	A1	-0.04	0.58	-0.28	0.39	-0.48	0.62	-0.27	0.68
Coniferous High Forest	A2	0.04	0.08	0.13	0.19	0.03	0.03	0.00	0.00
Mixed High Forest	A3	0.22	0.25	0.50	1.48	0.60	1.14	0.39	0.42
Scrub	A4	-0.59	1.32	-0.17	0.72	0.10	0.34	-0.25	0.83
Clear Felled, Newly Planted	A5	0.36	0.80	0.41	1.72	0.45	1.93	0.41	1.27
Total Woodland	**A**	**0.00**	**3.03**	**0.59**	**4.50**	**0.70**	**4.05**	**0.28**	**3.21**
Lowland Heath	B1	-0.08	0.08	0.00	0.00	0.00	0.00	-0.05	0.05
Chalk Grassland	B2	-0.06	0.11	-0.12	0.16	0.00	0.00	0.01	0.01
Total Semi-Natural Veget.	**B**	**-0.13**	**0.19**	**-0.12**	**0.16**	**0.00**	**0.00**	**-0.04**	**0.06**
Cultivated Land	C1	0.12	15.14	-1.34	16.79	-10.75	20.21	-7.21	18.19
Improved Pasture	C2	-4.07	14.36	-1.01	17.01	0.66	13.75	-1.81	12.91
Rough Pasture	C3	0.45	4.57	0.78	3.13	0.71	4.91	0.51	5.36
Set-Aside	C4	1.24	1.24	0.69	0.69	3.26	3.26	2.92	2.92
Total Agro-Pastoral	**C**	**-2.27**	**35.31**	**-0.87**	**37.63**	**-6.11**	**42.13**	**-5.59**	**39.37**
Urban Land	D1	0.87	0.96	0.30	0.30	4.27	4.38	3.56	3.69
Major Transport Routes	D2	0.57	0.57	0.50	0.50	0.50	0.50	0.54	0.54
Isolated Industrial Estates	D3	0.26	0.30	0.00	0.00	0.46	0.53	0.50	0.58
Derelict Land	D4	1.17	1.27	0.00	0.00	-0.01	0.12	0.76	0.92
Isolated Rural Developments	D5	0.32	0.39	0.29	0.29	0.38	0.41	0.38	0.45
Quarries, Mineral Works, Pits	D6	-0.44	0.62	0.00	0.00	0.30	0.37	-0.07	0.67
Parkland	D7	-0.37	0.46	-0.68	0.81	-0.51	0.51	-0.35	0.37
Total Developed Land	**D**	**2.38**	**4.56**	**0.40**	**1.90**	**5.39**	**6.81**	**5.32**	**7.21**
Inland Water	E1	0.02	0.02	0.01	0.01	0.02	0.02	0.03	0.03
Total Inland Water	**E**	**0.02**	**0.02**	**0.01**	**0.01**	**0.02**	**0.02**	**0.03**	**0.03**

Tab. 37. 1968-1991 net and gross changes in land-cover (% of designated area) in Green Belt and AGLV .

Landscape Class		Inside				Outside			
		AONB		SSSI		AONB		SSSI	
		Net	Gross	Net	Gross	Net	Gross	Net	Gross
		%	%	%	%	%	%	%	%
Broadleaved High Forest	A1	-0.18	0.36	1.34	1.62	-0.29	0.65	-0.34	0.56
Coniferous High Forest	A2	0.00	0.00	0.00	0.00	0.04	0.06	0.04	0.05
Mixed High Forest	A3	0.47	0.47	-0.81	5.91	0.41	0.76	0.47	0.50
Scrub	A4	-0.35	0.64	1.87	3.25	-0.20	0.83	-0.32	0.70
Clear Felled, Newly Planted	A5	0.00	0.87	-0.04	3.69	0.49	1.50	0.43	1.30
Total Woodland	**A**	**-0.05**	**2.34**	**2.37**	**14.47**	**0.45**	**3.80**	**0.28**	**3.11**
Lowland Heath	B1	0.00	0.00	-0.91	0.91	-0.04	0.04	0.00	0.00
Chalk Grassland	B2	-0.21	0.27	-0.44	0.44	0.01	0.01	-0.01	0.04
Total Semi-Natural Veget.	**B**	**-0.21**	**0.27**	**-1.35**	**1.36**	**-0.03**	**0.05**	**-0.01**	**0.04**
Cultivated Land	C1	1.28	13.05	-2.64	3.07	-6.91	18.72	-5.72	18.42
Improved Pasture	C2	-4.68	11.29	-0.71	5.95	-0.99	14.57	-1.62	14.38
Rough Pasture	C3	1.38	1.80	1.29	6.42	0.43	5.31	0.56	4.67
Set-Aside	C4	1.18	1.18	0.92	0.92	2.52	2.52	2.36	2.36
Total Agro-Pastoral	**C**	**-0.84**	**27.31**	**-1.14**	**16.36**	**-4.95**	**41.12**	**-4.42**	**39.83**
Urban Land	D1	0.17	0.17	0.09	0.09	3.14	3.25	2.77	2.86
Major Transport Routes	D2	0.84	0.84	0.02	0.02	0.47	0.47	0.55	0.55
Isolated Industrial Estates	D3	0.00	0.00	0.01	0.01	0.44	0.50	0.38	0.43
Derelict Land	D4	0.01	0.01	0.00	0.00	0.65	0.79	0.57	0.69
Isolated Rural Developments	D5	0.06	0.06	0.00	0.00	0.41	2.95	0.37	0.42
Quarries, Mineral Works, Pits	D6	0.00	0.00	0.00	0.00	-0.06	0.58	-0.05	0.51
Parkland	D7	0.00	0.00	0.00	0.00	-0.52	0.58	-0.46	0.51
Total Developed Land	**D**	**1.09**	**1.09**	**0.13**	**0.13**	**4.52**	**9.13**	**4.12**	**5.98**
Inland Water	E1	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02
Total Inland Water	**E**	**0.02**	**0.02**	**0.01**	**0.01**	**0.02**	**0.02**	**0.02**	**0.02**

Tab. 38. 1968-1991 net and gross changes in land-cover (% of designated area) in AONB and SSSI.

