Land use mapping of selected areas of county Durham, north-east England, by satellite remote sensing and field survey methods

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Land Use Mapping of Selected Areas of County Durham, north-east England, by Satellite Remote Sensing and Field Survey Methods

by

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A thesis presented for the degree of Master of Science at the University of Durham

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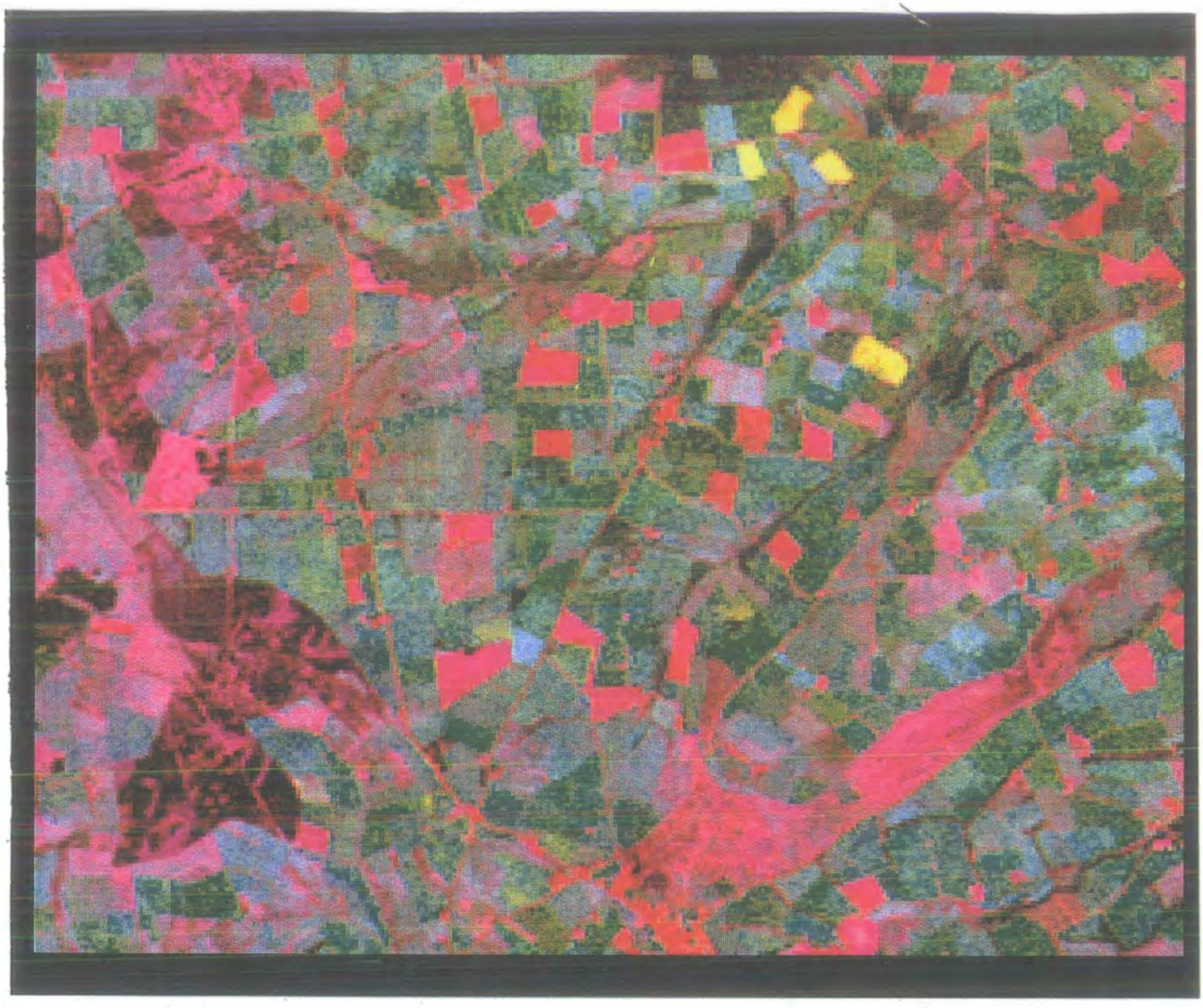
September 1994

To the memory of my beloved father SHEIKH MUSTAFA MOHAMMAD GHODIEH and my uncle SHEIKH IBRAHIM MOHAMMAD GHODIEH.

also to my mother, my wife Raeda, my son Qutaiba, my coming baby, my sisters, my brothers and all my family.



A Landsat-TM Enhanced Colour Composite of one of the Study Areas (Satley), Northern England.

The data was obtained by Landsat-5 on May 31, 1985. This print has been produced by using bands 5(1.55-1.75 μm), 4(0.76-0.9 μm) and 3(0.63-0.69 μm).

DECLARATION

The work contained in this study has not been submitted elsewhere for any other degree of qualification and that unless otherwise referenced it is the author's own work.

STATEMENT OF COPYRIGHT

Acknowledgements

First of all Praise to God, without whose willingness none of this work could have not been accomplished.

I am grateful to my supervisor, Dr Daniel Donoghue, for his diligent academic and technical supervision, constructive comments, inspiring encouragement and enthusiastic active interest throughout the preparation of this thesis.

I am also grateful to my second supervisor, Dr. Peter Atkins, for his great help especially during the field work stage, without whose support and encouragement, this important stage of the work could have not been accomplished properly.

Thanks also extended to all colleagues and staff of Geography Department and its administration. Also my thanks go to all the staff in Computer Centre and the main University Library for their great help and co-operation.

I am also grateful to all the farmers in County Durham, especially Mr. David Cowton, for their co-operation throughout the field work carried out on their farms. My thanks also go to the undergraduate students in the department for their help in the field work.

Special thanks to the British Council for their generous award to accomplish this study. My thanks go to my programme officers in the British Council Mrs. Angie Stephenson and Sara Lewis for their unique co-operation and advice throughout the period of the study. I also thank the British Council administration in Newcastle for their entertainment programmes during the study period.

I am grateful to the Graduate Society for their frequent social programmes and entertainment events which relieved the pressure of work. My thanks also go to the Language Centre in the University of Newcastle upon Tyne for their useful English Language Course and their help to adapt to the social life in England. I also thank all individuals and families who supported me during my stay in the United Kingdom.

All special thanks go to Durham the city, Durham the distinctive beauty, and Durham the kind helpful people.

Last, but no means the least, I would like to thank my mother whose prays helped me to overcome difficulties faced me during the preparation of this thesis.

Special thanks to my wife Raeda, my son Qutaiba and my coming baby who accepted my preoccupation with the affairs of this thesis. Without their sacrifice, patience and encouragement, this thesis could not have been completed.

I am also grateful to my sisters and brothers and all my family who were always supporting me.

- **Land Use Mapping of Selected Areas of County Durham, north-east England, by Satellite Remote Sensing and Field Survey Methods.**

- **AR.M.M.Ghodieh**

Abstract

This thesis investigates the use of field and satellite data for agricultural land use mapping and land use change in six selected areas of County Durham, north-east England. These areas are selected to represent the major land use patterns of the County.

The satellite data were obtained by the Thematic Mapper (TM) sensor on board Landsat-5 on May, 31, 1985, August, 1, 1990, and July, 10, 1992. TM data were geometrically corrected to the British National Grid.

Land use maps for these study areas were produced by field survey to become the basis on which the research was based. These land use maps along with images were integrated in a Geographical Information System (GIS) called ARC / INFO. The total surface area of the study area is 5483.86 hectare, or 2.3% of the whole County Durham. The field area measurements were taken and the final hectare estimates were obtained for each land use / land cover type.

The research demonstrated the ability of Landsat-TM to produce accurate land use maps of the study area. Results obtained emphasised that Satellite data when integrated in a Geographical Information System (GIS), can be used for mapping relatively small agricultural fields.

A land cover classification scheme appropriate for the study area was applied. Number of land use \ land cover classes produced varied from one study area to another and from one image date to another also (18-25 classes). These detailed classes were generalised to their broader classes. Using the Landsat-TM data, classification accuracy varied from one study area to another and from one date to another also, but it was not less than 80%. The classification accuracy was assessed using the grid-by-grid overlay method.

The study analysed the spectral properties of each land use \ land cover over the three image dates, and the importance of contextual and reference data to assess and improve the classification accuracy.

Results obtained by this study showed that the selected study areas can represent the major agricultural crops in County Durham by a percentage of 81-96%. Results of the study also suggests that a data base in digital format of land use, topography, geology, soil and climate is essential to set-up a special model for the County to be used for faster, easier and more efficient updating of land use data of the County.

Introduction

Many countries around the world, especially those in Europe and throughout the European Union find themselves forced to establish policies and regulations on how land resources can be used and protected from inappropriate use and degradation.

In the last two decades the world, particularly Europe, has been preoccupied with industrial and technological development more than land use management. Only in recent years has more attention begun to be focused on land use problems. The reason for this is first, agricultural land needs to be preserved properly from the expansion of urbanisation at the expense of the agricultural land. Second, the considerable increase of environmental pollution adds more hazards, and lastly the complicated economic network in the world requires updating of land use plans.

Land use information is vital for planning decisions, and so in Europe, local, national, and EU planners collect this information regularly by different means; starting from the field survey method, and passing through aerial photography to satellite remote sensing methods.

Satellite remote sensing provides an ideal means of acquiring data for the study of *large areas*. This technique has become the most *time and cost* effective method for land use/land cover studies.

To get the maximum benefit from this technique, the data can be integrated within a Geographical Information System (GIS). In order that, land use/land cover maps can be produced and analysed.

Aims of the Study

The aims of the study consist of the following:-

1. Until now a comprehensive land use survey of Britain including County Durham has not been available. Only two extensive national land use surveys have been carried out in the past. The first was under the direction of Dudley Stamp in the 1920s and 1930s, with a partial update by Alice Coleman in the 1950s and 1960s. However, both surveys were incomplete. There is a need to update land use information, and the present study can make a contribution to the methodology.

2. As a member of the European Economic Community, Britain was asked to update its land use information in order to regulate its agriculture under the Common Agricultural Policy (CAP), especially after the recent membership of Spain and Greece in the EC, and their remarkable supply, particularly Spain, of the European market with different types of agricultural products. So, the EC started to apply the set aside policy to control the surplus of food production in the market.

3. As part of the EU's CAP, since summer 1992, the British Government began to encourage farmers to grow grass crops rather than arable crops, so this study aims to look at evidence from land use statistics to investigate the response of farmers to new agricultural trends.

4. The application of Remote Sensing Techniques in different subjects including land use mapping is not yet as wide as other techniques such as aerial photography. This study aims also to invistigate the capability of remote sensing techniques to produce accurate land use maps and whether they can be an alternative to other conventional techniques.

5. To detect land use change in the study areas using Landsat imagery from three dates.

6. To integrate remote sensing data in a Geographical Information System (GIS) and produce land use maps and detailed statistics for the study areas.

CONTENTS

CHAPTER ONE

Chapter 1: Geographical Description of the Study Area

1.1 Location

The study area consists of six Civil Parishes (CP) in County Durham, north-east England. The selection of these parishes is based on the general land use characteristics of the County. So these parishes represent all the major agricultural patterns and land uses types in the County. The study areas are: -

***(1) Hawthorn Civil Parish*:-** This area is located in Easington District on the coast of the North Sea. It was chosen to represent the agriculture of the Coastal Plain in the Eastern Region.

***(2) Hett Civil Parish*:-** This area is located in Durham District, a few miles south the City Durham. It was chosen to represent the agriculture of the Wear Lowland in the East Region.

***(3) Wackerfield Civil Parish*:-** This area is located in Teesdale District, a few miles south of Bishop Auckland. It was chosen to represent the agriculture of the Tees Lowland in the Eastern Region.

***(4) Greencroft Civil Parish*:-** It is located in Derwentside District, few miles to the north east of Lanchester.

***(5) Satley Civil Parish*:-** It is located in Derwentside District, to the south west of Greencroft CP. These two areas were chosen to represent the agriculture of the Central Corridor Region.

***(6) Edmundbyers Civil Parish*:-** It is located in Wear Valley District. It was chosen to represent the agriculture of the Upper Lands of the Dales Region (The Moorland).

It can be seen from the map of the study area fig (1:1) that the areas were selected regionally, and the main three agricultural regions were represented fig (1:6).

To establish a good understanding of the geographical characteristics of the study area, it is essential to deal with the area as regions rather than small parishes. So the geographical thematic description will deal with the County Durham as one geographical unit.

Figure (1.1) : Location of the study areas on the map of County Durham

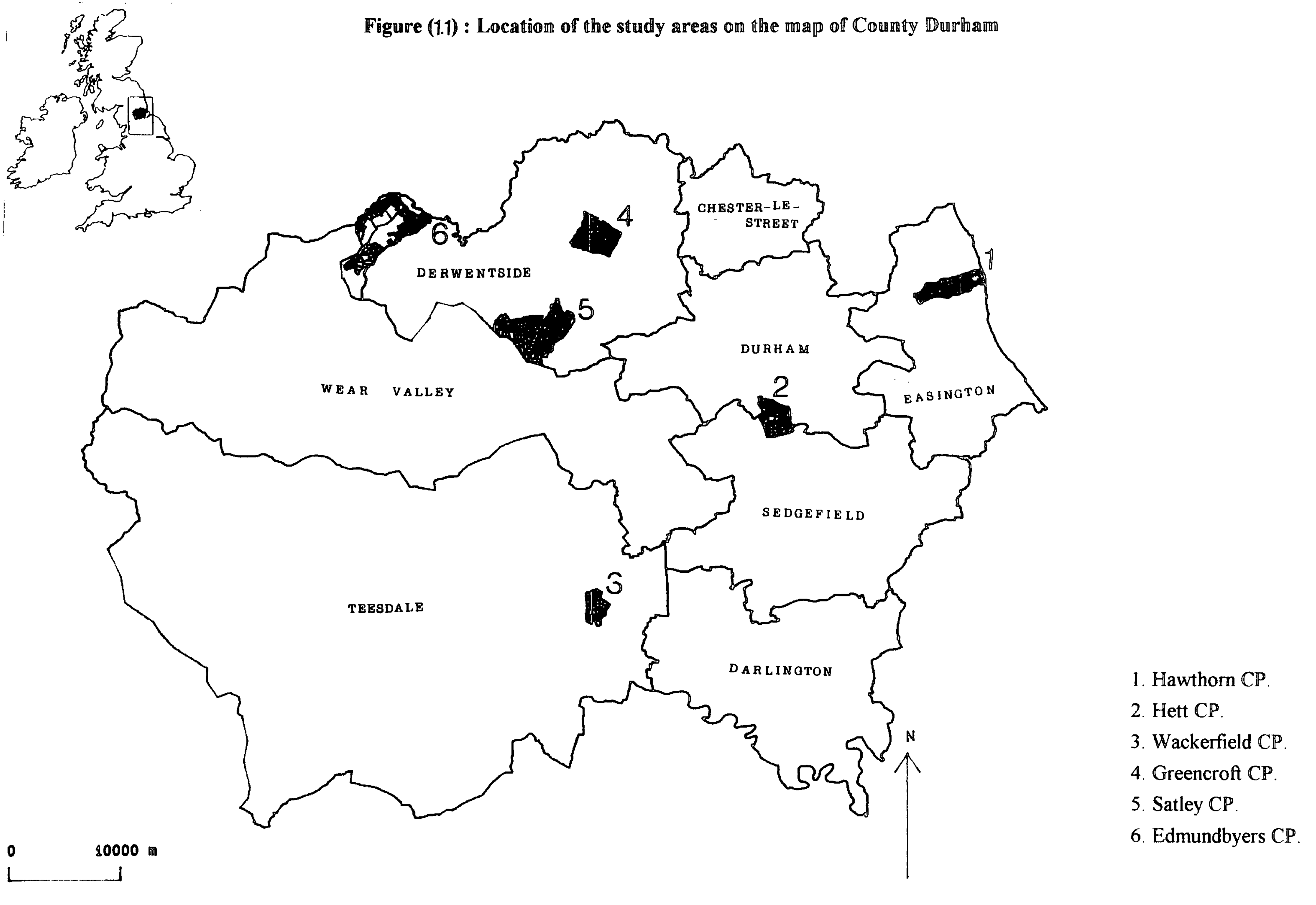
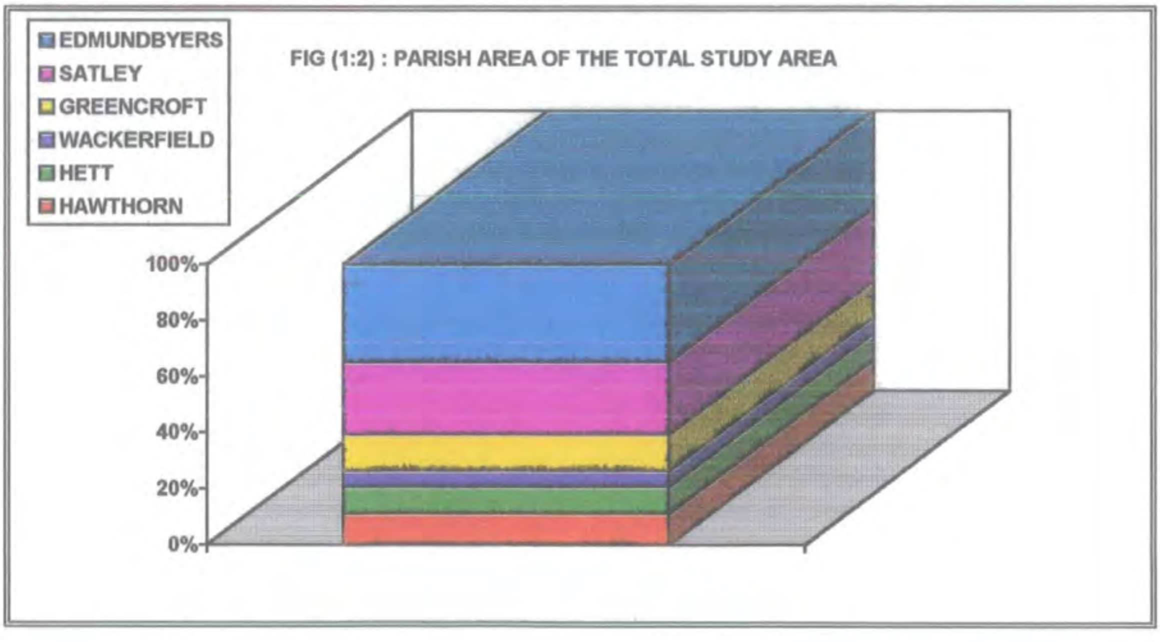


Table (1:1): Parish area of the total study area.

No	Parish Name	Parish Area(ha)	%
1	Hawthorn	577.24	11.01
2	Hett	505.31	9.64
3	Wackerfield	303.65	5.79
4	Greencroft	678.88	12.95
5	Satley	1354.72	25.84
6	Edmundbyers	2064.06	37.64
	Total Area	5483.86	100



1.2 Geology

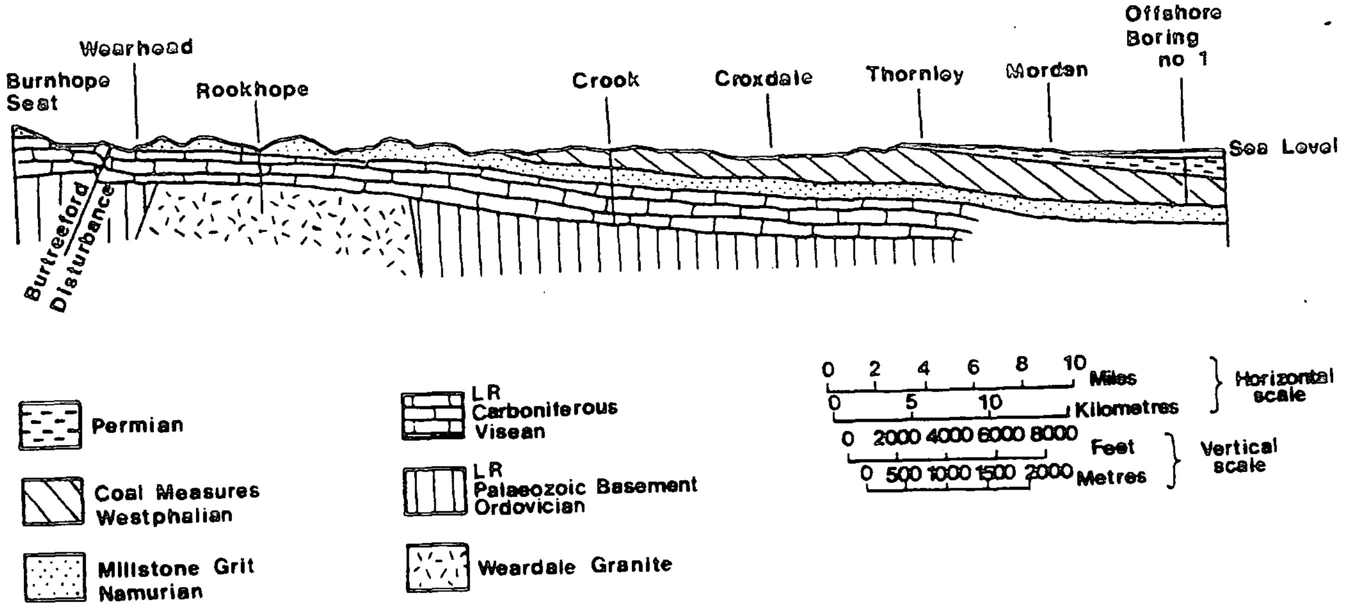
Geology has a substantial impact on land use patterns, because a strong correlation between geology and soil properties exists. In County Durham, the rocks of the Upper Carboniferous and Permian age are the main rocks which underlie the region fig (1:3). The present geological position of the County was a result of the tectonic evolution of North England which has been affected by three major periods of earth movements (Beaumont 1970).

The geological structure of the region is exerted in the hardness of the rocks and their resistance to erosion. Soft shales and poorly cemented sandstones of the Permian and Triassic generally outcrop in valleys; and unrestricted shales of the coal fields from relatively low ground relieved by a subdued escarpment formed by the thicker sandstones (Taylor et al. 1971).

According to Beaumont 1967, the coal measures in the county are divided into three divisions; Lower, Middle, and Upper coal measures. The thickness of these coal measures is of 2000 ft. and have mainly the dark grey colour.

The soil of County Durham has been affected by the geological strata of the Permian. The Permian consists mainly of the Lower Magnesian Limestone, Marleslate, and Basal Sands Strata (Johnson, 1970). In the Eastern Region, a composite of glacial deposits is found , while on the Permian Plateau a single till sheet with associated gravel is visible. (Beaumont 1967, Brown 1978).

Figure (1:3): Horizontal Geological section shows the major strata structure of the County.



Source: Johnson (1970), in S.S. Shueb thesis (1990).

1.3 Topography

The topography of the County includes a range of altitude from the highlands in the western part (more than 2400 ft) to the lowlands in the east at the mean sea level. The highest point in the County is the Burnhope Seat with an altitude of 2452 ft in the extreme west of the County.

In County Durham, four topographical and geomorphological regions can be identified:-

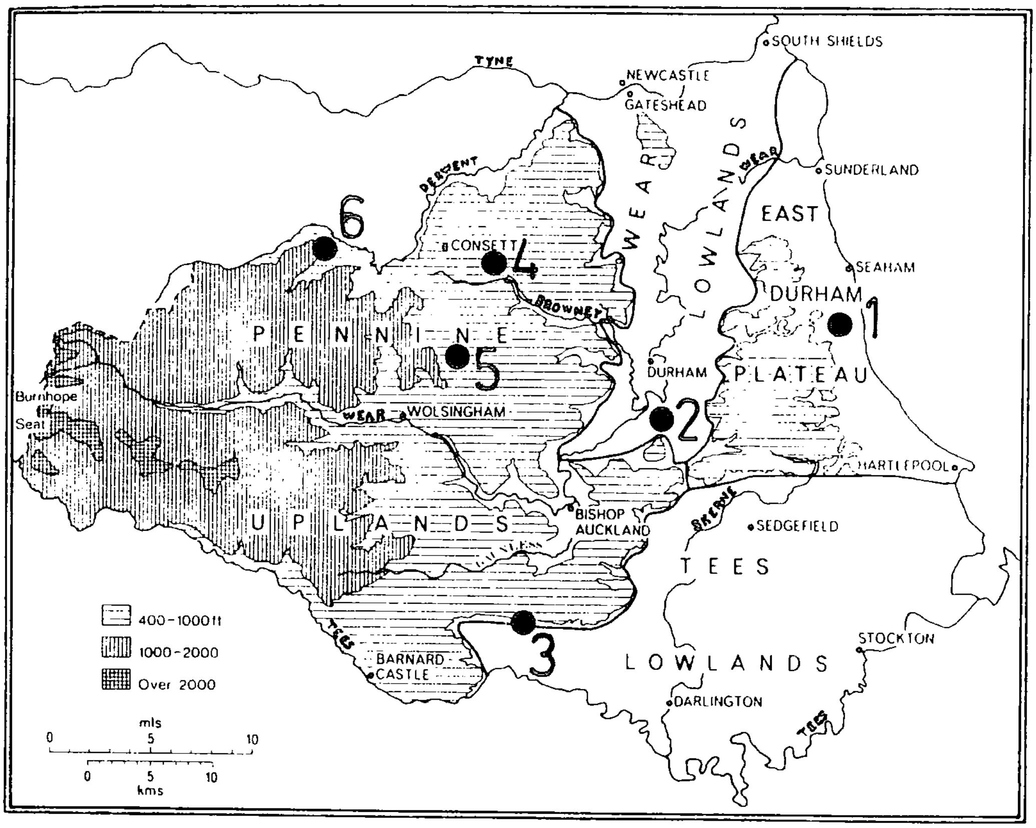
1. ***The Pennine Uplands*** is the largest area of the region and covers the western part of the County . It dips gently towards the east. Most drainage in the area is by the River Wear, with the catchments of the River Derwent in the north and the Tees in the south.

2. ***The Wear Lowlands*** is in the north-east area of the County where the Pennines dip gently to below 400 ft. The maximum length of this area is 24 miles and the maximum width is 8 miles.

3. ***The East Durham Plateau*** is to the south-east of the Wear Lowlands. The western ridge of the plateau is of about 200 ft; overlooking the Wear Lowlands. This ridge has a maximum altitude of 715 ft in the extreme south-west, but elsewhere the highest elevation is between 500-600 ft. The elevation of the ridge decreases northwards, descending from about 600 ft to 50 ft. Drainage lines in the coastal areas becomes more incised, and in some cases more than 200 ft below the general level of the topography.

4. ***The Tees Lowlands*** are to the south-east of Durham Plateau . All land there is below 400 ft. Drainage of the area is mostly via the River Skerne in its journey to meet the Tees south of Darlington. Topography here is extremely flat and the drainage is poor, so the land is marshy in many places.

Figure (1:4): Location of the study areas on the topographical map of County Durham.



Source: Beaumont, 1970

1.4 Climate (most of this section is derived from Smith, 1970)

The climate of County Durham is cool and cloudy. It changes from the east to the west. The climate of the County is to a great extent determined by two physical elements, these elements are:-

(a) The North Sea in the east.

(b) The Pennines Uplands in the west.

These two factors affect the climate, especially the amount of precipitation and the temperature which in turn affects the general land use characteristics of the County.

1. ***Wind:***- The prevailing winds over the County are south-westerlies. They represent about 60% of the total wind frequency in the area. The mean speed of the wind is to a great extent a reflection of three elements:- **(a)** Altitude, **(b)** Location, and **(c)** Season.

The frequency of strong gales on the eastern coast is much less than that of the western coast, at about five times a year. On the other hand, gales occur throughout the year on the Pennine Uplands. Local topography affects conditions of the wind in many ways; a certain amount of the deflection wind is found along the eastern coast, where Tynemouth experiences southerly airflow. The Pennine Uplands have their own wind system, and the direction of the Dales causes some funnelling of the westerly winds. In the Lowlands of County Durham; the local winds are usually accompanied by sea breeze effects.

2. ***Temperature:***- The mean annual temperature in the County is low, and this is due to a number of factors:- **(a)** The northern latitude.

(b) The coolness of the nearby North Sea.

(c) The increasing altitude westwards.

The temperature range is not large; the maximum temperature for any year may occur at any time from May to September. Also the minimum temperature may occur at any time from October to April. The most important factor that affects the temperature pattern in the County is the Pennine uplands, where the increase in altitude causes a reduction in the daily range of temperature.

From an agricultural point of view, the most important characteristics of temperature are:- (a) The occurrence of frost. (b) The length of the growing season.

The length of the growing season in County Durham varies substantially from one region to another. It is of about seven and a half months in the Lowland areas in the east, but in the areas which are over 500 m it is only five and a half months. Ground frost is most likely to occur in the months of January and February.

In addition to frost, human activities affect land use. In the last century much of the uplands witnessed important changes in land use, such as the construction of water supply reservoirs and afforestation. These man-made activities affected local microclimates, and urbanisation also influenced the characteristics of local climate (the heat-island phenomenon).

3. ***Precipitation:-*** Precipitation in County Durham increases with altitude, so the precipitation gradient is steep (fig.1:5). The annual average in coastal areas is about 650 mm, while in the uplands of Weardale and Teesdale it is about 1650 mm. The Pennine barrier provides an efficient shelter for the County. Thus the total precipitation on the slopes of Cross Fell (10 km to the west of the County) is of some 635 mm higher than that of both Weardale and Teesdale.

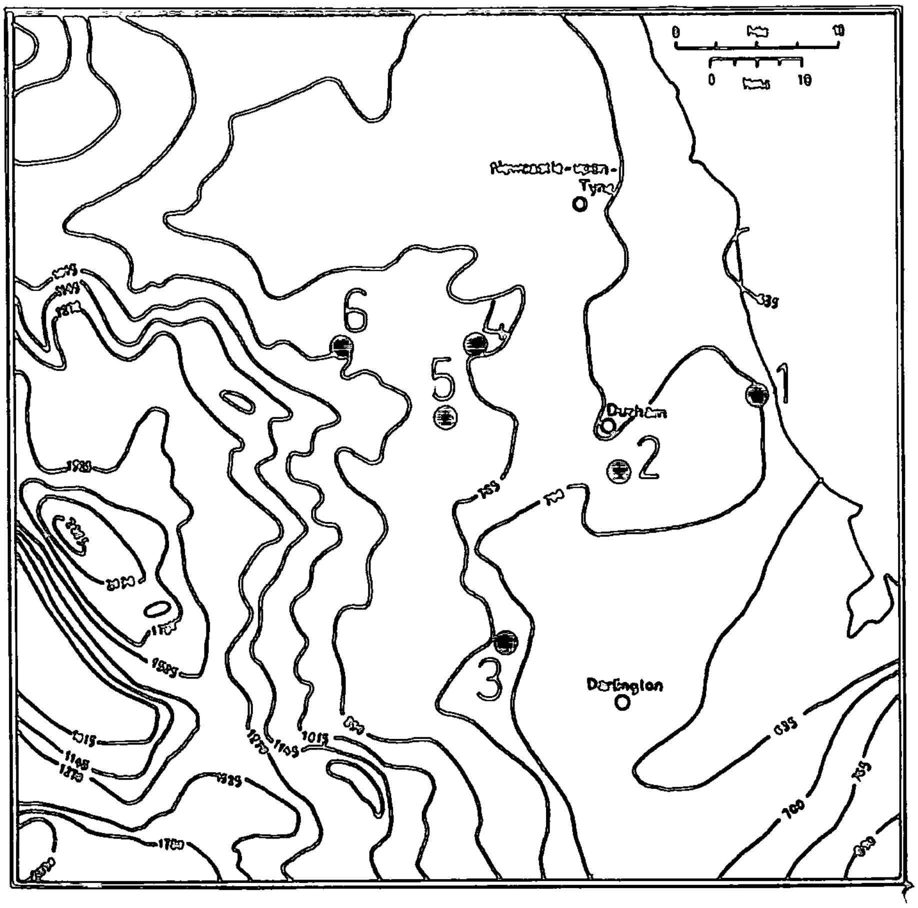
Despite the fact that the North Sea represents a secondary source of moisture in the area, the lowest parts in the region remain among the driest areas in Britain. Precipitation over the County is well distributed throughout the year, and this, of course, reduces the probability of prolonged periods of drought. It is noticeable that February and March have less precipitation despite the frequent showers of snow during these two months.

Snow is a remarkable characteristic of the climate in County Durham, and the heaviest falls comes with the northerly and the easterly winds which blow from the North Sea. This combines with an orographic effect up the exposed eastern dip-slope of the Pennines to make the upper parts of the Weardale and Teesdale reputedly one of the snowiest areas in England.

4. ***Sunshine, Cloud, and the Quality of the Atmosphere:-*** County Durham as an extension to the eastern coast does not receive the same amount of sunshine as the western coast areas which lies on the same latitude. This due to the " haar " of the North Sea which is a notable feature of the climate of Durham. The mean annual sunshine recorded by the Durham University Observatory is about 20 hours more than the coastal areas. Despite this slight increase of the sunshine inland, the main trend of the region is that it decreases towards the west.

The values of relative humidity show an increase with altitude, and for most of the year, readings at Moor House are in excess of 90%. There is very little fog over the area as a whole, and this due to the prevailing breeziness, but the incidence of fog increases with urbanisation and industrial pollution of the atmosphere.

Figure (1:5): Location of the study areas on the map of the mean annual precipitation, 1916-1950, of County Durham.



Source- K. Smith (1970).

1.5 Soil (most of this section is derived from Atkinson, 1970)

The type and distribution of soils are important in determining land use activities. Everywhere, formation of soil is controlled by a number of factors; these factors are:-

1. *Climate*
2. *Botanical Factors*
3. *Parent Material*
4. *Relief*
5. *Time*
6. *Humans*

The climate through its elements, especially precipitation and temperature has a fundamental effect on the formation of soils. In County Durham, the uplands in the west receive a total annual precipitation of about 1650 mm, and a mean of about 700 mm in the lowlands in the east. This means that the soil of the whole area is exposed to a process of continuous leaching and a loss of some of its contents such as minerals, so the properties of soils are in a state of continuous change.

Temperature in the County decreases with increasing altitude, and is not only important for the growth of crops, but also for the biological fertility and dynamism of soils. The uplands are poor in terms of organic matter decomposition and nutrient release compared with the lowlands.

The effect of parent material and topography on the soil formation is important locally. The large range of rock types underlies the soils, starting from the shales and clays to sandstones. Lithology controls the major soil groups in the County and reflects the characteristics of the soils (see figure 1.6).

A well defined hydrological sequence can be observed along the slopes in the central and eastern parts of the County. The freely drained soils occupy the flanks of the slopes, while the soils of imperfect drainage exist on the lower slopes. Freely or imperfectly drained soils occur on the interfluves, with poorly drained soils in topographic hollows.

Human influence on the formation of soil is strong in the lowlands of the County. Artificial drainage has improved the poor drainage status of soil especially in the flat topographical areas, while the nutrient status has been improved by the addition of fertilisers and liming. In areas of active open-cast coal mining pedogenesis has been influenced. In the Pennines the influence of people is weak because human activities there are limited.

The effect of the above-mentioned factors can be measured by time. The longer and the more the soil is exposed to these conditions the greater the effect on its formation. The efficiency of each factor varies from one geographical region to another. For example, the botanical factors affect soil formation more in the hot humid environment than in the cold dry one, and high temperature is more efficient in the humid vegetated environment than in the dry barren environment and so on.

1.5.1 Soil patterns in County Durham

To facilitate the recognition of the different types of soil in the County, the County can be divided into four major units.

1. *The Pennine Moors and Dales of West Durham.*
2. *The Wear Lowlands and North-West Durham.*
3. *The East Durham Plateau .*
4. *The Lowlands of South and South-East Durham.*

1. *The Pennine Moors and Dales of West Durham*:- This includes the northern part of Teesdale, the whole area of the Wear catchment, limited areas of the upper Derwent and the upper Burn Hope rivers . In this region many types of soils can be recognised:-

(a) Blanket Peat on the high ground of the Pennines.

(b) Peaty Gley Soil; it exists on the ground of the upland peat .

(c) Surface Water Gley Soil below the peaty gleys at an altitude of less than 431m.

(d) Ground Water Gleys or Basin Peat; it exists along the lands of dales.

(e) Podzols are the typical soils of the dry Calluna and heath lands.

(f) Brown Earths exists on lower sites, particularly on lower slopes.

2. ***The Wear Lowlands and North-West Durham:-*** This region is drained by the rivers Derwent, Wear and its tributary the Browney. These are separated by interfluves of about 246 m of altitude to the west of the area. Although being underlain by Carboniferous rocks, the whole area has been covered by a mantle of glacial drift. Most of this is heavy textured till with smaller areas of coarse textured fluvio glacial sands and gravels. These textural differences together with topography play a key role in determining soil drainage and hence soil type. The heavy textured till in the lowlands give rise to poorly drained Surface Water Gley soils which form the bulk of the agricultural soils of this sector. On the slopes of the interfluves, the soils are better drained Brown Earths of Low Base Status. Similar soils have developed on the coarse textured fluvio-glacial deposits, although where coniferous woodland is present Humus Iron Podzols have developed. Along the alluvium in the floor of the major river valleys Ground Water Gleys predominate.

3. ***The East Durham Plateau:-*** Topographically, the area consists of a dissected plateau of about 120 m altitude in its middle. On the high knolls limestone outcrops at the surface giving small areas in which Rendzinas have developed. In the areas of rolling relief the limestone is covered by varying thickness of till. On shallower sites Brown Earths of High Base Status prevail, where the till is deeper and has been leached Brown Earths of Low Base Status dominate. Although these soils are very fertile, the shallow variants are very droughty.

4. ***Lowlands of South and South-East Durham:-*** Soil types in this area reflect the parent material, and there is little topographic variation. The soil drainage is affected by two main factors: the texture of the subsoil, and the relative topographical location. The areas of poor drainage status are given over to pasture. Brown Earths with a low base status develop in the areas of better drainage and are derived from the Carboniferous Sediments. Carrs and Basin Peat Soils are limited in occurrence and extent. Riverine alluvium has mainly been deposited by the River Tees in its lower course. Much of this alluvium is of a heavy texture, so is poorly drained. The alluvium of light texture is also poorly drained because of the low-lying nature of the area which contains a high water

table, and this of course has affected the utilisation of these soils. River terraces have much gravel, giving free drainage and so supplementary irrigation is required in summer months. Limited areas of Warp Gley Soils occur along the coast north of the Tees estuary, and they are very poorly drained. Along the coast there is a small dune sand area, and this is subject to wind action affecting neighbouring areas.

1.5.2 Land Classification

The first attempt to assess the soils of County Durham was made in 1950 by The North East Development Association. The soil had been divided into three grades, gradel, grade 2, and grade 3. Only 15% (80,000 acres) of the County was classified as grade 1, 55% was classified as grade 2, and the rest which is mainly concentrated in the western part and some areas in the east was classified as grade 3.

Another soil classification was carried out by The Agricultural Land Service. In this classification; 5 grades were made. Most of the County was classified as grade 3, while none was classified as grade 1. These classifications emphasise the effects of the physical characteristics of the County.

The capability of soil in the County has been affected by a number of factors. These factors are:- **(a)** The soil drainage status; this factor affects the growth of crops by the adverse relationship between air and moisture in soil. Poorly drained soils such as the Carrs Soils are classified by the ALS as grade 4 or 5, while the top soils which are deep and freely drained and have a sufficient moisture offer a suitable environment for root growth; these soils were given the grade 2. The freely or excessively drained soils tend to be down graded because they suffer from a lack of moisture and need supplementary irrigation, especially during the summer months. It is clear that the majority of the agricultural soils are either imperfectly drained Brown Earths or Surface Water Gleys. The limitations imposed by poor air/moisture relationship are reflected in the dominant soil capability class of grade 3.

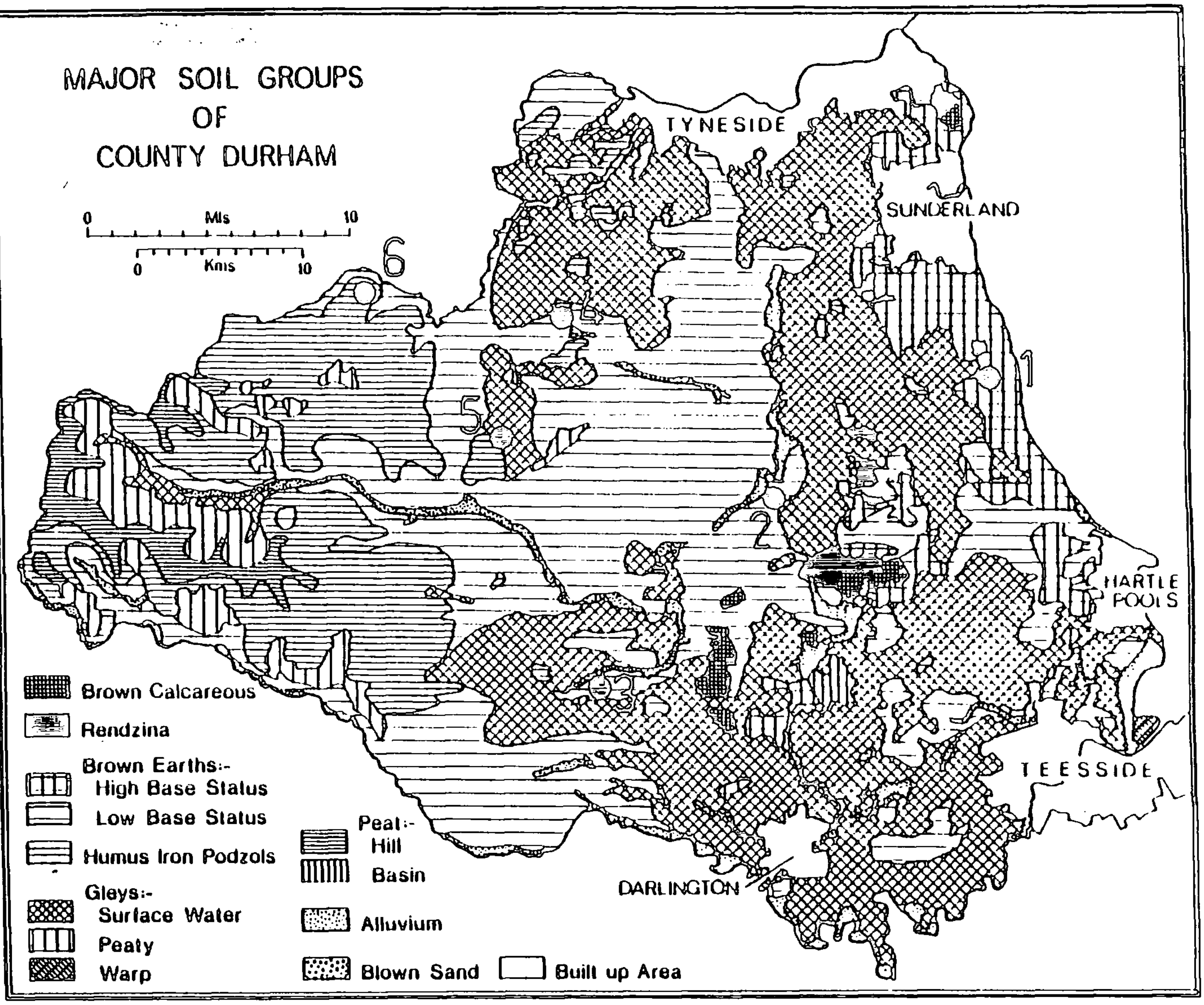
(b) Stoniness and Soil depth. This factor is important in The Magnesian Limestone Scarp, the plateau and some ridge tops in north-west Durham.