Landscape Class		Inside						Outside			
		Study Area	None	AGLV	AONB	APA	SSSI	AGLV	AONB	APA	SSSI
Linear Features		Km/Km2	Km/Km2	Km/Km2	Km/Km2	Km/Km2	Km/Km2	Km/Km2	Km/Km2	Km/Km2	Km/Km2
Hedgerows	G1	-0.538	-0.242	-0.989	-0.710	-0.977	-3.301	-0.689	-0.611	-0.683	-0.558
Woodland Edge	G5	0.014	-0.122	0.043	-0.105	0.186	0.044	0.054	0.046	0.013	0.014
Fences, Ditches and other boun.	G6	0.217	0.059	0.266	0.198	0.568	2.103	0.278	0.239	0.236	0.225
Point Features		Num/Km2	Num/Km2	Num/Km2	Num/Km2	Num/Km2	Num/Km2	Num/Km2	Num/Km2	Num/Km2	Num/Km2
Single Trees Outside Linears	H2	-2	-5	-4	0	-2	1	-3	-2	-2	-2
Single Trees Inside Linears	H4	-10	-22	-12	-11	-10	-54	-12	-10	-12	-10

Tab. 39. Density of selected linear and point features: difference between 1968 and 1991 in the study area and selected countryside designation zones.

CHARTS

CHART N. 1 and N. 2 : Linear and point features in the study area (96 Km2) for 1968, 1981, 1991.

Legend

G1	Hedgerows
G2	Double Hedgerows
G3	Strip Woodland
G4	Rows of Trees
G5	Woodland Edge
G6	Fences, Ditches and other boundaries
H1a	Agricultural Parcels
H1b	Non Agricultural Parcels
H2	Individual Trees Outside Linear Features
H3	Groups of Trees
H4	Individual Trees In Linear Features
H5	Inland Water
H6	Pylons

Chart N.1: Length of Linear Features

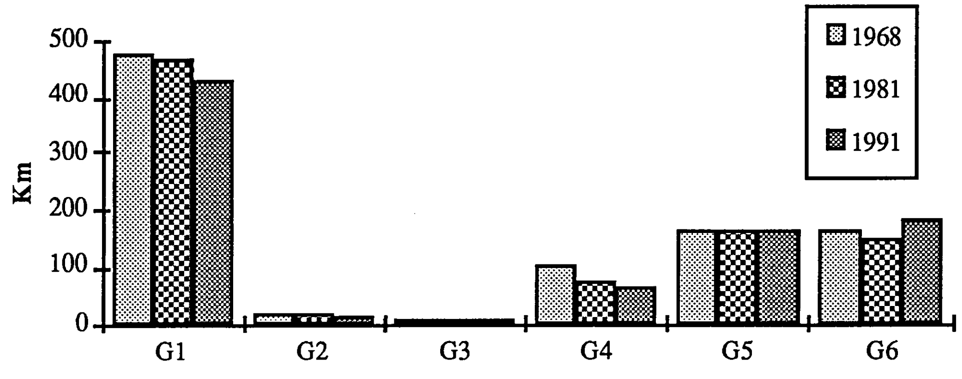


Chart N. 2: Number of Point Features

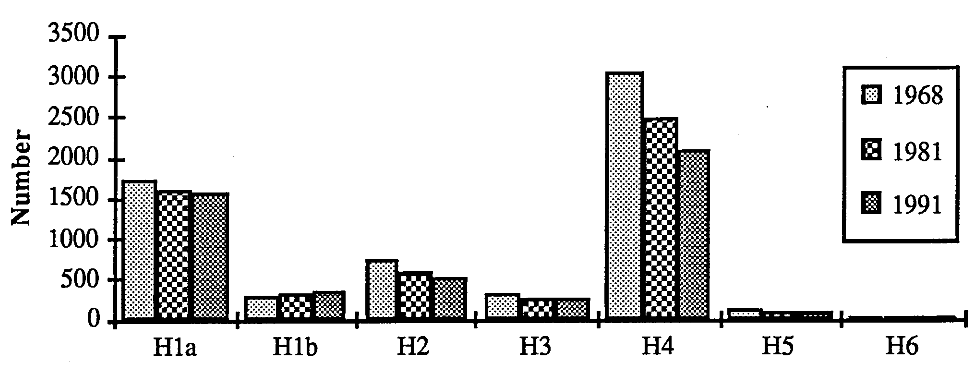


CHART N. 3 : Gross changes 1968 - 1991 in cultivated land (C1) in the study area (96 Km2): gains from- and losses to- other classes.