(c) Altitude; it affects soil capability especially in County Durham through its fundamental effect on the climate of the County, especially rainfall and temperature.

(d) The Nature and Type of Slope. Gentle slopes offer a balanced relationship between air and moisture in soils and do not expose soil to erosion, while steep slopes not only affect the erosion potential of the soil, but also hamper the mechanical operations involved in cultivation. The nature of slopes (convex or concave) affect soil drainage.

(e) Human Activities; such as quarrying and open-cast mining reduce the quality of soils and affect the topographical characteristics of the area.

Figure (1:6): Location of the study areas on the soil map of County Durham.



Source:- Stevens and Atkinson (1970).

1.6 Agriculture

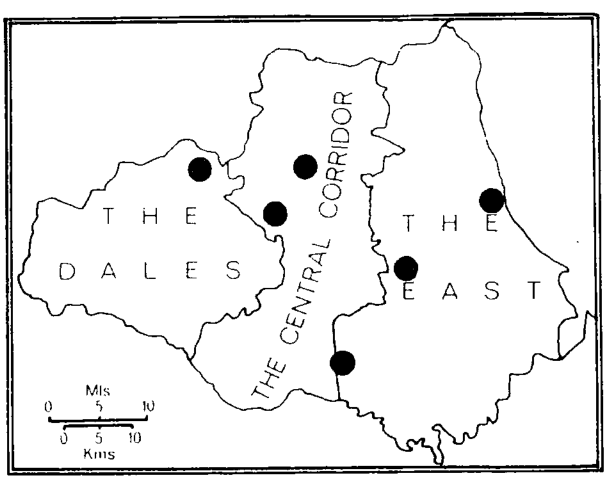
More than 50% (350,000 acres) of the total area of the County is given to crop and grass cultivation, and about 17% is in rough and common grazing. The majority of the latter area is concentrated in the upland region.

The eastern region which mainly consists of Coastal Plain, Tees Lowlands, and the Magnesian Limestone is flat if compared with other regions of the County. The central region is more varied in its relief, and extends to the lower slopes of the Pennines.

Soils of the County vary regionally; most soils in the eastern and central regions are of a medium to heavy texture. These two regions are the main agricultural regions in the county. Agriculture in these regions is affected by two factors:- **(a)** The bad natural drainage which is resulted from the soil quality; **(b)** subsidence, which results from mining activities in the area. In the Dales, the soil is thin because of the continuous erosion process.

In addition to these physical limitations, human activities through urbanisation have had diverse effects on the agricultural area and the number of crops types suitable for the area.

Figure (1:7): Location of the study areas on the map of agricultural main regions of County Durham.



Source: Dewdney, 1970

1.6.1 Types of Farms

Farms in County Durham can be classified by region. Three main regions can be recognised:-

(a) The Dales Region:- In the western dales two types exists; *Sheep Farms and Cattle Farms Producing Sucklers*, while in the lower dales *Livestock and Small Dairy Farms* exist.

(b) Central Region:- In this region *Dairy Farms, Stock Rearing, Cereals, and Seed Potato Production are found.*

(c) East Durham Region:- Four types of farms exist in this region: *Cereals, Potatoes, Milk Farming, and Beef Farming.*

It can be seen from this spatial distribution of farms types that there is a polarisation between arable farming in the eastern region and the livestock farming in the dales region. In the central region, both arable and livestock farming are found. This reflects the effect of topographic variations of this region on land use.

The crop calendar for County Durham shows that arable crops are sown in two seasons; autumn and spring (winter crops and spring crops). The separation of sowing between them is about six months, while the separation of harvesting is only one month. Despite the fact that spring crops stay in fields only five to six months, it is not possible to sow more than one crop a year because of climatic limitations. This fact requires more invistigation and study of the economic advantages of winter cropping. A comparison between the two types is carried out in table (1:2):-

Table (1:2): Comparison between winter crops and spring crops

No	Winter Crops	No	Spring Crops
1	It stays in field between 9-11 months	1	It stays in field 5-6 months.
2	It needs more weedkiller spraying	2	It does not need weedkiller spraying.
3	It has high probability to be diseased	3	It has low probability to be diseased.
4	Ground frost is more frequent.	4	Ground frost is less frequent.
5	It is more exposed to flood damages	5	It is less exposed to flood damages.
6	It needs more labour.	6	It needs less labour.
7	Early wet winters hamper cultivation.	7	Soil gets dry faster.
8	It produces more hay.	8	It produces less hay.
9	Soils exposed during winter	9	Soils not exposed during spring
10	It is harvested in July and August.	10	It is harvested in August and September

Table (1:3):- The crop calendar for County Durham

No	Crop	J	F	M	A	M	J	J	A	S	O	N	D
1	Winter wheat								H	H	S	S	
2	Winter Barley							H	H		S	S	
3	Spring Wheat				S					H			
4	Spring Barley				S				H	H			
5	Oilseed Rape					F		H		S			
6	Potatoes					S				H	H		
7	Swedes+Kale							H	H		S	S	
8	Sheep Rape									H	S		
9	Linseed									H	S		
10	Oats									H	S		

S: Sowing **H: Harvesting** **F: Flowering**

1.6.2 Agricultural Change

It can be seen from table (1:4) that the main agricultural change in County Durham between the years 1981-1992 was in **oilseed rape, cereals, and improved grass.** Table (1:4a) shows that the cumulative area of wheat and barley in both dates is almost equal. This indicates that the area of cereals did not change, but that change is only from one type of cereal to another (in this case the change is from barley -50% to wheat + 162%). This change is not necessarily a new trend of land use in the County and can be a matter of crop rotation (wheat-wheat-barley-oilseed rape). It can be seen also that the area of oilseed rape increased drastically through this period (+764%) and became one of the major land use patterns in County Durham. The insertion of new crops develops the soil, because each type of crop interacts with soil in a different way. This variation of soil-crop interaction renews the soil dynamism. Table (1:4a) shows that the areas of horticultural crops, potatoes, and crops for stockfeeding are relatively small in both dates, and there is a substantial reduction of their area (-75%, -42%, -33% respectively). The reduction of the area of horticultural crops is due to their intensive labour requirements, and their sensitivity to ground frost which has a high frequency in the county, while the reduction of the potatoes area due to the restrictions of soil quality in this region, especially in the lowland area of the eastern region. The reduction of the area of stockfeeding crops is because they need more labour than grass. A substantial increase in the area of grass occurred from 1981 to 1992 (+33%). This grass area increase refers to a shift from intensive farming to extensive farming. In general, land use changes in the county between 1981 and 1992 shows a competition between arable crops especially oilseed rape and grass on other types of agricultural crops especially those that need intensive labour.

Table (1:4a): Agricultural change in County Durham between 1981-1992 (ha)

Crop Type	1981	1992	% Change
Wheat	8,020	21,039	162
Barley	26,823	13,425	- 50
Oilseed Rape	812	7,014	764
Horticultural Crops	570	140	- 75
Potatoes	1,479	865	- 42
Crops for Stockfeeding	1,347	899	- 33
Grass	80,643	107,112	33

Table (1:4b): Type of farms change between 1981-1992 (ha)

Farm Type	1981	1992	% Change
Dairying	22,580	14,369	-36
Cattle and Sheep	73,340	82,605	13
Cropping	51,374	54,153	5
Pigs and Poultry	4,191	1770	-58
Horticulture	306	207	-32

Source: MAFF, 1981, 1992

1.7 Conclusion

The location map of the study areas shows that the major agricultural regions in County Durham are represented. So, results of this study should reflect not only land use trends of the chosen parishes, but also the general land use trends in the County as a whole. Physical characteristics, through climate, soil, and topography controls the spatial distribution of farms types which reflects the general land use status. Despite the climatic limitations, it is possible to sustain arable crops in winter in addition to spring. This significant development in land use status of the county requires more geo-economical studies. The agricultural change in the county between 1981 and 1992 shows a shift in land use from intensive farming to extensive farming.

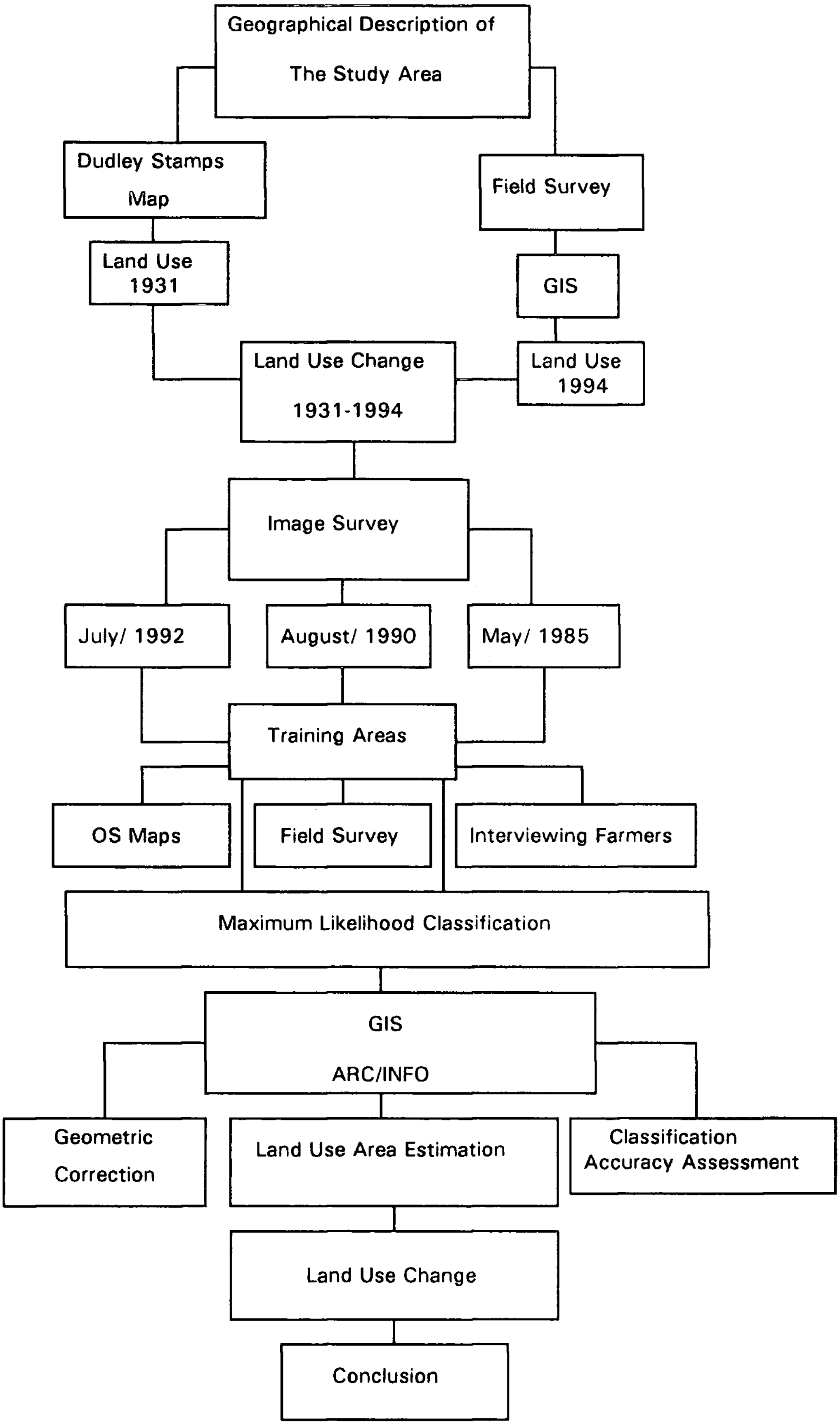


Figure (1:7): Flowchart for the research project

CHAPTER 2

Chapter 2: Land Use Change of the Study Area by Map Measurement and Field Survey Methods (1931-1994)

2.1 Introduction

There is no doubt that the present is an extension to the past, and will be in part a determinant of the future. We therefore wish to take into account historical land use change in order to understand the development of farming in County Durham. For this purpose, a study of the land use survey of 1931 for the study area will be carried out. This study is based on map measurement, and the results are compared with the results of our land use survey in 1994. The latter is completely based on field work. This comparison gives an indication of land use trends in the study area over a sixty year period.

2.2 Previous Land Use Surveys

After the first world war in 1918 and the significant damage left by this war; especially in Europe, European countries including Britain had started to remanage their natural resources. Land use survey is a basic step to understand the existing resources to plan for future. In the 1920s and 1930s the hard economic situation, and socio-economic changes following the war forced the British Government to update its land use information. So, the first land use survey in Britain was launched in October 1930, with the aim of producing a complete cartographic record of the uses of the 'surface of the country' in 1931-1933 (Stamp, 1932). The survey is linked with the name L. Dudley Stamp and with the aid of thousands of volunteer schools to work out a national scheme of land use categories. Each land parcel was categorised under one of nine basic land use types (Fuller et al., 1994). The second world war in 1939 created difficulties in the way of this survey, so it is incomplete. After the end of the second world war, Britain was preoccupied by amending the damage of the war, which was more harmful than that of the first world war. In the 1950s and 1960s, the British Government had started again to update its land use information. This survey is initiated by Alice Coleman and aimed to repeat the first survey but with more detailed classification. The increased cost prevented the publication of a complete cover for Britain and only 120 sheets of this survey were printed. Apart from limited individual projects of land use surveys, only these two major land use surveys have been carried out.

2.3 Land Use of the Study Area in 1931

In this study, Dudley Stamp's original land use map is used. Some of the original land use information of this map is of the nineteenth century. In 1930s it had been revised and updated using aerial photography.

Method Of Study:- The following steps were followed in this study:-

(a) The study is completely based on map measurements. Ordnance Survey maps of scale 1: 63360 were used. The following land use classes were used in this study:-

1. Woodland **(WL)** (Deciduous, Coniferous, and Mixed Woodland).
2. Arable Land **(A)**; including fallow, rotation grass, and market gardens.
3. Meadowland and improved permanent grass **(IG)**.
4. Moor and heathland, common and rough pasture **(M+H)**.
5. Built-up Areas **(U)**.
6. Roads and Railways **(R+R)**.
7. Quarries **(Q)**.
8. Water Bodies **(WB)**.
9. Sand and Gravel **(S+G)**.

(b) A map of administrative boundaries of the same scale of the land use map was laid over the land use map.

(c) Two methods were used in polygons area measurements:-

1. Planimeter Measurements. In this method each land use class area was measured twice then the average of the two measurements was taken. This method was applied for the relatively larger polygons.

2. Millimetric Grid Measurements. In this method a transparent millimetric grid was laid over the land use map and the squares in each polygon were counted and converted to metric measurement units. This method was applied for the relatively smaller polygons such as the scattered built-up areas.

(d) The metric land use classes areas were converted to hectare areas (ha), 1 ha = 10,000 m^2.

Table (2:1): Land use of the six study areas for the year 1931 (%)

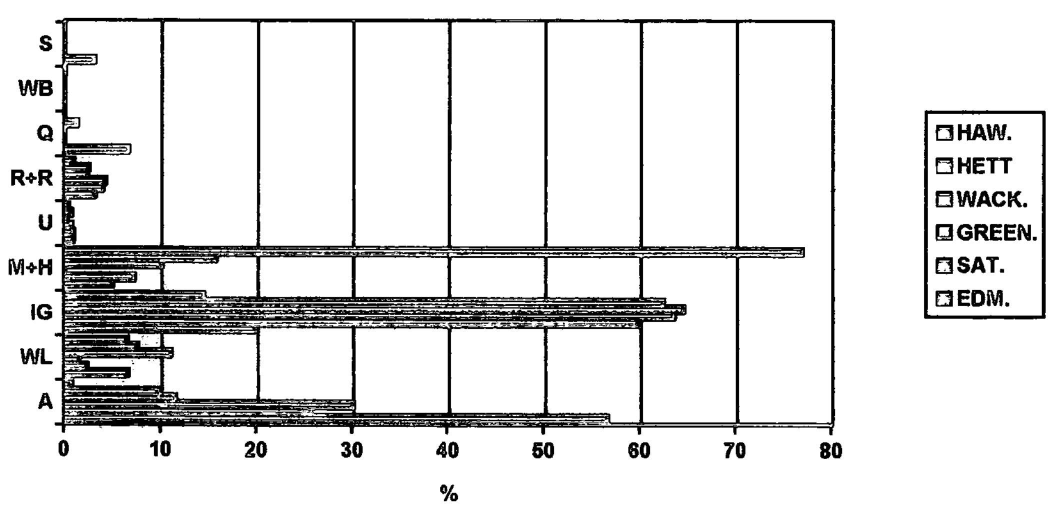
(details of individual parishes are shown in appendex A)

No	S.A	A	WL	IG	M+H	U	R+R	Q	WB	S	T%	T.ha
1	Haw.	56.57	6.6	19.79	4.99	0.92	3.17	6.7	-	3.1	100	577.24
2	Hett	25.65	2.34	59.85	7.28	0.89	3.99	-	-	-	100	505.31
3	Wack.	30.03	1.52	63.52	-	0.7	4.23	-	-	-	100	303.65
4	Green	11.55	11.08	64.52	10.10	0.34	2.41	-	-	-	100	678.88
5	Sat.	9.72	7.59	62.42	15.76	0.7	2.49	1.31	-	-	100	1354.72
6	Edm.	0.7	6.5	14.5	76.92	0.38	0.97	-	0.03	-	100	2064.06

S.A = Study Area, T = Total, Haw. = Hawthorn, Wack. = Wackerfield, Green = Greencroft, Sat. = Satley, Edm. = Edmundbyers,

T = Total

FIG (2:1) : LAND USE OF THE SIX STUDY AREAS FOR 1931

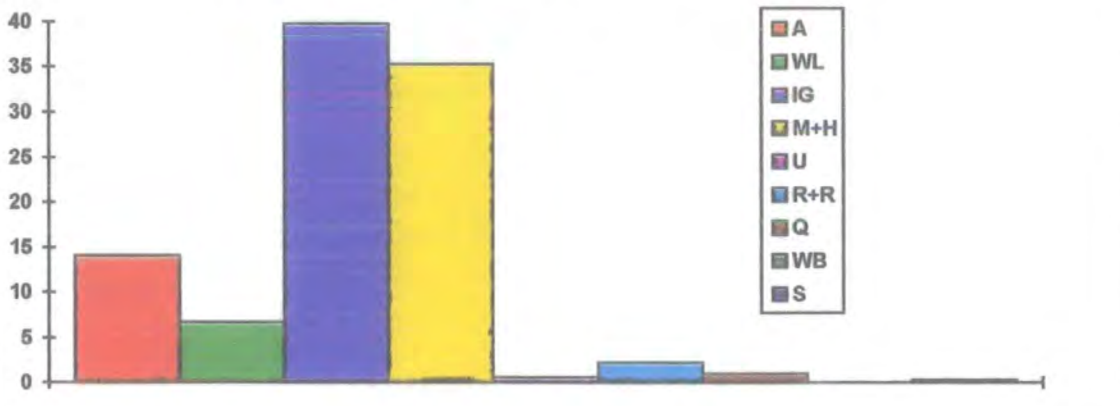


Details of individual parishes are included in appendix A.

Table (2:2): Total land use of the study area for the year 1931.

No.	Land use class	ha	%
1	Arable land	771.91	14.08
2	Woodland	369.25	6.73
3	Improved Grass	2181.94	39.78
4	Moor and Heathland	1936.12	35.3
5	built-up areas	31.61	0.58
6	Roads and Railways	121.53	2.22
7	Quarries	56.42	1.03
8	Water Bodies	0.58	0.01
9	Sand	17.89	0.33
	Total Area	5483.86	100

FIG (2:2) : TOTAL LAND USE OF THE STUDY AREA FOR THE YEAR 1931



2.4 Land Use of the Study Areas in 1994

2.4.1 Ordnance Survey maps:- The fieldwork took place in February 1994. Ordnance Survey Maps of different scales were used to carry out this study. **(a)** An administrative boundaries map at a scale of 1: 100,000 was used to define and separate the administrative boundaries of the parishes of interest.

(b) A road map at a scale of 1: 50.000 was used to get to the study areas. **(c)** Large scale maps (1: 10,000) were used for the purpose of field mapping of the relatively smaller parishes, and maps at a scale 1: 25,000 were used for the larger ones. Both have the limits of the fields clearly marked.

2.4.2 Method of Land Use Mapping:- Each field in each study area was visited and labelled on the Ordnance Survey map according to its actual land use/land cover type. The labels took the form of numbers and letters;e.g, the areas covered with coniferous wood were given the number 5 and the letters CW, while the areas covered with deciduous wood were given the number 4 and the letters DW. This process was repeated for all land use types. A field book was used for special notes and geographical phenomena of interest (details of land use in individual parishes are given in the appendix B).

2.4.3 Land Use Classes Included in Classification

No	*Land use Classification*	*Annotation Key*
1	Arable Crops (Wheat and Barley)	A
2	Improved Grass	IG
3	Oilseed Rape	OSR
4	Stubble	S
5	Mixed Woodland	MWL
6	Deciduous Woodland	DWL
7	Coniferous Woodland	CWL
8	Kale	K
9	Unimproved Grass	UG
10	Improved Grass + Deciduous Woodland	IG+DWL
11	Unimproved Grass + Deciduous Woodland	UG+DWL
12	Unimproved Grass and Coniferous Woodland	UG+CWL
13	Ploughed and Sown Land	P+S
14	Ploughed Land	P
15	Moor land	M
16	Bare Soil	BS
17	Bare Soil+Quarries	BS+Q
18	Sand and Gravel	S+G
19	Roads	R
20	Roads and Railways	R + R
21	built-up Areas	U
22	Water Bodies	WB

2.4.4 Agricultural Crops Discrimination

The ability to discriminate different types of crops varies from one type to another, and by the stage of growth of the crop. Crops of similar appearance require more effort and concentration. The following notes were recorded during the fieldwork :-

(a) It was possible with ease to discriminate between *deciduous and coniferous woodland*, because at this time of the year (February) deciduous tree leaves have dropped off.

(b) It was easy to discriminate between *improved and unimproved grass*, because they had different texture, colour, height and general appearance.

(c) The discrimination between *arable crops (wheat and barley) and improved grass* was more difficult, because at this time of the year they have similar appearance. To overcome this problem, more than one measure was taken into account:-

1. Texture; the texture of grass is rougher than that of arable crops. 2. Density; grass is denser than arable crops. 3. Height, grass is generally shorter. 4. Number of leaves; grass has more leaves than arable crops. 5. position of leaves opening; grass leaves open at a lower height. 6. seeds; seeds of grass are different from those of arable crops. 7. The strength of roots; roots of grass are stronger. 8. leaves; leaves of grass are thinner.

(d) The discrimination between *wheat and barley* was the most difficult task; they are of □a very similar appearance, so great care is required. For this purpose, more than one measure was used:- 1. seeds; at this stage of growth, seeds are still connected with the roots, so one or more seed plant can be checked. 2. Colour of leaves; there is a slight difference in colour between wheat and barley. Wheat leaves have a dark green colour, while barley leaves are lighter. This is because barley does not need as much water as wheat, and consequently the absorption by barley of minerals, especially iron, and nitrogen, is less than that of wheat. Barley also has a greater resistance to aridity and poor soil conditions. This measure should be taken with great care, especially in the areas of different soil types, different fertility levels, different topography conditions and different levels of illumination.

2.4.5 Integration of the Field Data into a Geographical Information System (GIS)

Following data collection and the construction of field maps the information was integrated into ARC / INFO by the following procedure:-

1. Digitising:- The administrative boundaries, field limits, and the co-ordinates of each study area were digitised using the ARC / INFO system. Other coverages such as contour lines, drains, roads...etc were digitised for further analysis purposes.

2. Labelling:- Each polygon on the digitised maps was labelled with a number which represents the actual land use class resulting from the field work.

3. Co-ordinates Transformation:- This is often used to convert the digitised coverage units (in this case inches) into the real world units which are represented on the digitised map (metres). These maps are represented by a certain projection. In this case the projection is UK National Grid.

4. Cleaning and Building:- Each map was cleaned of the errors which were introduced during digitising. These errors are usually of two types; (a) over shooting errors (b) under shooting errors. The Clean command corrects errors in the polygon and arc-node topology. The Build command creates feature attribute information (PAT, AAT) for each polygon or arc. Build is similar to clean, the difference between them is that Clean uses fuzzy tolerance and Build does not. So, clean can detect and create intersections and build can not. This means that by using build it is not possible to adjust the coordinates without having the coverage cleaned.

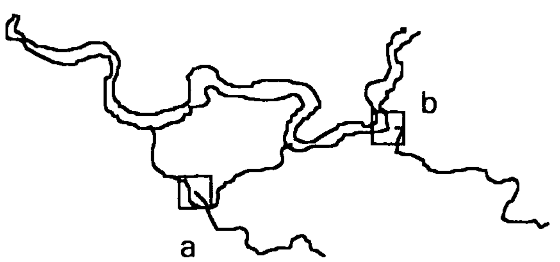


Figure (2:3): Types of digitising error

After having the coverages cleaned and the polygons and the arcs built, the Polygon Attribute Tables (PAT), the Arc Attribute Tables (AAT), and the Point

Attribute Table (PAT) can be used for further analysis. The Polygon Attribute Tables give information about each polygon in the coverage such as its area, label, and land use. The Arc Attribute Tables describe each line in the coverage such as its length and its class. The Point Attribute Table describes the points in the coverage, e.g. the spot heights and the ground control points. It gives information about their co-ordinates and class.

5. Small Micro Language File:- The creation of this file is necessary to have the coverages represented cartographically. This file contains the land use classes and their selected colours, the title, the north arrow, the scale bar and any other required information.

6. Key File:- This is the last stage of the GIS preparation for having the coverages ready to be plotted as a land use map. More than one coverage can be contained in one map, and more advanced analysis can be done using the GIS capabilities.

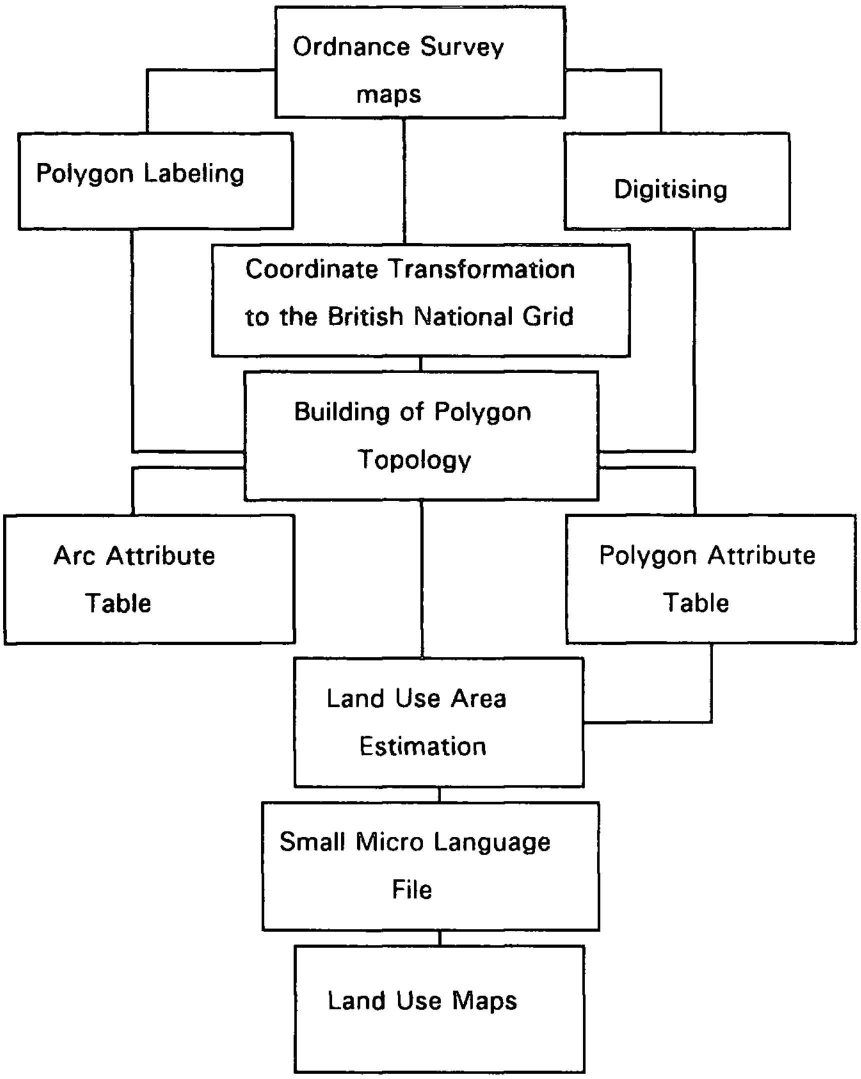


Figure (2:4): Flowchart of field data integration in a GIS (ARC / INFO)

Table (2:3): Land use of the six study areas for the year 1994 (%)

Class	Hawthorn	Hett	Wack.	Greencroft	Satley	Edmund.
A	21.1	25.1	18.5	8.8	3.09	-
IG	48.8	32.4	32.8	73.7	75.82	8.8
OSR	3.5	8.8	9.3	-	0.61	-
K	-	-	1.1	-	-	-
S	O.3	11.1	19.4	-	1.62	-
MWL	6.6	0.2	-	0.2	0.38	2.9
CWL	-	0.1	1.3	0.2	3.08	1.7
DWL	0.1	2.0	0.2	8.0	3.23	1.5
UG	0.4	1.6	1.3	2.2	2.31	24.3
IG+DWL	-	-	-	0.2	-	-
UG+DWL	-	-	-	1.8	-	-
UG+CWL	-	-	-	0.5	-	-
M	-	-	-	-	-	51.3
WB	-	0.1	-	0.1	-	8.0
P+S	2.4	4.5	11.2	-	3.29	-
P	0.6	6.6	-	0.7	2.0	-
BS	-	2.6	-	0.1	-	-
BS+Q	6.7	-	-	-	1.31	-
S+G	3.1	-	-	-	-	-
R	-	-	4.2	2.4	2.49	1.0
R+R	4.7	3.9	-	-	-	-
U	1.7	1.22	0.7	1.2	0.76	0.5
TOTAL%	100	100	100	100	100	100
ha	577.24	505.3 1	303.65	678.88	1354.72	2064.06

FIG (2:5) : LAND USE OF THE SIX STUDY AREAS FOR THE YEAR 1994

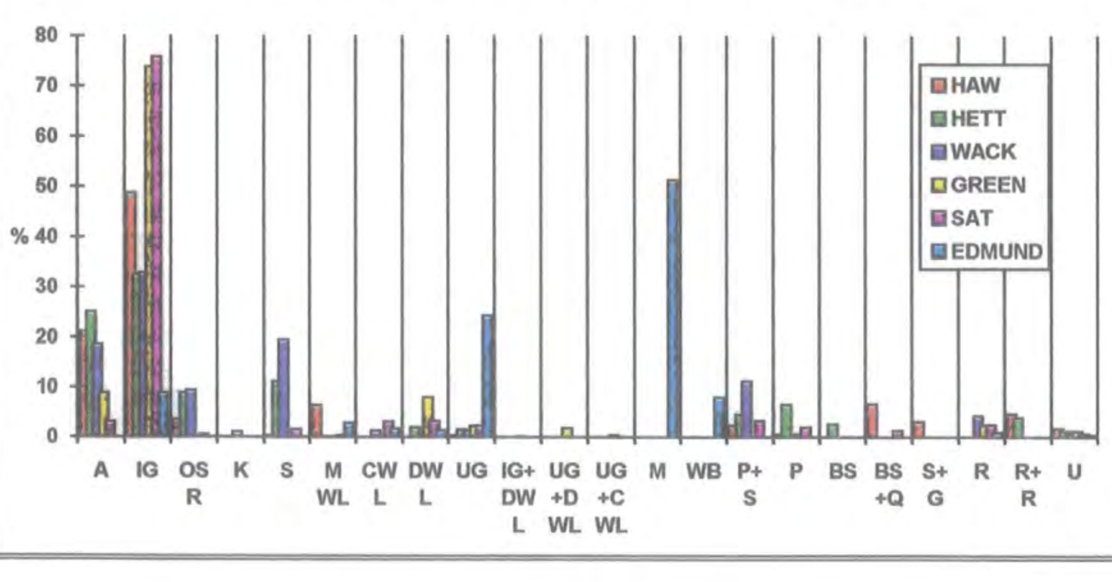


Fig.2.6

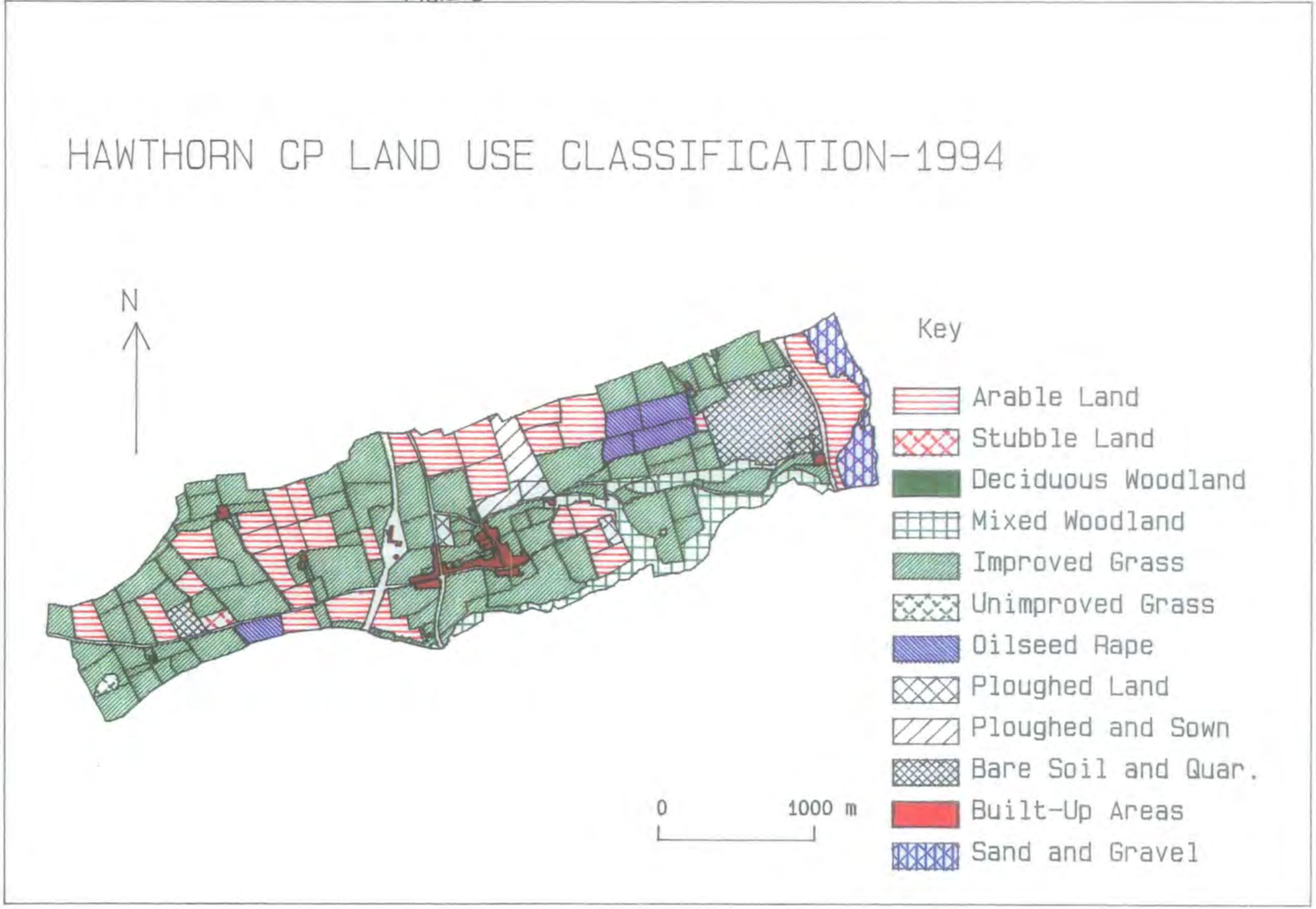

HAWTHORN CP LAND USE CLASSIFICATION-1994
N
Key
Arable Land
Stubble Land
Deciduous Woodland
Mixed Woodland
Improved Grass
Unimproved Grass
Oilseed Rape
Ploughed Land
Ploughed and Sown
Bare Soil and Quar.
Built-Up Areas
Sand and Gravel
0
1000 m

Fig.2.7

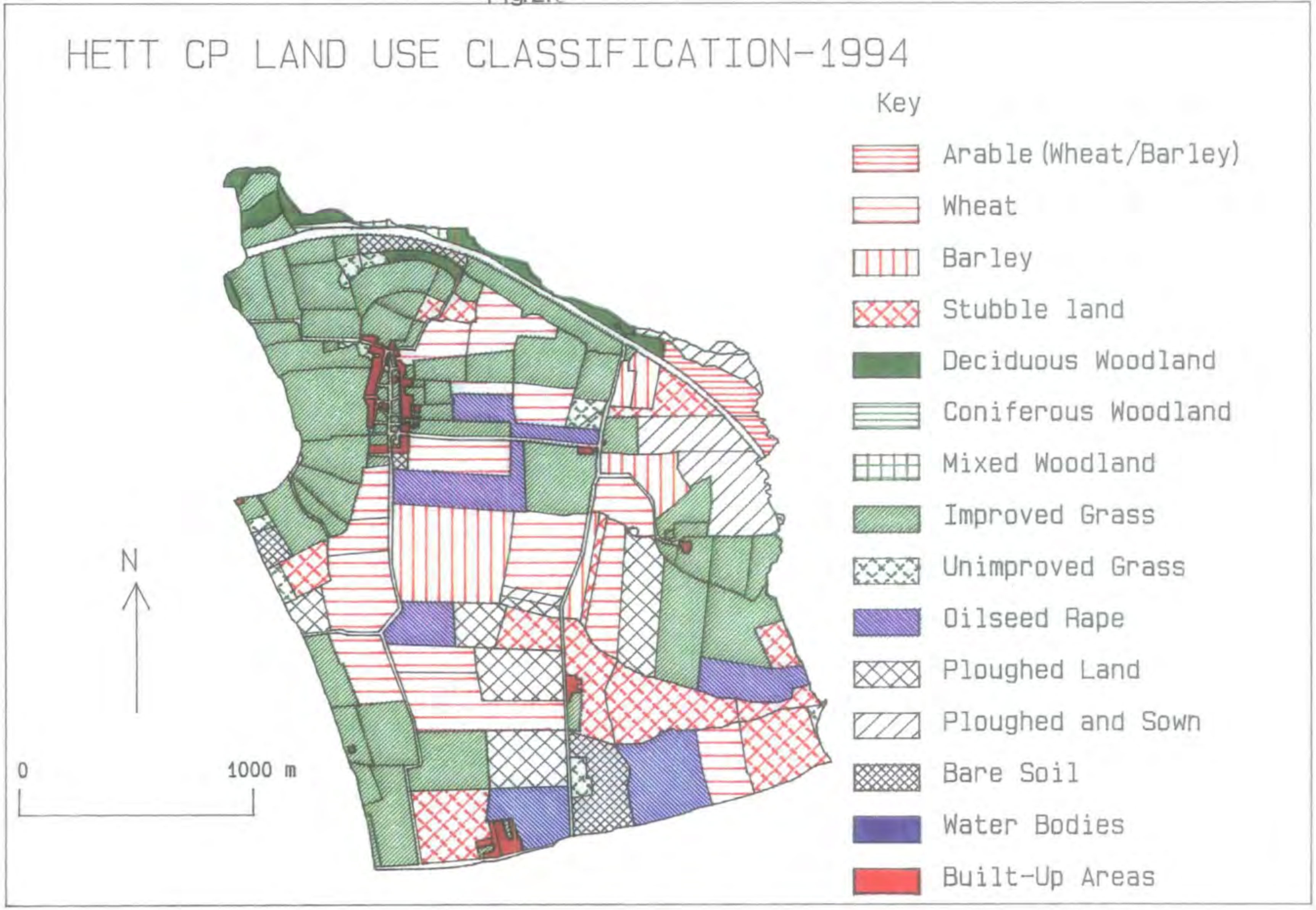

HETT CP LAND USE CLASSIFICATION-1994
Key
Arable (Wheat/Barley)
Wheat
Barley
Stubble land
Deciduous Woodland
Coniferous Woodland
Mixed Woodland
Improved Grass
Unimproved Grass
Oilseed Rape
Ploughed Land
Ploughed and Sown
Bare Soil
Water Bodies
Built-Up Areas
N
0
1000 m