Legend

A123 High Forest	A1 Broadleaved High Forest
	A2 Coniferous High Forest
	A3 Mixed High Forest
A4 Scrub	
A5 Clear felled/newly planted	
B Semi-Natural Vegetation	B1 Lowland Heath
	B2 Chalk Grassland
C1 Cultivated Land	
C2 Improved Pasture	
C3 Rough Pasure	
C4 Set - Aside Land	
D Developed Land	D1 Urban Land
	D2 Major Transport Routes
	D3 Isolated Industrial Estates
	D4 Derelict Land
	D5 Isolated Rural Developments
	D6 Quarries, Mineral Works, Pits
D7 Parkland	
E1 Inland Water	

Chart N. 3: Cultivated Land (C1)

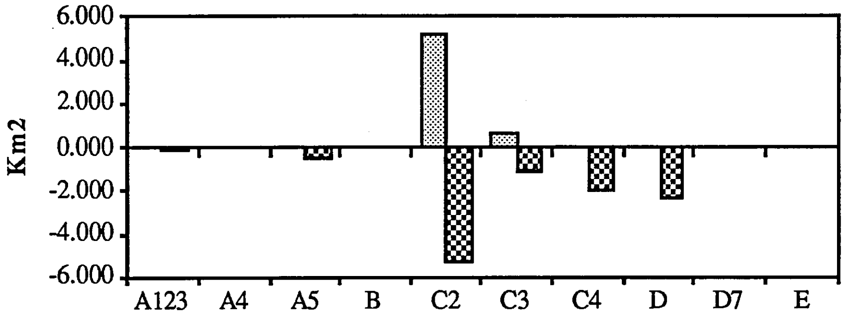


CHART N. 4 and N.5 : Gross changes 1968 - 1991 in improved pasture (C2) and developed land (D) in the study area (96 Km2): gains from- and losses to- other classes.

Legend

A123 High Forest — A1 Broadleaved High Forest, A2 Coniferous High Forest, A3 Mixed High Forest
A4 Scrub
A5 Clear felled/newly planted
B Semi-Natural Vegetation — B1 Lowland Heath, B2 Chalk Grassland
C1 Cultivated Land
C2 Improved Pasture
C3 Rough Pasure
C4 Set - Aside Land
D Developed Land — D1 Urban Land, D2 Major Transport Routes, D3 Isolated Industrial Estates, D4 Derelict Land, D5 Isolated Rural Developments, D6 Quarries, Mineral Works, Pits
D7 Parkland
E1 Inland Water

Chart N. 4: Improved Pasture (C2)

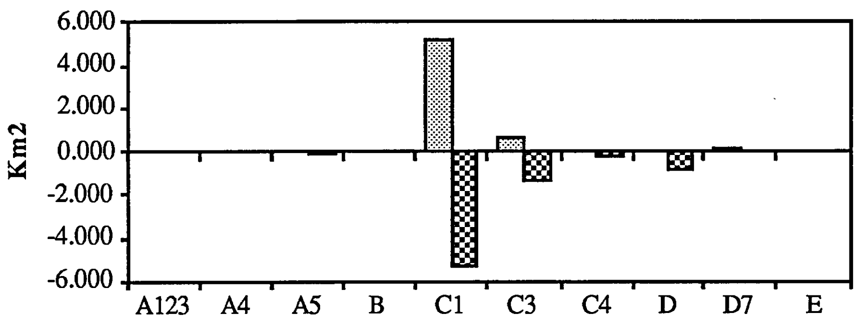


Chart N.5: Developed Land (D)

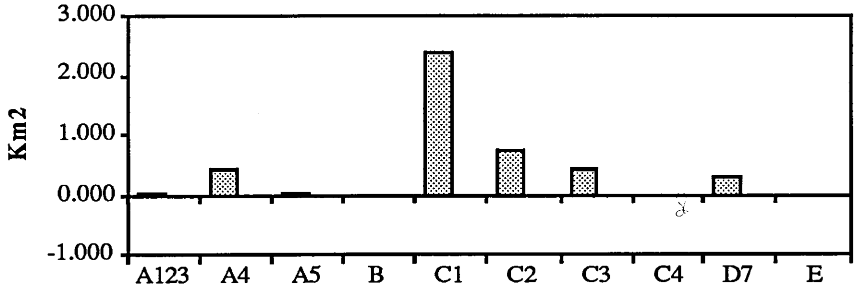


CHART N. 6 and N. 7 : Gross changes 1968 - 1991 in high forest (A123) and developed land (D) in the Areas of Great Landscape Value : gains from- and losses to- other classes.

Legend

A123 High Forest	A1 Broadleaved High Forest A2 Coniferous High Forest A3 Mixed High Forest
A4 Scrub	
A5 Clear felled/newly planted	
B Semi-Natural Vegetation	B1 Lowland Heath B2 Chalk Grassland
C1 Cultivated Land	
C2 Improved Pasture	
C3 Rough Pasure	
C4 Set - Aside Land	
D Developed Land	D1 Urban Land D2 Major Transport Routes D3 Isolated Industrial Estates D4 Derelict Land D5 Isolated Rural Developments D6 Quarries, Mineral Works, Pits
D7 Parkland	
E1 Inland Water	

Chart N.6: High Forest (A123)