Fig.2.8

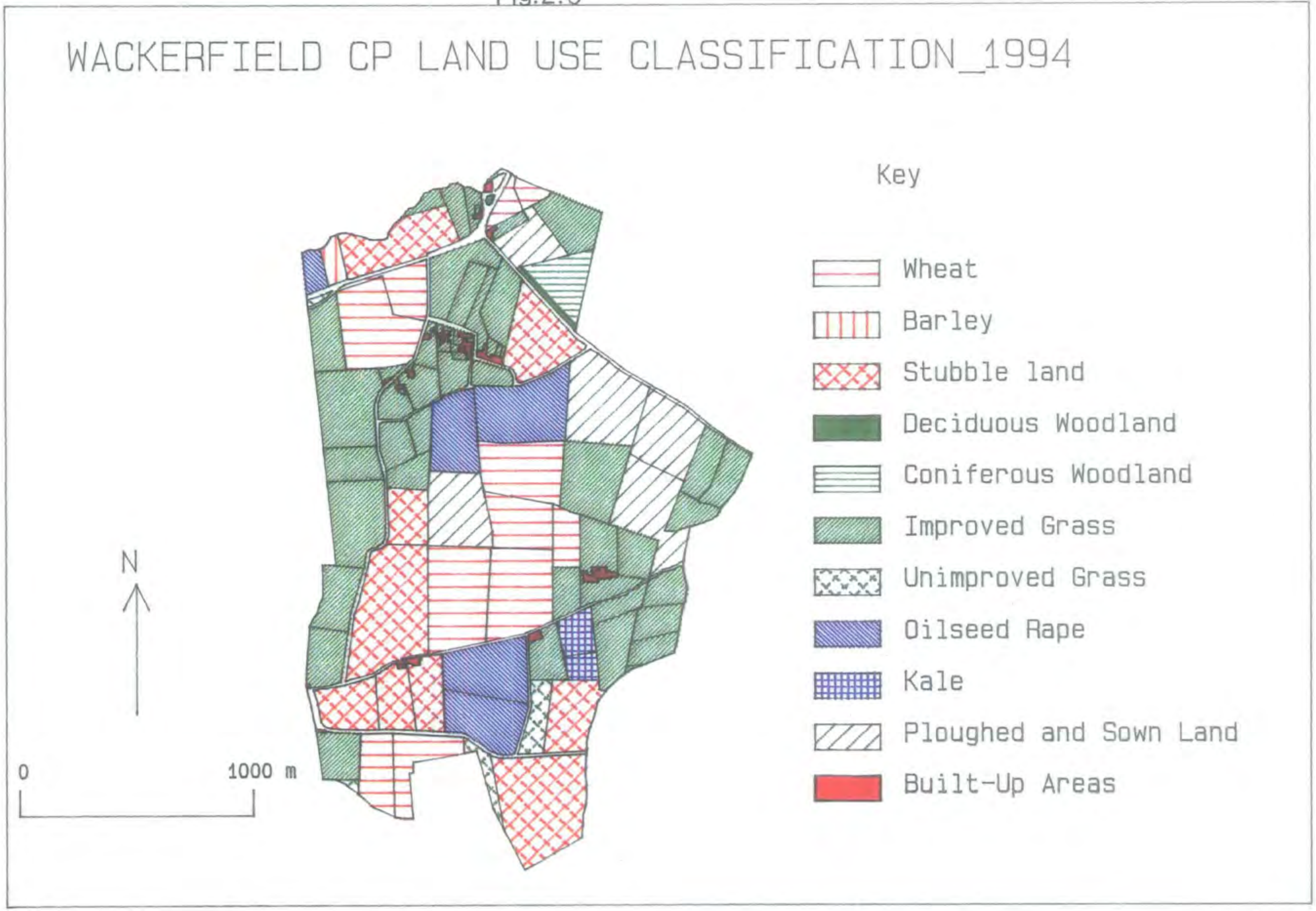

WACKERFIELD CP LAND USE CLASSIFICATION_1994
Key
Wheat
Barley
Stubble land
Deciduous Woodland
Coniferous Woodland
Improved Grass
Unimproved Grass
Oilseed Rape
Kale
Ploughed and Sown Land
Built-Up Areas
N
0
1000 m

Fig.2.9

GREENCROFT CP LAND USE CLASSIFICATION_1994

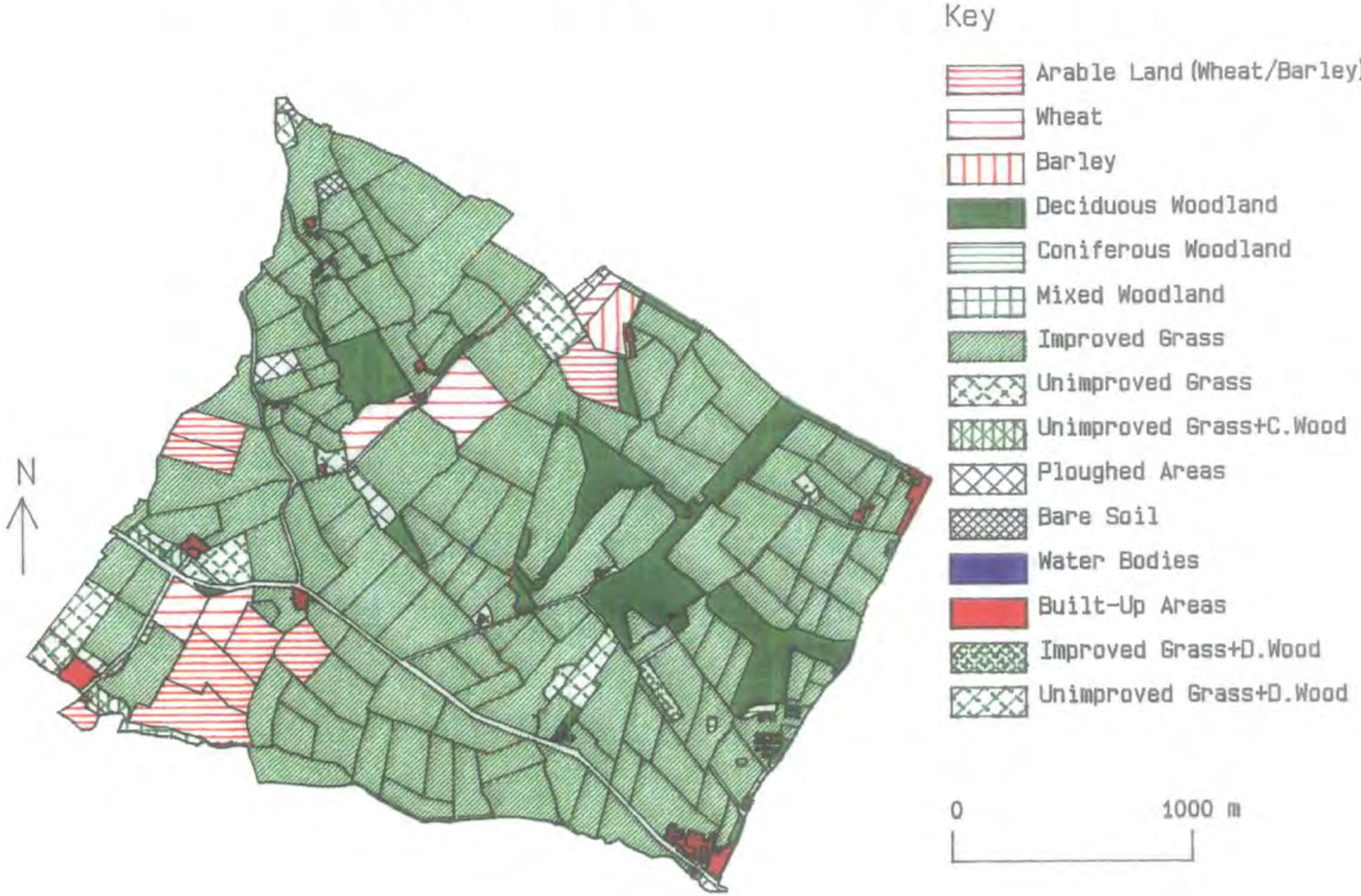


Fig.2.10

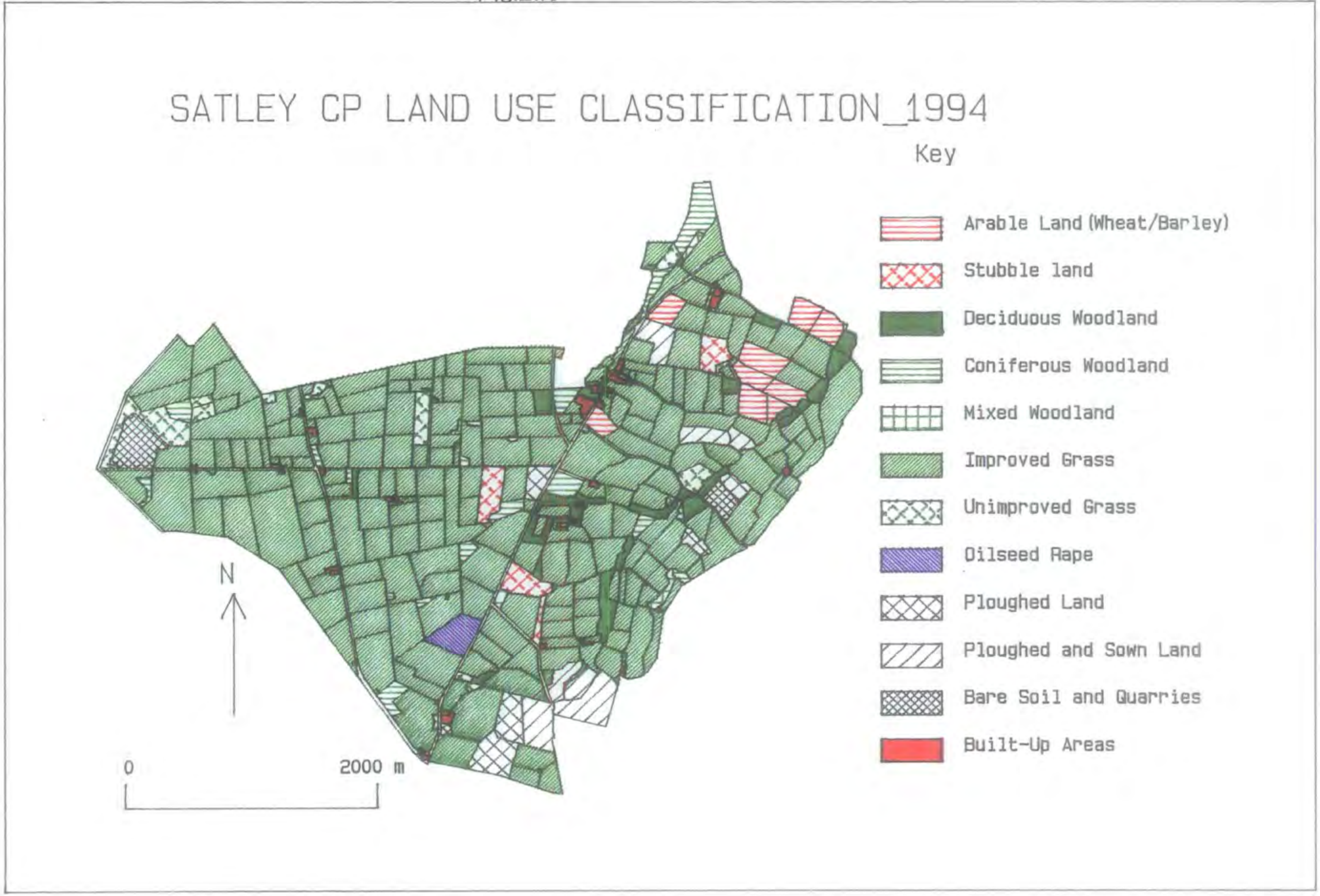

SATLEY CP LAND USE CLASSIFICATION_1994
Key
Arable Land (Wheat/Barley)
Stubble land
Deciduous Woodland
Coniferous Woodland
Mixed Woodland
Improved Grass
Unimproved Grass
Oilseed Rape
Ploughed Land
Ploughed and Sown Land
Bare Soil and Quarries
Built-Up Areas
N
0
2000 m

Fig.2.11

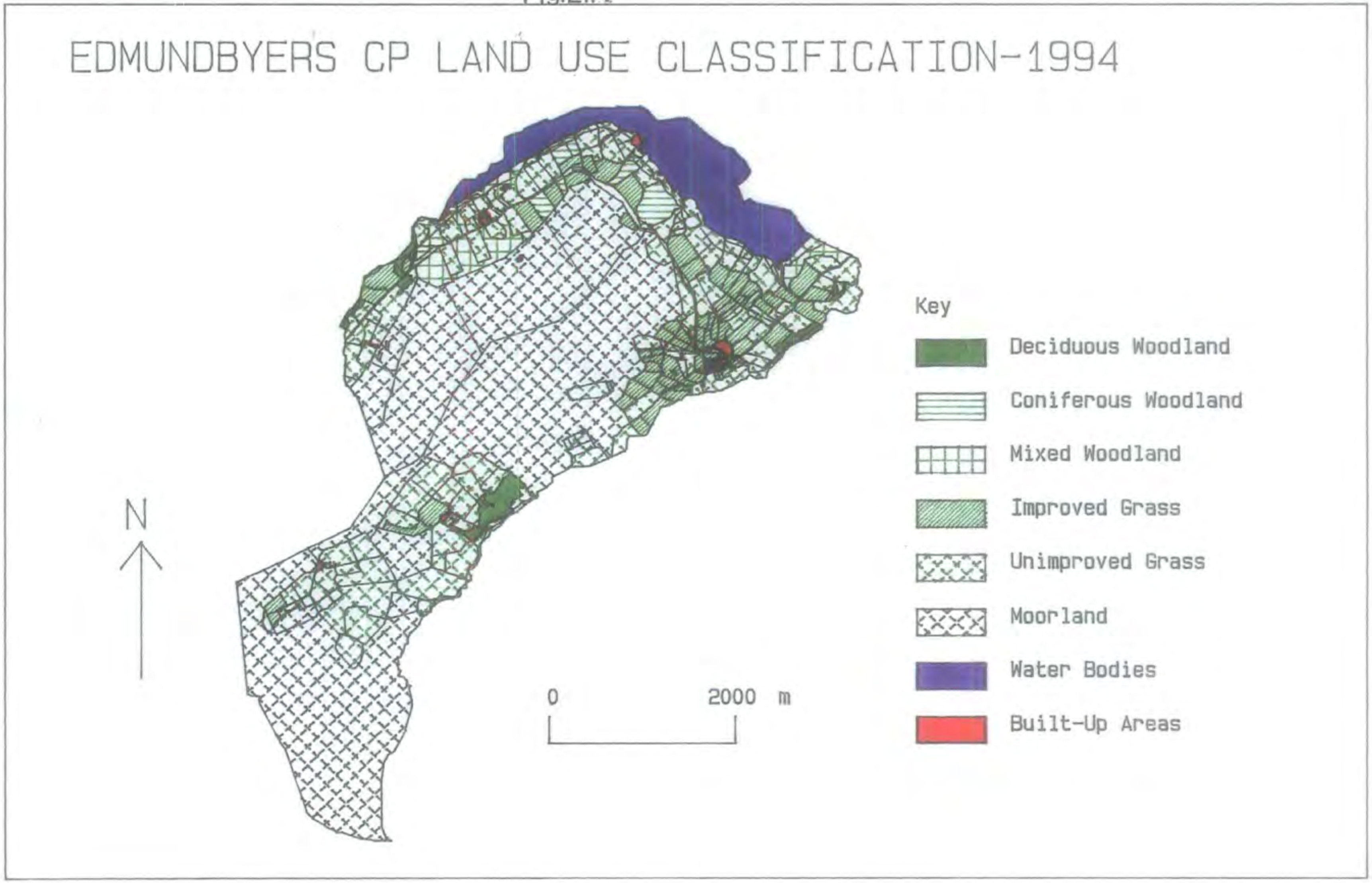

EDMUNDBYERS CP LAND USE CLASSIFICATION-1994
N
0
2000 m
Key
Deciduous Woodland
Coniferous Woodland
Mixed Woodland
Improved Grass
Unimproved Grass
Moorland
Water Bodies
Built-Up Areas

Table (2:4): Total land use of the study area for

the year 1994

No	Land use class	ha	%
1	A	405.90	7.41
2	IG	2254.24	41.11
3	OSR	101.04	1.84
4	K	3.35	0.06
5	S	138.68	2.52
6	MWL	105.58	1.92
7	CWL	82.57	1.51
8	DWL	140.46	2.56
9	UG	562.02	10.25
10	IG+DWL	1.36	0.02
11	UG+DWL	12.22	0.23
12	UG+CWL	3.33	0.06
13	M	1057.77	19.29
14	WB	166.03	3.03
15	P+S	115.17	2.11
16	P	68.66	1.25
17	BS	13.82	0.25
18	BS+Q	56.42	1.03
19	S+G	17.89	0.33
20	R	83.33	1.52
21	R+R	46.83	0.85
22	U	46.82	0.85
TOTAL		5483.86	100.0

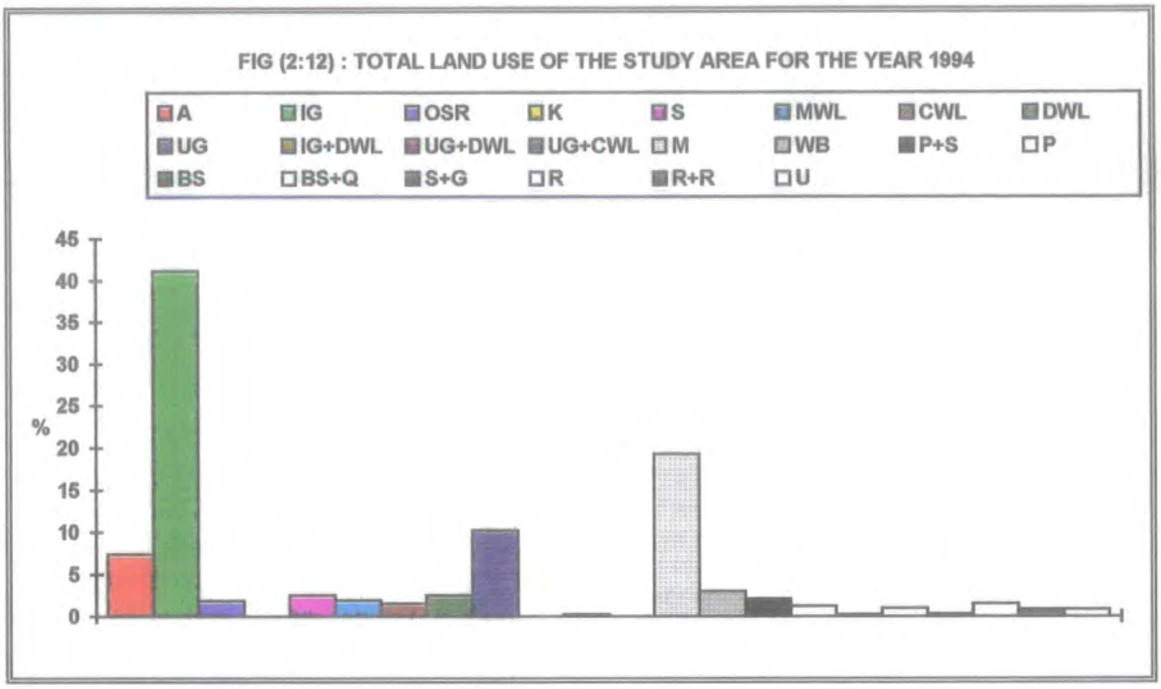


FIG (2:12) : TOTAL LAND USE OF THE STUDY AREA FOR THE YEAR 1994
A
IG
OSR
K
S
MWL
CWL
DWL
UG
IG+DWL
UG+DWL
UG+CWL
M
WB
P+S
P
BS
BS+Q
S+G
R
R+R
U
45
40
35
30
25
20
15
10
5
0
%

2.4.6 Generalisation of the 1994 Land Use Classification

To detect land use change during the period 1931-1994, the land use classification of the year 1994 has been generalised to match that of the year 1931. In this generalisation process, the 22 classes were compressed into 9 land use classes.

1. Arable Land (Wheat, Barley, Oilseed Rape, Ploughed, Ploughed and Sown, Stubble, Kale, and Bare Soil (Fallow)).
2. Woodland (Mixed Woodland, Deciduous Woodland, Coniferous Woodland, and half the Grass+Woodland classes).
3. Improved Grass.
4. Moor and Heath land (Unimproved Grass and half the Unimproved Grass+Woodland are concluded in this land use class).
5. Built-up areas.
6. Roads and Railways.
7. Quarries.
8. Water Bodies.
9. Sand and Gravel.

Table (2:5): Generalised land use of the six study areas-1994 (%)

No	Land use	Hawth.	Hett	Wack.	Green	Satley	Edmund.
1	Arable Land	27.9	58.38	59.50	9.66	10.64	-
2	Woodland	6.7	2.35	1.50	9.64	6.69	6.07
3	Improved Grass	48.8	32.45	32.8	73.68	75.82	8.8
4	Moor and Heathland	0.4	1.60	1.3	3.40	1.60	75.56
5	Built-up Areas	1.7	1.22	0.7	1.2	0.76	0.53
6	Roads and Railways	4.7	3.99	4.2	2.4	2.49	0.97
7	Quarries	6.7	-	-	-	1.31	-
8	Water Bodies	-	0.01	-	0.01	-	8.0
9	Sand and Gravel	3.1	-	-	-	-	-
	Total %	**100**	**100**	**100**	**100**	**100**	**100**
	Total ha	**577.24**	**505.31**	**303.65**	**678.88**	**1354.72**	**2064.06**

FIG (2:13) : GENERALISED LAND USE OF THE SIX STUDY AREAS IN 1994

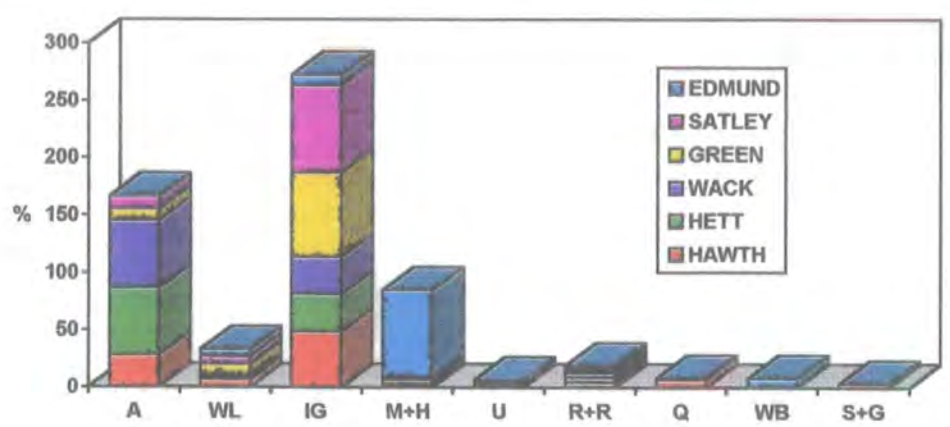
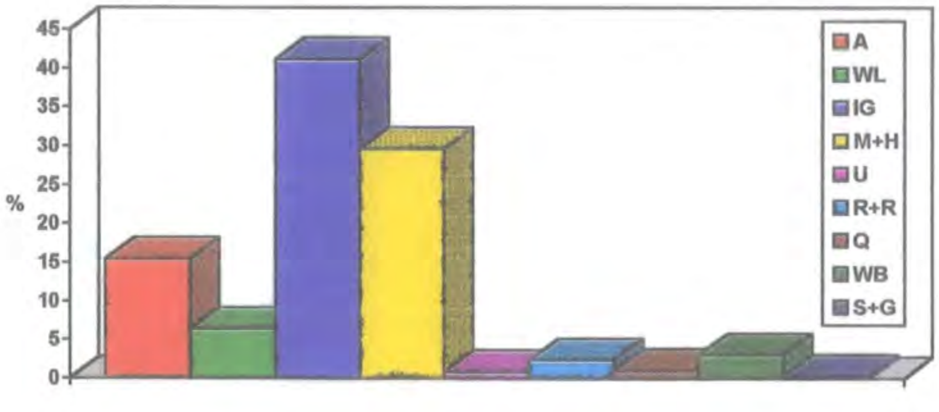


Table (2:6): Generalised total land use of the study area-1994

No	Land use class	ha	%
1	Arable Land	846.02	15.43
2	Woodland	346.36	6.32
3	Improved Grass	2254.24	41.11
4	Moor and Heathland	1621.07	29.56
5	Built-up Areas	46.82	0.85
6	Roads and Railways	129.71	2.37
7	Quarries	56.42	1.03
8	Water Bodies	166.03	3.03
9	Sand and Gravel	17.89	0.33
	Total Area	**5483.86**	**100**

FIG (2:14) : GENERALISED TOTAL LAND USE OF THE STUDY AREA IN 1994



2.5 Land Use Change Between 1931-1994

Table (2:7) : Land use change of the six study areas between 1931-1994

(%)

Land use class	*Hawth.*	*Hett*	*Wack.*	*Green*	*Satley*	*Edmund.*
Arable Land	- 28.67	32.73	29.52	- 1.89	0.92	- 0.7
Wood land	0.1	0	0	- 1.44	- 0.9	- 0.43
Improved Grass	29.01	- 27.4	- 30.86	9.16	13.4	- 5.66
Moor and Heath land	- 4.59	- 5.67	1.34	- 6.7	- 13.46	- 1.35
Built-up Areas	0.78	0.33	0	0.86	0.06	0.15
Roads and Railways	1.53	0	0	0	0	0
Quarries	0	-	-	-	0	-
Sand and Gravel	0	-	-	-	-	-
Water Bodies	-	0.01	-	0.01	-	7.97

FIG (2:15) : LAND USE CHANGE OF THE SIX STUDY AREAS BETWEEN 1931 - 1994

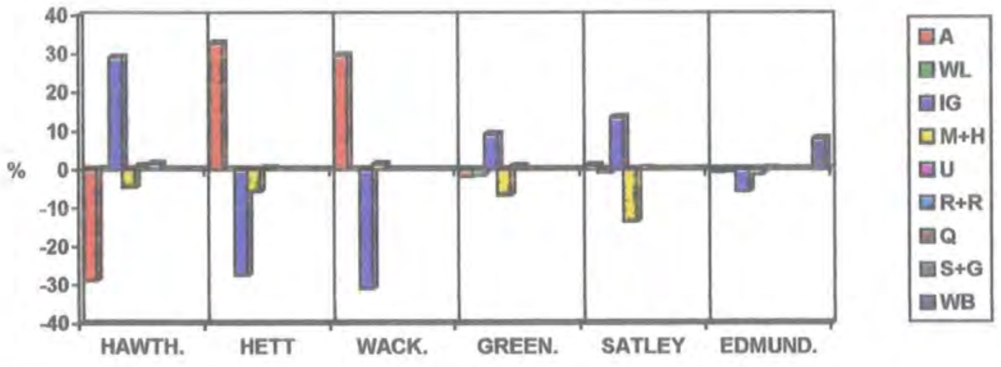
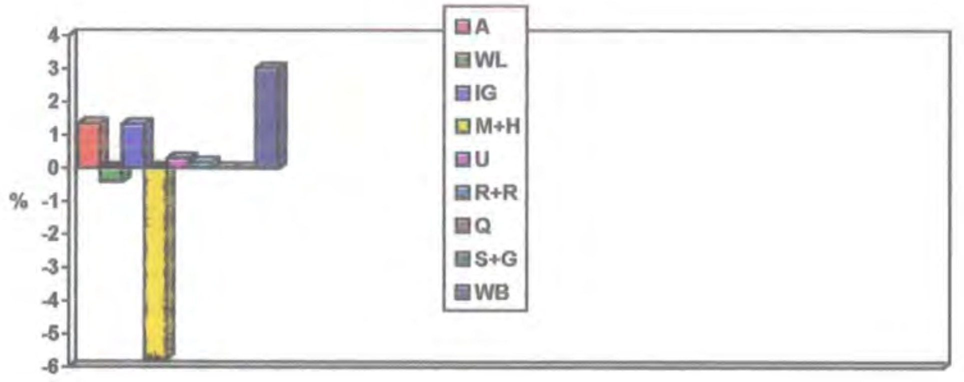


Table (2:8): Total land use change of the study area between the years 1931-1994

No	Land use class	Land use change (ha)	Land use change %
1	Arable Land	74.11	1.35
2	Wood Land	- 22.89	- 0.42
3	Improved Grass	72.3	1.32
4	Moor and Heath Land	- 315.05	- 5.75
5	Built-up Areas	15.21	0.28
6	Roads and Railways	8.18	0.16
7	Quarries	0	0
8	Sand and Gravel	0	0
9	Water Bodies	165.43	3.02

FIG (2:16) : LAND USE CHANGE OF THE STUDY AREA BETWEEN THE YEARS 1931 - 1994



2.6 Results

The land use classifications for the two dates 1931 and 1994 of the study areas show the following:-

1. Hawthorn, in the Coastal Region, and Hett and Wackerfield in the Lowland Region are mainly given over to arable crops and improved grassland. Deep soil, flat terrain, and the relatively better climate made these two regions more suitable for arable crops than the other regions of the County.

2. Greencroft and Satley in the Corridor Region are mainly under grass. The considerable variations of topography, the colder climate and its substantial effect on the length of the growing season, the steeper surface and its effect on mechanical operations, and the thinner soil and its effect on the soil moisture and minerals contents have made this region more suitable for grass than other crops.

3. Edmundbyers in the Upland Region is mainly moor and heath. The high altitude and its effects on climate, the heavy rain and its effects on soil erosion and leaching, the low temperature and its effect on the growing season length, and the thin soil and its effect on soil moisture and mineral content, have made this region unsuitable for intensive agricultural activities.

4. Local topography has a great influence on land use activities in all the regions.

A strong relationship is found between woodland and unimproved grass on one hand, and natural drains and rivers on the other hand, so this type of land cover has more presence in the Corridor and the Lower Pennine Regions.

Variations of topography of the Corridor Region, represented by Greencroft and Satley, resulted in variations in ground steepness, soil profile, drainage status and local soil capabilities. This has a significant impact on local land use \ land cover distribution. Flatter and lower areas are given to arable crops for their more fertile soil and easier agri-mechanical operations. The relatively steeper areas are given to improved grass. This high 'agri-spatial' frequency in this region gave it a rougher agricultural surface.

5. The detailed land use classification of Feb., 1994 shows the adverse effect of the early wet season on land use (the total rainfall of September 1993 was 117.6 mm or

232.4% of average, and that of October was 73.6 mm or 114.5% of average) (Durham University Observatory, 1993). It shows that 11.1% of Hett and 19.4% of Wackerfield land use are classified as Stubble Land. This can be explained that farmers were unable to plough their fields, or the fields are left for spring crops.

6. Land use and land use change in the study areas between 1931-1994 give the following indications:-

(a) In the Coastal Region represented by Hawthorn, and in the Lowland Region represented by Hett and Wackerfield, the agricultural land use change is mainly between arable and improved grass crops. In Hawthorn there is a remarkable change from arable to grass crops, while in Hett and Wackerfield the change is from grass to arable crops. In the Corridor Region represented by Greencroft and Satley, there is no great change in arable crops areas; this is due to its limited area existence in this region. Finally, in the Upland Region represented by Edmundbyers, a slight change of arable land area is the result of the construction of the Derwent Reservoir. In general, there is a slight *increase in area of arable land (1.35%)* of the total study area as a result of the improvement of moor and heath lands (rough grass and common land) in the coastal and the lowland regions.

(b) In the Corridor Region represented by Greencroft and Satley, there is a considerable *positive change of improved grass crops*, due to the improvement of the moor and heath lands. Most of these improved areas are given to grass because of the dominant topographic limitations on arable cropping. In general, there was an *increase in area of improved grass lands (1.32%).*

(c) There was a negative change of woodland area (-0.42%). This was due to the construction of the Derwent Reservoir and the deforestation of some areas in Greencroft and Satley.

(d) In the Upland Region represented by Edmundbyers, a substantial land use change has resulted from the construction of the Derwent Reservoir. A decrease in all types of land use \ land cover occurred. Such reservoirs add a new land use \ land cover dimension to such environments. They, on one hand, reduce the soil erosion and leaching, and on the other hand they reduce the dangers of floods occurring in the plain areas of the rivers in the County, especially in the inhabited areas (e.g. the floods of winter 1994 which caused a lot of damage to the farmers' properties in the lowlands). So, *the land use change in the study area due to the construction of water reservoirs (3.02%).*

(e) There is a *negative land use change in the moor and heath lands* in all the study areas except Wackerfield. In Wackerfield a limited area (4 ha) is left to rough grass. This negative land use change in the moor and heath land is the result of reservoir construction in the Upland Region, the improvement of the rough grasslands, and the change of the agricultural system from common land to private cultivation. *This land use change represents the main land use change in the study area (-5.75%).*

(f) There *has been an increase in the urban areas* (built-up areas, roads+railways). This change is considerable in two of the six parishes; Hawthorn and Greencroft. This distribution of change in the urban areas is mediated by the effect of the relative location. Hawthorn and Greencroft are close to urban centres and main roads, while the other four parishes are relatively isolated. *The total urban land use change in the study area is 0.44%.*

2.7 Problems and Limitations of the Field Land Use Mapping Method

Each method or technique of land use mapping has its own problems and limitations. The following problems and limitations arose during the field land use mapping:-

1. In many cases, it was not possible to gain access to fields from the road side. These fields were assigned to their general land use class; e. g. wheat and barely were assigned to arable class...etc. This of course creates limitations to further detailed studies.

2. In some cases, the field boundaries have changed since the production of OS maps, so a disagreement between the map and the actual fields boundaries may exist.

3. The field land use mapping method is a laborious one.

4. It is time-consuming.

5. The level of classification used by the aerial photography method does not give a perfect idea of the land use \ land cover status in the county. For example, the moor and heath land class included in the 1931 classification contains land cover\land use features of different characteristics such as common land and rough grass. These two land cover\land use features have completely different meanings; the common land has a socio-economic meaning while rough grass has a morphological meaning. This mixing leads to a misunderstanding of the actual geographic characteristics of the region because, for example, the moor and heath land of the lowland region is different from that of the upper land.

6. For the above mentioned reasons, the photogrammetric and field survey methods are not efficient for large area mapping.

2.8 Advantages of the Field Land Use Mapping

Despite the limitations of this method, it has some advantages over other techniques of land use mapping. These advantages are:-

1. The probability of misclassification is low.

2. It improves the geographical knowledge and interpretative ability of the researcher.

3. It establishes an accurate basis for further studies.

2.9 Conclusion

The results of this geographical land use study have emphasised the crucial effect of the physical characteristics of this region on land use activities, especially in the western part of the region. From a purely agricultural point of view, the chance of improving agricultural activities in the western region is low. However, from the geographical, environmental, and resource management point of view, it is possible to attract other activities to this region by firstly, the creation of artificial and natural reservoirs. Reservoirs not only attract human attention, but also create a better environment for birds and animals, and consequently encourage tourism. Secondly, the improvement of the communication network between this region and the other regions of the County on one hand, and the Atlantic face of the Pennines on the other hand. This road network between two zones having completely different environmental characteristics may offer a new and different life to the region. Technically, the study emphasised that the field land use mapping method alone is not applicable for large area studies, and the updating of the land use information by means of aerial photography land use mapping is time consuming. ***To overcome these deficiencies and to benefit from the advantages of the field mapping method, a combination of field land use mapping and satellite remote sensing will be applied in this study.***

CHAPTER THREE

Chapter 3 : Image Pre-processing

3.1 Introduction

Satellite Remote Sensing developed from airborne remote sensing in the 1960s and 1970s (Harris, 1987). This revolution in data acquisition technology began to change from experimental to applied studies and spread rapidly throughout the world. It can be seen from the study of land use that despite the advantages of field survey and photogrammetric methods, they are not appropriate for large study areas. So, in this study, a combination of satellite remote sensing and field survey techniques were used to produce land use maps.

3.2 Landsat Satellite Data

It is important to know about seasonal changes in land cover types being studied especially for agricultural crops, so that the optimum date for spectral discrimination can be obtained. This optimum date is not the same for all land cover types. For example, deciduous vegetation can be best discriminated from evergreen on a winter scene. To know the date best suited to a certain agricultural study, it is necessary to understand the crop calendar in the study area. This calendar shows the periods of sowing, fertilising, harvesting, and foliation. The spectral response of land cover to the wavebands used should be considered carefully when choosing the date of study. Previous research has shown that multi-temporal data analysis can improve classification accuracy, but the analysis in terms of image processing, registration, and accuracy assessment is considerably more involved. Care should be taken to avoid scenes with low sun elevation angles because topographic effects may reduce the clarity with which land cover is displayed. In Britain, particularly in the North East, weather conditions affect the selection of images substantially because of the high frequency of cloudy days. Fortunately, it was possible to acquire data for three well separated dates representing three different stages of crop growth for the study area. Landsat satellite data from the *Thematic Mapper* (Landsat TM5) for three dates. The path/row annotation of these data is 203/22 fig (3:2). The following table summarises the data used for this study:-

Table (3:1): Images dates of the study area

No	Image acquisition date	TM bands
1	9.40 am 31st May 1985	2-5
2	9.40 am 1st August 1990	1-7
3	9.40 am 10th July 1992	1-7

3.3 Landsat Series

The Landsat series are of two generations:-

1. First generation : The first generation consists of three Landsat satellites; Landsat1, Landsat2, and Landsat3. Landsat1 was launched on July 23rd, 1972, Landsat2 was launched on January 22nd, 1975, and Landsat3 was launched on March 5th, 1978. The characteristics of the spectral systems of these satellites is shown in table (3.2).

Table(3:2): Main characteristics of MSS spectral bands

Band No.	**B. Width (μm)**	**B. Name**	**Spatial Resolution (m)**	**Detectors Number**	**Cycle**	**Area Coverage (km)**	**Grey Levels**
4	0.50-0.60	green	79	6	18 days	185 ×185	0-64
5	0.60-0.70	red	79	6			
6	0.70-0.80	near infrared	79	6			
7	0.80-1.10	near infrared	79	6			

Source: Curran, 1985

2. Second generation. It consists of two Landsat Satellites:- Landsat 4 and Landsat5. The former was launched on 16th July 1982, and the latter was launched on 1st March 1985. Each area on the earth is imaged by these satellites once every 16 days, compared to the 18 days cycle of Landsat 1, 2, and 3. Landsat 4 and 5 carry the same sensors as the first generation apart from three main different characteristics:-

1. Pixel size (spatial resolution).
2. The MSS bands have been renamed 1, 2, 3, and 4 instead of 4, 5, 6, and 7.

3. Landsat 4 and 5 carry a new sensor called the Thematic Mapper (TM). This new sensor increased the coverage of spectral bands between 0.45-12.5 μm, from the visible to the thermal infrared.

Landsat Thematic Mapper (Landsat TM) has the following advantages over the Multispectral Scanner System (MSS):-

(1) Spectrally, the acquisition of data is in seven bands instead of four. The range of the wavelength and location of TM bands in the electromagnetic spectrum were chosen to improve the spectral discrimination of major earth surface features.

(2) Radiometrically, the TM converts the analogue signals to digital ones over a range of 256 digital numbers (DN), while in the MSS the acquisition range is only 64 digital numbers. These DNs represent the grey levels resulted from radiometric differences between different features on earth. So, the TM offers observation of smaller changes in radiometric magnitudes in bands individually and together.

(3) The spatial resolution of the TM is 30 m, while that of the MSS is 79 m. Agriculturally, this increase of the spatial resolution offers better image clarity, higher levels of analysis and land use classification, and less mixed pixels (mixels); especially in the areas of small fields and high crops frequency. Table (3:3) summarises the main characteristics of Landsat TM bands and their general applications.