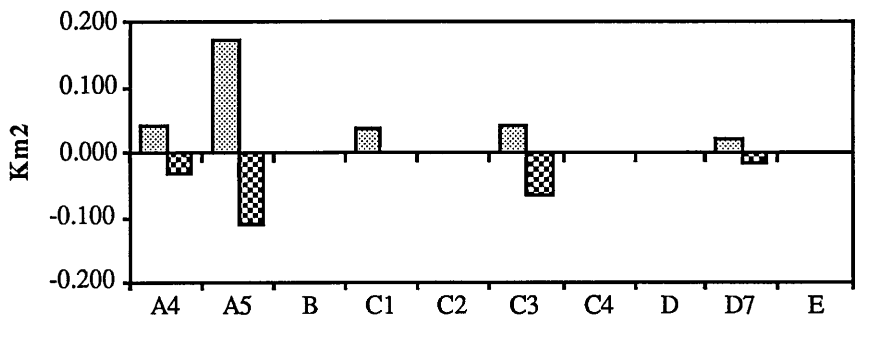


Chart N. 7: Developed Land (D)

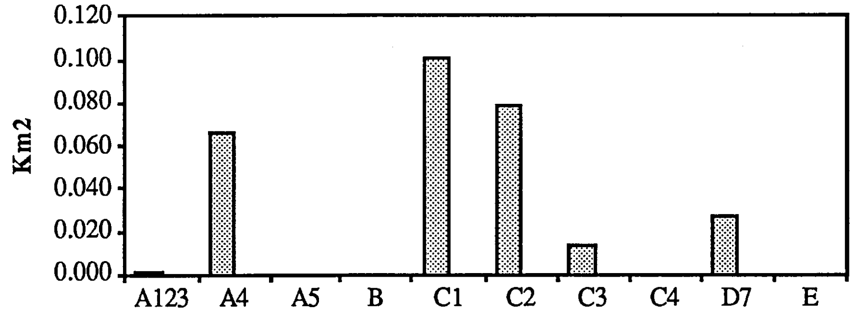


CHART N. 8 and N. 9 : Gross changes 1968 - 1991 in cultivated land (C1) and developed land (D) in the Green Belt : gains from- and losses to- other classes.

Legend

A123 High Forest	A1 Broadleaved High Forest
	A2 Coniferous High Forest
	A3 Mixed High Forest
A4 Scrub	
A5 Clear felled/newly planted	
B Semi-Natural Vegetation	B1 Lowland Heath
	B2 Chalk Grassland
C1 Cultivated Land	
C2 Improved Pasture	
C3 Rough Pasure	
C4 Set - Aside Land	
D Developed Land	D1 Urban Land
	D2 Major Transport Routes
	D3 Isolated Industrial Estates
	D4 Derelict Land
	D5 Isolated Rural Developments
	D6 Quarries, Mineral Works, Pits
D7 Parkland	
E1 Inland Water	

Chart N.8: Cultivated Land (C1)

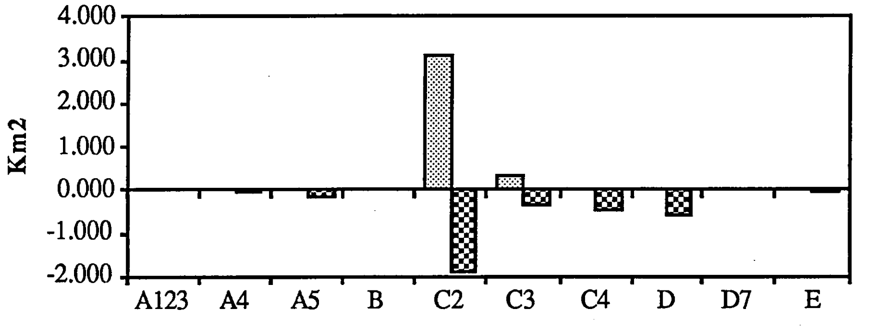


Chart N. 9: Developed Land (D)

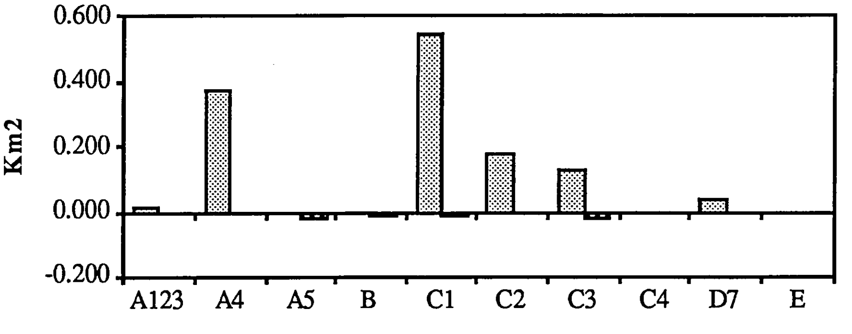


CHART N. 10 and N. 11 : Gross changes 1968 - 1991 in high forest (A123) and seminatural vegetation (B) in the Sites of Special Scientific Interest : gains from- and losses to- other classes.