Figure (3:1): Ground Coverage of TM Scenes for U.K. (NRSC)

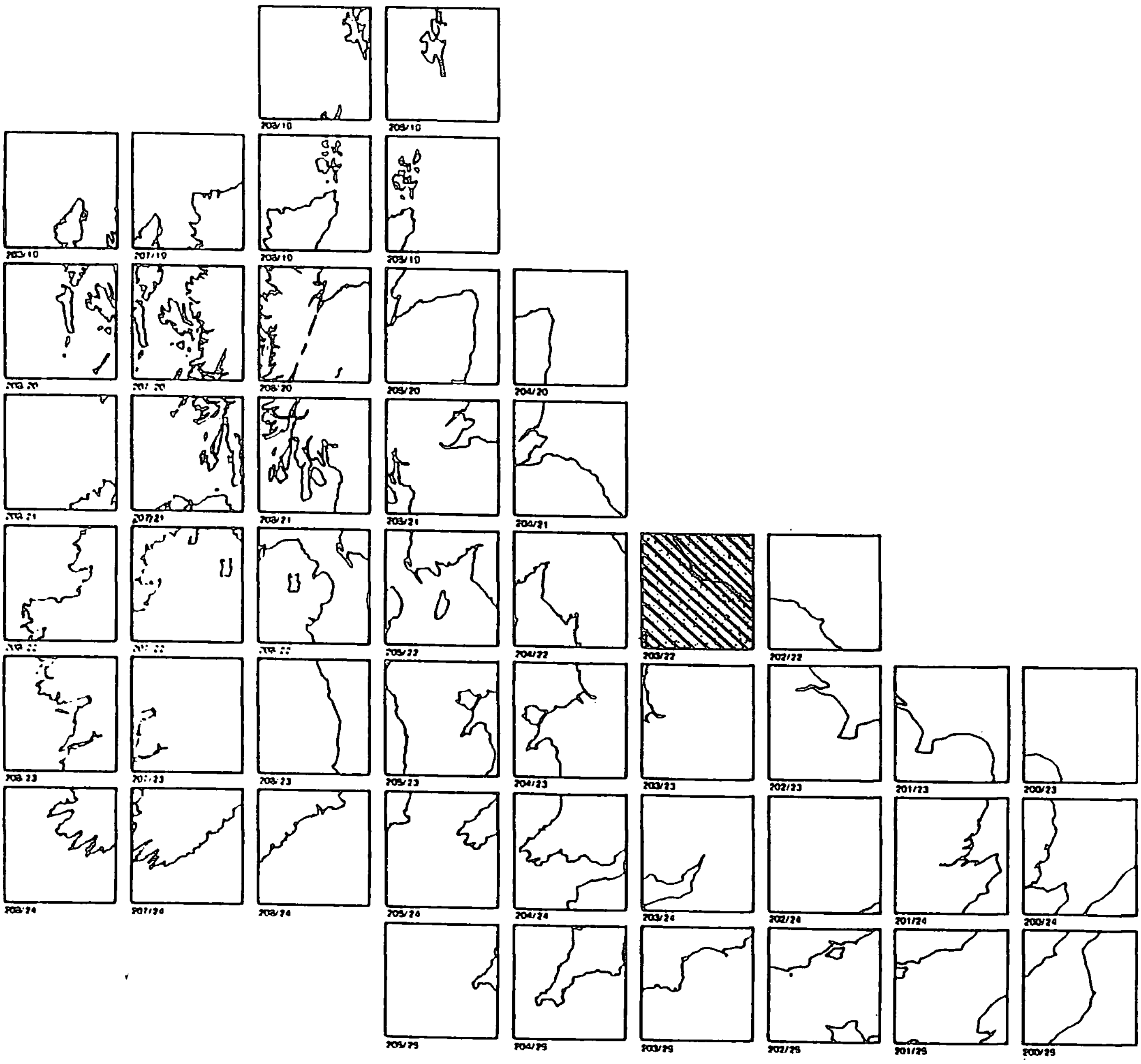


Table (3:3): Landsat TM bands and their main characteristics.

Band	*Band Width (μm)*	*Band Name*	*Resolution (m)*	*Application*
1	0.45-0.52	Blue	30	good water penetration, good for soil-vegetation differentiation
2	0.52-0.60	Green	30	strong vegetation reflectance, good for vegetation vigour assessment
3	0.63-0.69	Red	30	strong chlorophyll absorbance, important for vegetation discrimination.
4	0.79-0.90	Near infrared	30	high land / water contrast, useful for determining biomass content.
5	1.55-1.75	Short infrared	30	strong moisture sensitive, good for detecting crops stage of growth.
6	10.4-12.5	Thermal infrared	120	strong soil moisture sensitive, useful for vegetation stress analysis and evapotranspiration.
7	2.08-2.35	Short infrared	30	useful for geological discrimination.

Source:- Lillesand & Kiefer (1987), and Freden & Gordon (1983).

3.4 Weather Conditions

There is no doubt that weather conditions have a fundamental influence on the spectral response of features on the surface of the earth. Cloud is the most important weather element that affects the clarity of image data and may cause two types of noise; (1) It hides image data and may cause misclassification with features of similar appearance on the image such as snow and sand. (2) Its shadow, especially in the images of low solar elevation, may cause misclassification. They have tonal appearance on the image similar to those of water bodies and forests. A lower solar elevation results in long shadows but these shadows have a light tone. In this case, shadows may be confused with forests. On the other hand, high solar elevation results in smaller and darker shadows. These shadows are often confused with water bodies. For vertical solar elevation no cloud shadows occur.

Temperature affects image clarity and the spectral response of ground features through its interaction with other features on the earth and the atmosphere and its role in causing haze. High temperature increases the evaporation rate of water bodies and the transpiration of vegetation and so increases the atmospheric water vapour content. The size of water drops in the air depends on the aerosol size, and the latter depends on the environment of the region especially the scale, size, and type of urbanisation in the area. The emittance of the day-gained heat of urban areas especially the industrial ones; through the relatively cold nights and its interaction with colder-humid ground and air surfaces causes water condensation and consequently produces haze. This layer of haze reduces the clarity of image data.

Rainfall affects the spectral response of the ground surface features through its influence on soil moisture. To know the effect of this factor; it is necessary to look not only at the image rain conditions on the day of its acquisition, but also on the pre-acquisition period. Sunshine has the opposite effect and so these two factors can not be separated.

Sunshine affects the spectral response of ground features in two ways:-

1. Direct effect, it produces illuminated features, and this is a fundamental issue in remote sensing.
2. Indirect effect, the period features on the surface of the earth are exposed to sunshine affects their temperature. Each feature has its own spectral properties and the physiological system of each feature interacts with the solar radiation in a certain way. The accumulated period of interaction between the electromagnetic radiation and these features to some extent determines the temperature of the feature. For agricultural features, high temperature increases transpiration and decrease the leaf water content and consequently may cause changes in leaf geometry. The effect of this factor on the leaf geometry is higher in arid and semi-arid environments. The leaf geometry in such environments varies considerably through the day. In the morning, and by the effect of dew, the lower part of the leaf is more exposed to solar radiation than in the mid-day. In the mid-day, when the sun is overhead, leaves lose a lot of water content very rapidly and the soil dries. So, the upper part of the leaf is more exposed to solar radiation. These differences in leaf geometry affect the spectral reflectance behaviour of agricultural crops.

Wind has an effect on the spectral response of some earth surface features. This is of a transitory nature which has the mobility character and affects some agricultural crops and water bodies. The principle effect is that it changes the surface geometry of agricultural features and water surface.

The effects of weather conditions on the spectral response of features on the surface of the earth that are described above emphasises the need to understand these conditions in order to interpret the images correctly.

FIGURE (3:3) : MONTHLY MEAN TEMPERATURE FOR THE YEARS IN WHICH THE IMAGES WERE ACQUIRED

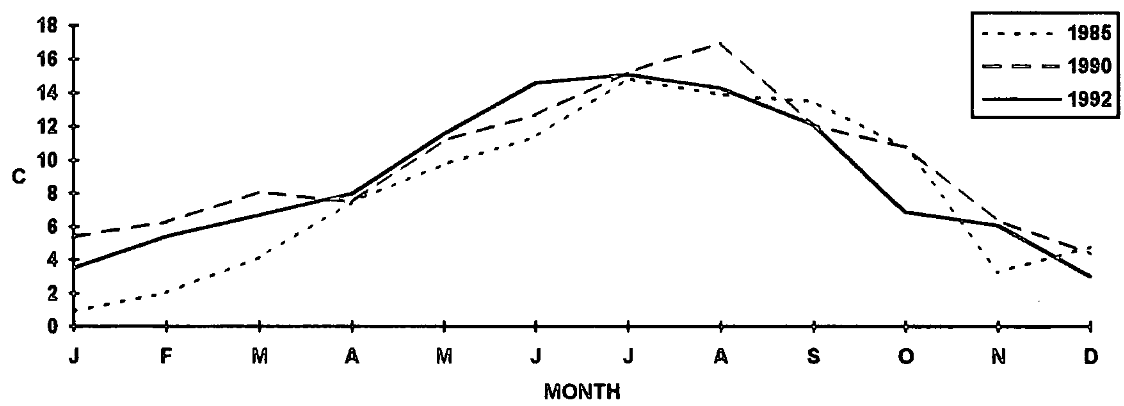
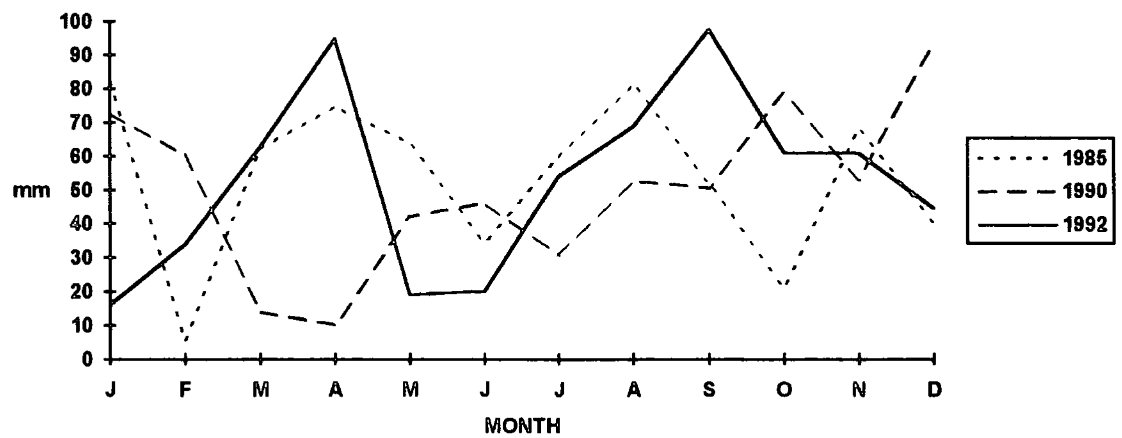


FIGURE (3:4) : MONTHLY RAINFALL FOR THE YEARS IN WHICH THE IMAGES WERE ACQUIRED



Yearly average rainfall (1936-1965) is 650.1 mm.

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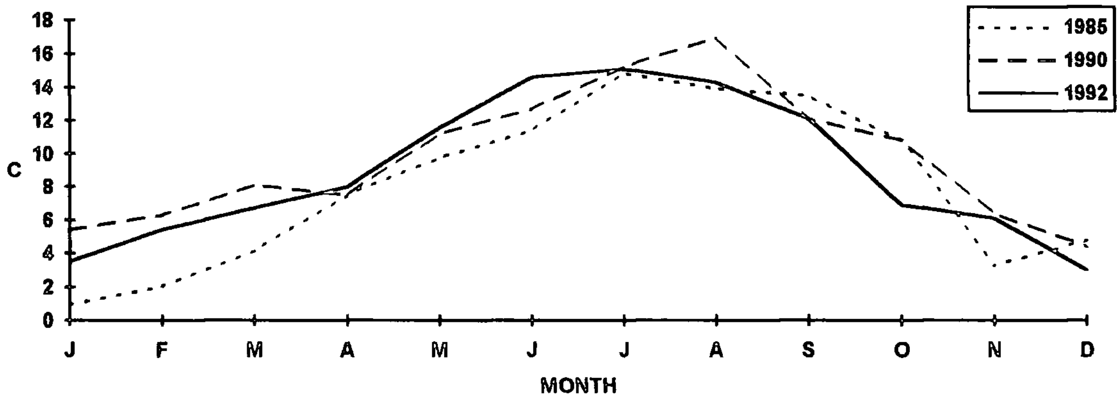
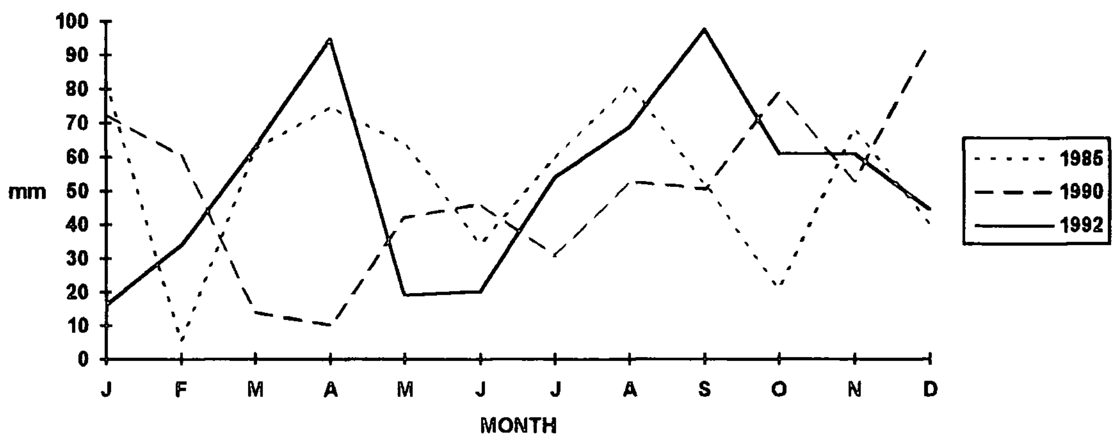
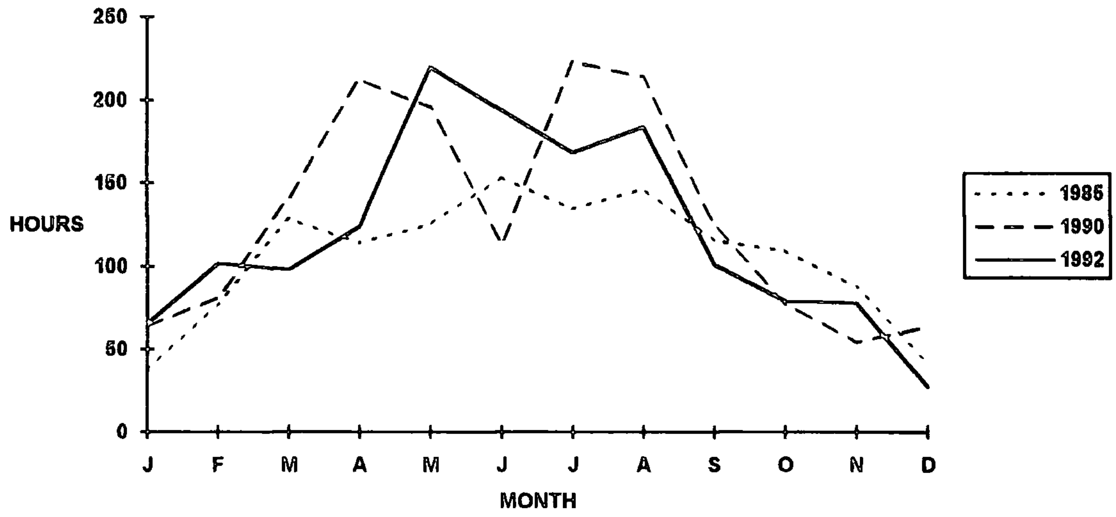


FIGURE (3:4) : MONTHLY RAINFALL FOR THE YEARS IN WHICH THE IMAGES WERE ACQUIRED



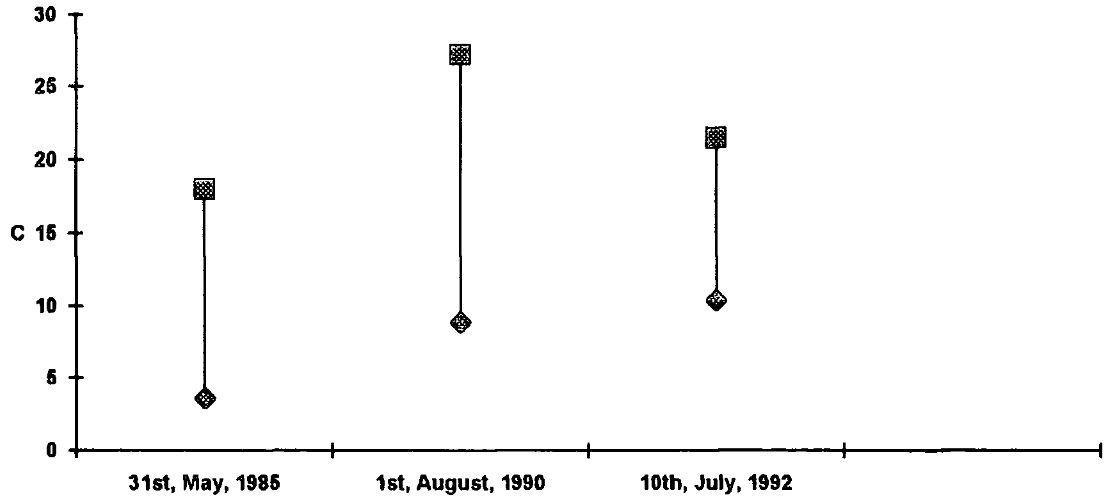
Yearly average rainfall (1936-1965) is 650.1 mm.

FIGURE (3:5) : MONTHLY SUNSHINE FOR THE IMAGE ACQUISITION DATES

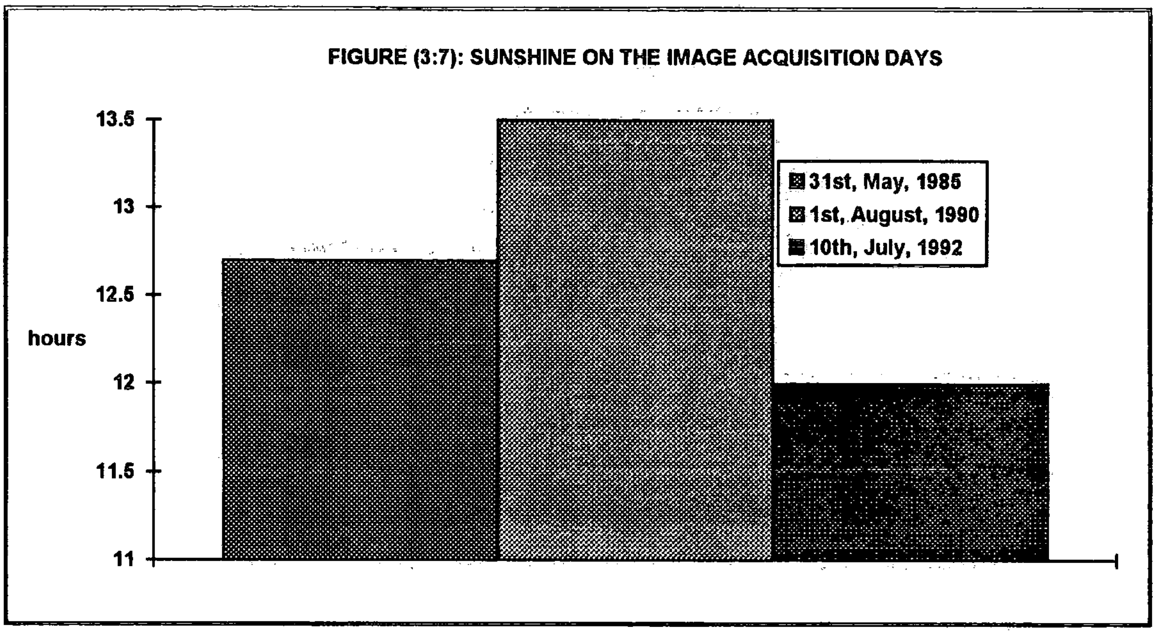


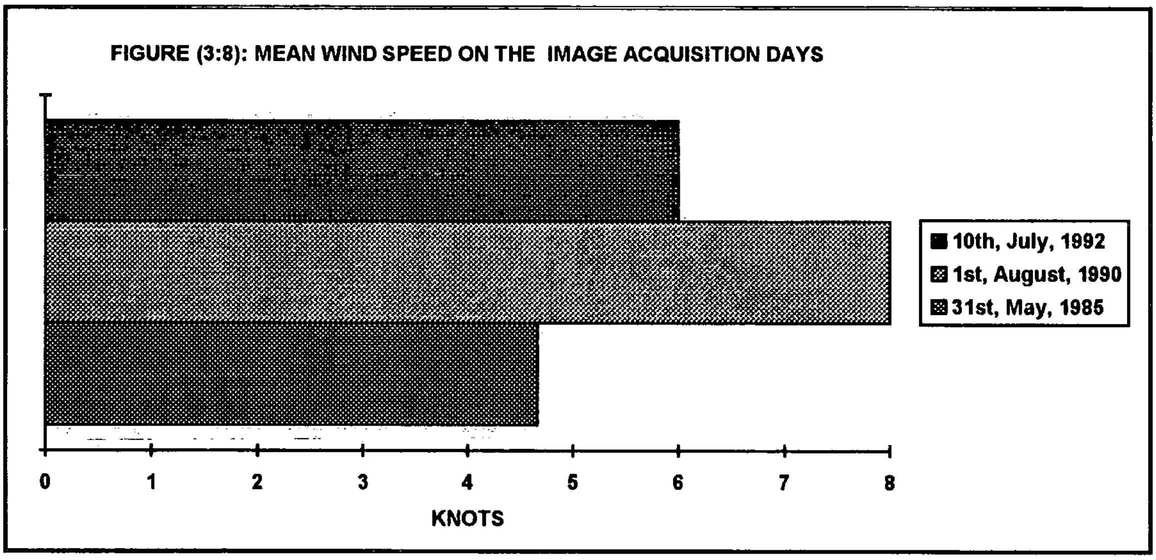
Yearly average sunshine (1936-1965) is 1313.4 hours.

FIGURE (3:6) : MINIMUM AND MAXIMUM TEMPERATURE ON THE THE DAYS THE IMAGES WERE ACQUIRED



Source:- Durham University Observatory, 1985, 1990, 1992.