Legend

A123 High Forest — A1 Broadleaved High Forest; A2 Coniferous High Forest; A3 Mixed High Forest

A4 Scrub

A5 Clear felled/newly planted

B Semi-Natural Vegetation — B1 Lowland Heath; B2 Chalk Grassland

C1 Cultivated Land

C2 Improved Pasture

C3 Rough Pasure

C4 Set - Aside Land

D Developed Land — D1 Urban Land; D2 Major Transport Routes; D3 Isolated Industrial Estates; D4 Derelict Land; D5 Isolated Rural Developments; D6 Quarries, Mineral Works, Pits

D7 Parkland

E1 Inland Water

Chart N. 10: High Forest (A123)

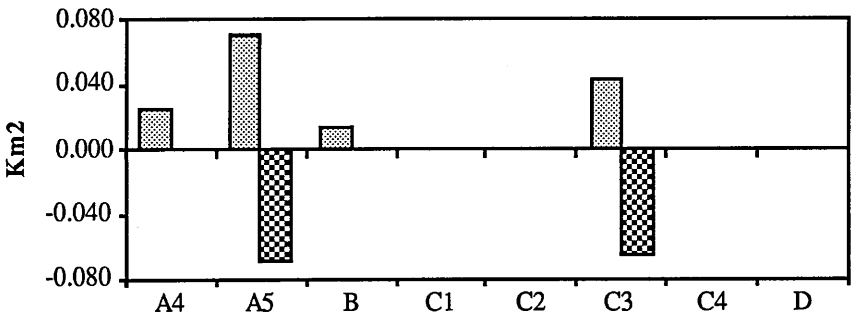
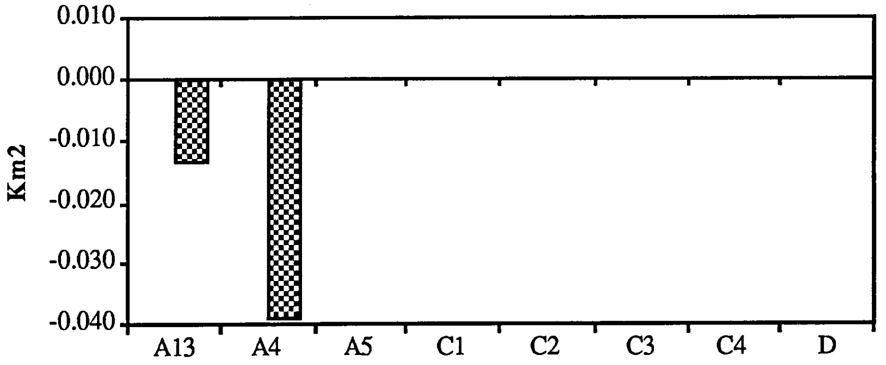


Chart N. 11: Semi-Natural Vegetation (B)



APPENDICES

APPENDIX 1. CLASSIFICATION SCHEME OF THE MLCNP PROJECT

A Linear Features	A1 Hedgerows	
	A2 Fences and insubstantial field boundaries	
	A3 Walls	
	A4 Banks	
	A5 Open Ditches	
	A6 Woodland Edge	
	A8 Strip Woodland	
	A9 Grips	
B Small or Isolated Features	B1 Individual Trees in Linear Features	
	B2 Individual Trees outside Linear Features	
	B3 Groups of Trees, All Species	
	B6 Inland Water	
C Wood and Forest Land	C1 Broadleaved High Forest	
	C2 Coniferous High Forest	
	C3 Mixed High Forest	
	C4 Scrub	
	C5 Clear Felled/Newly Planted Areas	
D Moor and Heath Land	D1 Upland Heath	
	D2 Upland Grass Moor	(b) Grass Moor
		(d) Blanket Peat Grass Moor
	D3 Bracken	
	D4 Unenclosed Lowland Areas	(a) Rough Grassland
		(b) Heath
	D6 Upland Mosaics	(a) Heath/Grass
		(b) Heath/Bracken
		(c) Heath/Blanket Peat
	D7 Eroded Areas	(a) Peat
		(b) Mineral Soils
	D8 Coastal Heath	
E Agro-pastoral Land	E1 Cultivated Land	
	E2 Grassland	(a) Improved Pasture
		(b) Rough Pasture
Water and Wetland	F1 Open Water, Coastal	
	F2 Open Water, Inland	
	F3 Wetland Vegetation	(a) Peat Bog
		(b) Freshwater Marsh
		(c) Saltmarsh
Rock and Coastal Land	G2 Bare Rock	(a) Inland
		(b) Coastal
	G3 Other Coastal Features	(a) Dunes
		(b) Sand Beach
		(c) Shingle Beach
		(d) Mud Flats
Developed Land	H1 Built-up Land	(a) Urban Area
		(b) Major Transport Routes
	H2 Quarries, mineral workings and Derelict Land	(c) Quarries and Mineral Working
		(b) Derelict Land
	H3 Isolated Rural Developments	(a) Farmsteads (>0.25 ha)
		(b) Other (> 0.25 ha)
	I Unclassified Land	

APPENDIX 2. DEFINITION OF LANDSCAPE CATEGORIES

Area Features

(A) WOOD AND FOREST LAND.

A1 Broadleaved high forest.
Areas greater than 0.25 ha, wider than 20 m and having a tree canopy cover of at least 20% by area. At least 80% of the canopy should be of broadleaved species.

A2 Coniferous high forest.
Areas greater than 0.25 ha, wider than 20 m and having a tree canopy cover of at least 20%. At least 80% of the canopy should be coniferous species.

A3 Mixed high forest.
Areas greater than 0.25 ha, wider than 20 m and having a tree canopy cover of at least 20% by area. Composed of an intimate mixture of broadleaved and coniferous species, where the minority group comprises more than 20%.

A4 Scrub.
Areas with diffused boundaries with less than 20% cover by area of mature timber species with a rough understory of shrubs and grasses. Trees are classified as scrub when they are less than 3.5 m high.

A5 Clear felled/newly planted areas.
Areas with hard boundaries, generally integral with stands of high forest and which have recently been felled or planted. Evidence of logging, rowing up of trash and drainage may be present.

(B) SEMI-NATURAL VEGETATION.

(B1) Lowlands heath.
Areas with greater than 80% cover of heather.

(B2) Chalk grassland.
Unenclosed areas with greater than 80% cover of grass species. It is present in the Chilterns Hills on chalk soils. Bushes of Blackthorn *(Prunus spinosa)*, Hawthorn *(Crategus spp)* and scattered trees may be present. It may be grazed.

AGRO-PASTORAL LAND.

C1 Cultivated land.
Areas of ploughed and cropped land, including cereals, ley grasses, legumes, field vegetables, potatoes and root crops, rape and fodder crops. The category also covers orchards and allotment gardens. Ley grasses are difficult to discern and impossible after the first year when they will be classified as C2 (Improved pasture). They are indicated by drilling rows, uniformity of species composition, often present in fields of large size and are usually to be found in situations where arable cropping is included.

C2 Improved pasture.
Grassland that is intensively managed for grazing and/or fodder production. Characterised by significantly modified swards produced by the use of fertilisers, herbicides, drainage and/or occasional reseeding. Species such as rushes, thistles and bracken are normally eradicated but could be present in small quantities. However daisies, buttercups, etc. may be present. It does not cover grass leys and generally occurs within the limits of mechanical operations. The sward may be lumpy due to uneven fertilisation from cow pats, and may have artificial boundaries caused by strip grazing. From spring to late summer cutting for hay or silage may occur.

C3 Rough pasture.
Enclosed areas subject to little or no management. Characterised by a high density of native grasses and often containing invasive species such as bracken, bramble, thistle, rushes and scattered trees. Tussocks may be also in evidence. Generally occurs on steep slopes, poorly drained sites and on soils of low fertility. Frequently includes areas that can be accessed by farm machinery indicating that it may have been managed in the past.

C4 Set Aside land.
Portions of land taken out of production for arable crops, and left fallow, converted to woodland or used for other non agricultural purposes under the Set-Aside Scheme administered by MAFF (as described in Chapter I). This is a typical example of land use represented by different land covers. When the land is left fallow, it can be identified as rough pasture, characterised by grass and often by a lumpy surface. Distinctive factors may be the regular shape of the field, the large size, rows of ploughing or drilling lines. It is mainly present in intensively cultivated areas where the extensive areas of rough pasture wouldn't normally occur if not under subsidized schemes.

DEVELOPED LAND

D1 Urban land.
Areas of buildings, including gardens, car parks, etc. and urban open spaces such as parks, playing fields etc. Any settlement consisting of more than one group of buildings will be included.

D2 Major transport routes.
Transport routes which cover a significant area, defined as multicarriageway roads, functioning multi-track railways, railyards, airports and navigable canals (when present). Grass verges, roundabouts, car parks, and service stations (only in motorways) obviously associated with the transport route are included.

D3 Isolated industrial estates.
Isolated estates characterised by the presence of groups of factories often associated with large car parks, goods or raw materials stored outside, disturbed land. The buildings are easily recognizable for their large size and regular shape often with shiny colours and materials.

D4 Derelict land.

Significantly disturbed land in need of reclamation prior to utilisation. It includes closed and disused tips, worked out mineral excavations, abandoned military or service installations, land which is affected by surface collapse resulting from disused underground mining operations. Land derelict from natural causes or damaged by development which has blended into the landscape (e.g. flooded mineral excavation used for fishing or sailing) is not included.

D5 Isolated rural developments.
Developments consisting of one group of buildings but covering an area larger than 0.25 ha. It includes farmsteads (farmhouse and associated farm buildings) and any other type of isolated rural development (dairies, garages, public houses etc.) Farmsteads near the urban land edge are included in the latter.

D6 Quarries, mineral works, pits.
Open surfaces of land excavated for the extraction of building stone, gravel, sand, and minerals, often associated with sites utilised for their working. Characterised by the presence of irregular surfaces, disturbed land and often by of the colour of the minerals worked.

D7 Parkland.
Areas of grassland characterised by the regular presence of scattered mature trees (often oaks) or groups of trees. Often these pieces of land are part of the great estates of 19th century Bedfordshire which were characterised by a mixture of farmland, woodland and park land. Located outside urban areas, they are often used for recreational purposes; if they are part of farm land they are managed in the same way as improved or rough pastures. The number of trees per ha may vary, although they should be regularly distributed.

WATER

E1 Inland water (> 0.25 ha).
Natural and man made water bodies with an area greater than 0.25 ha. Flooded mineral excavation used for fishing or sailing is included. Rivers, lakes within quarries in use and sewage works are not included.

LINEAR FEATURES

G1 Hedgerows.
Any amount of hedge, however discontinuous and in any condition is classified as hedgerow unless it can be classified as point features H2, H3, H4 or as linear features G2 or G4. Rows of bushes planted for ornamental purposes are included in this category. Characteristically found as field boundaries, they may have been replaced or supplemented by fences for stock control purposes. Trees less than 4.5 m high, planted in rows and regularly trimmed and rows of just planted trees are included in this category. Also hedgerows which are dead or in bad condition are included.

G2 Double hedgerows.
Any amount of hedge parallel to another hedge, however discontinuous and in any condition. Two hedgerows are considered as double hedgerow when they run

alongside ditches, footpaths, bridleways or if the distance between the two hedgerows is less than 3 m. Double hedgerows alongside asphalted roads or main roads are classified as single hedgerows.

G3 Strip woodland.
Isolated strips of woody vegetation with more than a single line of trees, which are more than 50 m long but less than 20 m wide. If the strips are composed of rows of trees the tree canopies should cover most of the area. In this category are comprised high double hedgerows incorporating a line of trees and two rows of trees incorporating a high hedgerow or scrub.

G4 Rows of trees.
Single lines of mature trees more than 4.5 m high. It should be possible to distinguish the shape of the canopy, and the distance between each tree (taken from the edge of each canopy) should not be more than a few meters, otherwise they are classified as point feature H2 or H4. When a row of trees is associated with a hedgerow only the former is taken into consideration.

G5 Woodland edge.
Boundaries around wood and forest land (all A categories). The boundaries of category A5 are not considered unless the new plantation is more than 2 m high. The types of boundaries (hedge, fence, etc.) are not defined since these are usually obscured on aerial photography by tree canopies.

G6 Fences, ditches and other boundaries.
Field boundaries formed by fences, ditches or other features like low banks, not associated with other linear features. Provisional electric fences have not been included. This category groups mainly artificial boundaries; a combined analysis of this category with the categories representing the natural boundaries G1, G2, G3, G4, G5 may provide information on the rate of interchange between them. Planted hedgerows which are difficult to detect for their lack of shadow and their low and thin appearance are included in this category.

POINT FEATURES

H1 Number of parcels.
Individual fields and parcels corresponding to landscape area feature and surrounded by distinct and permanent boundaries. Each parcel is represented by a centroid, which is a point approximately located in the centre of each parcel. Two sub categories belong to this class:

H1a Agricultural parcels: they represent fields whose land cover is C1, C2, C3, C4. Those parcels of parkland (D7) which can clearly be identified as utilised for agricultural purposes are counted in this class.

H1b Non agricultural parcels: they include all the other landscape area features (A, B, D, E). The parcels of parkland clearly utilised for recreational aims are included in this class.

The distinction between agricultural and non agricultural parcels aimed to investigate the possible process of reorganization of the agricultural land, like enlargements of fields which have occurred since the 1960s'.

H2 Individual trees outside linear features.
All mature trees, more than 4.5 m high, that can be distinguished as individuals, outside linear features. Large bushes are not included, although occasionally they may be counted in this class as a consequence of errors while carrying out the API. Individual trees included in class A5 were not counted.

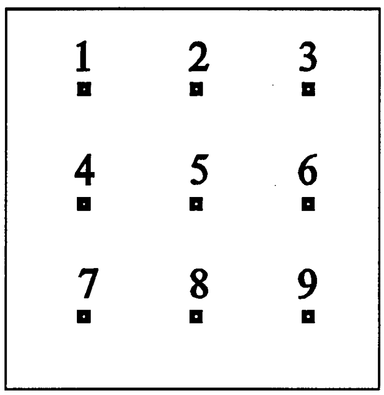
H3 Groups of trees, all species.
Groups of trees covering an area less than 0.25 ha. Groups of big bushes often present in the corners of the fields are included.

H4 Individual trees in linear features.
As H2 but occurring along a linear feature.

H5 Inland water (< 0.25 ha)
Farmland ponds, small reservoirs, natural water bodies, etc. which are less than 0.25 ha in area.

H6 Pylons.
Large vertical steel tower-like structures supporting high tension electrical cables. Easily detectable, when present, for their location in lines and their regular distance.

APPENDIX 3. GROUND SURVEY GRID FOR THE EXTRACTION OF LANDSCAPE FEATURES



Points 1, 3, 5, 7, 9 were used for the extraction of area features
Points 1, 2, 3, 4, 5, 6, 7, 8, 9 were used for the extraction of linear and point features

APPENDIX 4. GROUND SURVEY COUNT FORM

(The data on run, number, square number and coordinates are referred to the 1991 photographs.)

Run ______________ Number______________

Square N.______________

	East (m)	North (m)
coordinates LB	______________	______________
coordinates TR	______________	______________

Square Number (ground survey plan) ______________

	GROUND SURVEY	**API**
A1 Broadleaved high forest	__________	__________
A2 Coniferous high forest	__________	__________
A3 Mixed high forest	__________	__________
A4 Scrub	__________	__________
A5 Clear felled/newly planted	__________	__________
B1 Lowlands heath	__________	__________
B2 Chalk grassland	__________	__________
C1 Cultivated land	__________	__________
C2 Improved pasture	__________	__________
C3 Rough pasture	__________	__________
C4 Set-Aside land	__________	__________
D1 Urban land	__________	__________
D2 Major transport routes	__________	__________
D3 Isolated Industrial estates	__________	__________
D4 Derelict land	__________	__________
D5 Isolated rural develop.	__________	__________
D6 Quarries, mineral works, pits.	__________	__________
D7 Parkland	__________	__________
E1 Inland water (>0.25 ha)	__________	__________
Linear features		
G1 Hedgerows	__________	__________
G2 Double hedgerows	__________	__________
G3 Strip woodland	__________	__________
G4 Rows of trees	__________	__________
G5 Woodland edge	__________	__________
G6 Fence, ditches and other b.	__________	__________
Point features		
H2 Individual trees outs l. f.	__________	__________
H3 Groups of trees	__________	__________
H4 Individual trees in l. f.	__________	__________
H5 Inland water (< 0.25 ha)	__________	__________
H6 Pylons	__________	__________

APPENDIX 5. LINEAR AND POINT FEATURES COUNT FORM

(The data on run, number, square number and coordinates are referred to the 1991 photographs.)

Run ______________ Number______________

Square N.______________

	East (m)	North (m)
coordinates LB	______________	______________
coordinates TR	______________	______________

Length of the two diagonals (cm)

1)____________ 2)____________

Linear features	**1968 count**	**1981 count**	**1991 count**
G1 Hedgerows	__________	__________	__________
G2 Double hedgerows	__________	__________	__________
G3 Strip woodland	__________	__________	__________
G4 Rows of trees	__________	__________	__________
G5 Woodland edge	__________	__________	__________
G6 Fence, ditches and other b.	__________	__________	__________

Point features	**1968 Number**	**1981 Number**	**1991 Number**
H1a Agricultural parcels	__________	__________	__________
H1b Non agricultural parcels	__________	__________	__________
H2 Individual trees outs l. f.	__________	__________	__________
H3 Groups of trees	__________	__________	__________
H4 Individual trees in l. f.	__________	__________	__________
H5 Inland water (< 0.25 ha)	__________	__________	__________
H6 Pylons	__________	__________	__________

APPENDIX 6. EXAMPLE OF TABULATED OUTPUT FOR LINEAR FEATURES

LENGHT OF LINEAR FEATURES (KM) IN BEDFORDSHIRE STUDY AREA (96 KM2) PER KILOMETRE SQUARE

No square	No square	1968	1968	1968	1968	1968	1968	1981	1981	1981	1981
SPANS	MAP	G1	G2	G3	G4	G5	G6	G1	G2	G3	G4
1	218	8.309	0.000	0.000	0.389	0.673	0.932	6.080	0.122	0.000	0.268
2	219	4.229	0.000	0.000	0.095	2.925	0.656	3.992	0.000	0.000	0.229
3	220	4.003	0.000	0.000	1.511	5.651	0.549	3.414	0.000	0.000	1.452
4	116	2.524	0.000	0.000	0.575	4.504	0.000	2.175	0.000	0.000	0.575
5	117	4.529	0.000	0.000	1.634	1.595	0.945	4.135	0.000	0.000	1.083
6	118	7.417	0.000	0.000	0.420	0.654	2.102	6.584	0.000	0.000	0.119
7	119	4.849	0.399	0.000	0.000	0.000	0.000	4.849	0.399	0.000	0.000
8	120	4.703	0.111	0.000	0.775	0.245	0.000	5.414	0.111	0.000	0.490
9	223	7.973	0.000	0.000	1.953	0.317	0.895	6.549	0.000	0.000	1.261
10	224	6.546	0.281	0.000	0.585	0.390	0.000	6.157	0.281	0.140	0.281
11	225	6.995	0.000	0.213	0.553	0.601	0.198	5.256	0.000	0.213	1.462
12	121	2.486	0.000	0.000	0.545	3.047	0.000	1.323	0.000	0.000	0.545
13	122	2.756	0.000	0.000	0.591	7.191	0.056	3.036	0.000	0.000	0.344
14	123	2.136	0.000	0.000	0.220	8.827	0.187	2.827	0.000	0.000	0.220
15	124	1.660	0.862	0.000	0.435	4.387	0.000	1.581	0.862	0.000	0.364
16	125	1.428	0.000	0.000	0.127	4.720	0.658	0.734	0.000	0.000	0.262
17	303	5.243	1.247	1.321	2.229	0.594	0.433	5.532	1.164	1.218	1.940
18	304	4.573	0.114	0.090	0.457	1.164	0.204	2.409	0.114	0.090	0.898
19	305	6.102	1.237	0.342	0.667	0.903	2.075	5.126	1.009	0.220	0.618
20	601	5.758	0.181	0.173	0.115	0.000	1.255	4.401	0.000	0.173	0.000
21	602	2.034	0.000	0.276	0.191	1.043	1.096	2.104	0.000	0.276	0.074
22	603	5.071	0.000	0.000	2.661	0.562	2.431	6.202	0.000	0.000	1.446
23	604	3.214	0.000	0.358	2.644	2.034	1.139	2.807	0.000	0.358	1.525
24	605	4.240	0.000	0.000	0.000	2.988	0.000	3.998	0.000	0.000	0.105
25	308	6.188	1.516	0.697	0.951	0.000	0.139	6.188	0.963	0.697	0.574
26	309	6.818	0.073	0.000	1.094	2.184	0.959	6.410	0.204	0.000	0.294
27	310	6.188	0.803	0.000	0.721	0.688	1.844	4.754	0.803	0.000	0.246
28	606	5.656	0.661	0.140	2.543	0.421	2.395	5.615	1.032	0.140	0.669
29	607	0.715	0.000	0.000	0.909	0.656	2.162	2.903	0.000	0.000	0.000
30	608	5.679	0.000	0.219	3.765	0.825	1.914	7.151	0.000	0.000	1.199
31	609	3.758	0.000	0.000	1.478	0.000	1.378	4.342	0.000	0.000	0.559
32	610	3.494	0.000	0.000	0.715	0.532	0.341	3.868	0.000	0.000	0.216
33	313	3.715	0.220	0.000	1.470	3.266	2.246	3.266	0.220	0.000	1.204
34	314	7.944	0.284	0.000	0.454	0.000	5.269	6.120	0.065	0.211	0.454