1 knot = 1.82 km.

Source:- Durham University Observatory, 1985, 1990, 1992

3.4.1 Summary of the Images' Weather Conditions

Weather conditions for the image of 31st May 1985 were as follows:-

(a) It is a cloud-free image.

(b) Total rainfall of May was 63.9 mm (118% of the average).

(c) Mean temperature of May was 9.75°C.

(d) The maximum temperature at the day of the image acquisition in 18°C, and the minimum is 3.6°C.

(e) Mean wind speed at the day of the image acquisition is 4.67 knots.

(f) The sunshine hours at the day of the image acquisition are 12.7 hours.

It can be seen that weather at the day of imaging is bright, sunny and the wind was relatively calm on one hand, while, on the other hand, the total rainfall of May was high. This means that soil; at the day of imaging, is still moist and may affect the spectral response of earth features particularly bare soil.

Weather conditions for the image of 1st August 1990 were as follows:-

(a) It was a cloud-free image.

(b) Total rainfall of July was 30.9 mm (6.8% of the average).

(c) Mean temperature of July was 15.2°C.

(d) The maximum temperature at the day of imaging was 27.2°C, and the minimum is 8.9°C.

(e) The mean wind speed at the day of imaging was 8 knots.

(f) The sunshine hours of the image acquisition day was 13.5 hours.

It can be seen that weather at the day of image acquisition was sunny, warm, and dry. The relatively high temperature and low rainfall emphasises that soil at the imaging day was dry. Temperature range at the imaging day was high (18.3°C). Wind speed indicates that it was breezy. So, the remarkable weather condition for this image which may affect the spectral conditions of features was temperature. And lastly, weather conditions of the 10th July 1992 were as follows:-

(a) It was a cloud-free image.

(b) Total rainfall between 10th, June and 10th, July was 43.4 mm (65.9% of the average). Most of this amount of this rainfall was concentrated in July (39.7 mm or 91%).

(c) Mean temperature of between 10th, June and 10th, July was 13.9°C.

(d) Minimum temperature at the day of imaging was 10.4°C, and the maximum was 21.5°C.

(e) Wind speed at the day of imaging was 6 knots.

(f) sunshine duration was 12 hours.

It can be seen that weather at the day of imaging was bright and sunny. Temperature range is moderate (11.1°C), and wind is relatively calm. Soil was less moist than that of the 1985 image but more moist than that of the image of 1990.

3.5 Image Data Display

Digital image data have the form of digital numbers (DN). Each number represents a brightness value for an image area unit (spatial resolution) called pixel, and the size of this pixel varies from one imaging system to another. The purpose of the study is one of the major determinants of the pixel size to be used. For this study Landsat TM data are available over 7 bands.

Image displaying can be done in two ways; (a) Greyscale / Monochrome, and in this case only one band can be displayed. (b) Colour composite, in this case, the three main colours are used (blue, green, and red). Each colour is represented by a spectral wave-band. The use of the corresponding wave-bands of these colours (the visible wave-bands in the electromagnetic spectrum), results in a ***true colour*** image which looks like the actual colour of the earth surface. These bands in the TM remote sensing system are numbered 1, 2, and 3 and named as the blue, the green, and the red band respectively. As our eyes can deal with more colours than shades of grey, the use of coloured images increase the amount of information that can be displayed. When the combination of bands includes bands from outside the visible domain of the electromagnetic spectrum, the displayed images are known as ***false-colour composites***

(FCC). Each colour of the three represent an image of the scene, and the variations in the spectral response of features in these three wavebands cause colour differences which helps in features identification.

The selection of wave-bands to be displayed depends on ***first***, the general characteristics of the imaged area (agricultural, urban, or hydrological). ***Second***, the specific aim of data processing. The selection of bands to be displayed should aim to achieve the maximum image data discrimination. So, a good understanding of the spectral behaviour of each band and its interaction with different types of earth's surface is a fundamental matter. For agricultural scenes, different studies proved that a combination of band 3(0.63-0.69μm), band 4(0.79-0.90μm), and band 5(1.55-1.75μm) achieves the maximum discrimination between different agricultural land use \ land cover types (Fuller & Parsell, 1990, Armstrong, 1993, Shueb, 1990). So, the images of the study area were displayed using a false colour composite of these TM bands.

For better colour interpretation these bands were displayed in the following order:- Band 5(near infrared) was displayed as the blue colour. Band 4 is displayed as the green colour, and Band 3 was displayed with its actual red colour. The reason for this order of display is that first, displaying band 3 with its true colour reduces the colour composite confusion. Second, the display of the near infrared band 4 as the green colour enhances vegetation discrimination, because this band is very sensitive to vegetation reflectance.

Raw images generally contain defects and distortions that are due either to the sensing system or to natural processes such as earth rotation. Noise is mainly due to the malfunction of detectors, and geometric distortions result from the characteristics of the optical system and the relationship between the motion of the satellite and the earth. The former defects result in high frequency black stripes that negatively affect image interpretation, and cause a loss of information. The latter defects result in a rotated image, but do not affect the interpretability of the image, and it is preferred to be done after image classification because actually, image rectification can change the actual brightness values of features through resampling (Mather, 1987). To have better and more accurate image interpretation, the noise defects should be removed.

Remote sensing systems record the total reflectance of features within its field of view with different levels of energy including the atmospheric conditions, so the DN for the bulk of the scene are compressed to occupy the lower part of the reflectance range. This data compression results in a low contrast of colour and spatial details. So, a contrast enhancement is needed.

3.6 Image Pre-processing

Digital image processing has become increasingly important since the advent of the Landsat satellite system. It involves numerical analysis of digital images. Image Pre-processing includes all the operations which aim to improve the image interpretability. It involves the removal of noise such as errors of banding and striping, distortions, and calibration of image radiometry.

3.6.1 Contrast Manipulation

Contrast manipulation is the radiometric transformation of each pixel in the image, and aims to enhance the clarity, colour, and visual discrimination of low contrast image features, and consequently increase the accuracy of the image interpretation results (Drury, 1990). The contrast is the ratio between the highest and the lowest brightness value for a band.

Before any contrast manipulation is applied, it is necessary to examine the image histogram to form an idea about the statistical distribution of grey levels in an image in terms of the percentage of pixels having each grey level. Grey level varies according to types and number of image data components. Images with a poor spread of digital numbers display low contrast, while those with a wide spread of values have higher contrast. Figure (3:9) shows histograms for different types of scenes.

For agricultural scenes; types of crops and their calendar, season of image acquisition, and crop stage of growth are the major determinants of image contrast. For example, the image of the study area that was acquired on 31st May (late spring) has a lower contrast than the image of 10th, July (early summer)and of that of 1st of August (mid-summer). The reason, is that in spring most agricultural crops of the same family such as wheat and barley are in the same stage of growth, and the accumulated energy gained by both types of crops has not yet create higher contrast between these two types of crop. In July, the contrast of these crops is higher because barley leaves lose their water content at a higher rate than wheat and dry earlier. In August, the discrimination between these two crops is good because at this time barley is mostly harvested, while wheat is still not harvested. The shape of histogram is affected by the distribution of grey levels in the scene. Higher radiance levels in the scene result in an extended tail to the image histogram, and moderate radiance levels results in a normal (Gaussian) shaped histogram (Schowengerdet, 1983).

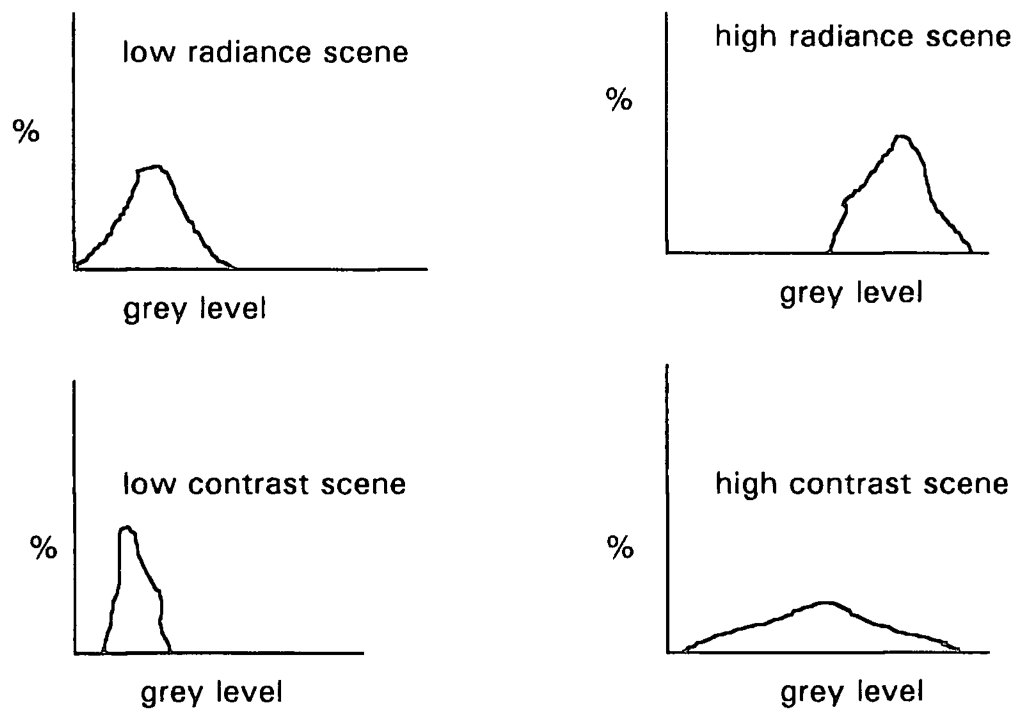


Figure (3:9): Histograms for different types of scenes

Source: Schowengerdet, 1983

3.6.1.1 Contrast Stretching

The choice of image enhancement method depends on the general characteristics of the image, and the purpose of this enhancement. So, more than one method can be used. ***Linear transformation*** increases the contrast of a displayed image by expanding the original grey level range to fill the dynamic range of the display device. To achieve a greater image contrast, some saturation can be accepted at both extremes of the output range unless important image structure is lost in the saturated areas, figure (3:10).

The most common non-linear transformation method is the ***histogram equalisation,*** the function of this enhancement method is that it reduces the contrast in the brightest and the darkest areas on one hand, and spreads out the brightness values of the middle grey levels towards the ends of the radiance scale (Schowengerdet, 1983). The most frequently occurring image values are spread out over a large portion of the output brightness levels from 0-255. The less frequency occurring brightness values in the image are assigned to a small portion of the output range, Figure (3:11).

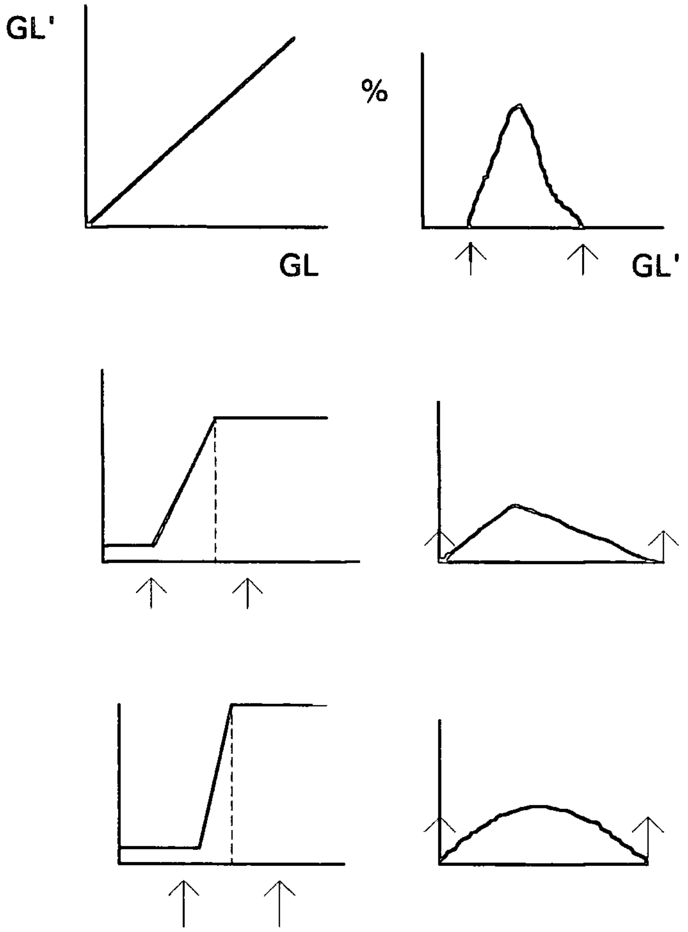
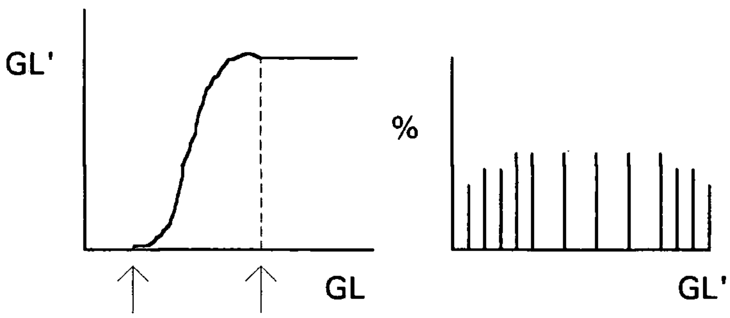


Figure (3:10): Linear contrast enhancement with variable saturation



Where GL is the original grey level, and GL' is the grey level after image stretching

Figure (3:11): Histogram Equalisation

Source: Schowengerdt, 1983

The histogram equalisation enhancement method was applied to the image of 31st May 1985. The reason for that is that the crops of similar reflectance such as wheat and barley occupy the middle of the grey level range. This method of contrast stretching spreads out this section over a larger portion of the radiance range, and consequently achieves better discrimination between these two crops.

For the images of 10th, July 1992 and 1st August 1990, a combination of linear stretching and histogram equalisation stretching is applied. The reason for that is that at these stages of crop growth; the contrast between similar crops which occupy the middle portion of the range is higher, so there is no need to saturate the range on one hand, or spread fully the middle grey levels towards the ends of the range on the other hand.

3.6.3 Image Filtering

The function of the image spatial filtering is that it emphasises or suppresses image data of various spatial frequencies. High spatial frequency images result in images of rough appearance, while low spatial frequency images result in smoother appearance. For agricultural scenes, farm size, topographic characteristics, crop types, and crop frequency in the scene are the major factors that determine the scene's texture. Scenes of small farms, considerable topographic variations, and crops and land cover of different families, result in high frequency images and vice versa. In the case of high frequency images filtering process is required.

Spatial filtering involves a number of techniques, and each technique has a certain effect on the image digital data either on screen or in disk to disk mode. The technique of spatial filtering to be applied depends on the physical and cultural characteristics of the image and the specific purpose of filtering. So, a pre-knowledge of the physical and cultural characteristics of the study area is essential. This knowledge can be gained from maps, aerial photographs, fields visits, or the spatial filtering process. Spatial filtering was applied on the study area for the scenes of high spatial frequency namely, Greencroft, Satley, and Edmundbyers. These three study areas have considerable topographic variations, relatively small farms, and high agricultural and land cover frequency. Edge filtering technique is applied to these areas.

Edge Filtering:- The use of this technique aimed to detect linear features in these images particularly natural drains, roads, fields edges or change in land use. Detection of these features helps in forming more accurate idea about physical and cultural characteristics of the study area. A more perfect image interpretation results are to a great extent dependant on the understanding of the study area characteristics. The principle of edge enhancement technique is illustrated in figure (3:12).

(a)

(b)

Figure (3:12): A contrast-stretched image of Landsat MSS band 7 data

(a) for part of Jordan reveal several faults which do not appear on local geological maps. In (b) the image shown in (a) has been subjected to an eastward directional filter.

Source: Drury, 1990

3.7 Factors that Affect Reflectance of Different Agricultural Plants

Agricultural plants have different optical properties, and the interaction of these plant canopies depend on these properties. The anatomical structure of leaves, the plant stage of growth, the leaf water content and the leaf geometry are the main determinants of the plant spectral behaviour. For a successful interpretation of agricultural remotely sensed data, the mechanism of interaction of electromagnetic radiation with plants and their environment must be known. The spectral portion of the electromagnetic spectrum which interests the study is the visible and the near and middle infrared portion (0.45-2.35 μm). In the visible portion (0.45-0.70 μm) especially in the blue and the red channels, reflectance is low (less than 15%) because most of the incident radiation is absorbed by chlorophyll pigments in plant leaves. In the near infrared portion (0.70-1.3μ m), reflectance reaches 50%, while absorbance is less than 10%. This level depends on the anatomical structure of leaves. In the short wave infrared portion (1.3-2.5μm), the optical properties of leaves are affected mainly by their water content. So, Thematic Mapper channels TM 5 and TM 7 are sensitive to leaf water content. Figure (3:13) describes the general vegetation reflectance over the visible and the near and the short infrared bands.

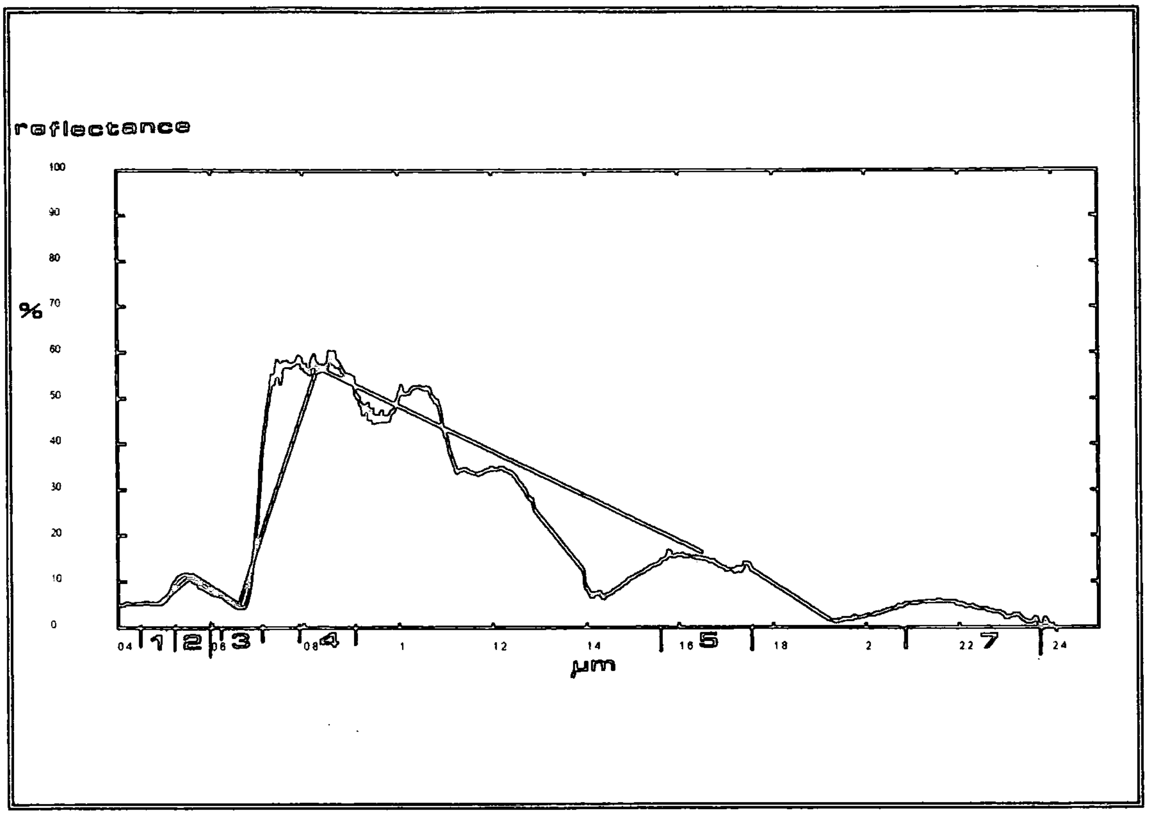


Figure (3:13): General vegetation canopy reflectance over the visible and the infrared domain, and the signature resampled by TM bands.

The optical properties of plants and vegetation are changeable. Factors that affect these properties can be divided into two general types:-

1. Sun-sensor geometry and atmospheric conditions, such as the angular relationship between solar radiation, agricultural objects, and sensing system, weather conditions...etc .

2. Target geometry and its conditions, such as underlying soil, local topography, crop row orientation, leaf age, and canopy geometry.

Sun-sensor geometry and atmospheric conditions:- The angular relationship between solar radiation, targets, and sensing system involves solar elevation, zenith view angle, and size of the viewed area.

Solar elevation affects reflectance of plant canopy by determining the ratio between shadowed and illuminated surfaces in the remotely sensed areas. This effect is of two time scales, the day and the year. The relationship between the solar elevation and the plant canopy reflectance varies from the visible to the infrared. This variation depends on type of land cover. Zenith view angle affects the plant canopies reflectance through its determination to soil \ vegetation ratio. So, its effect varies from the visible to the near infrared domain. In the visible, the reflectance increases with low inclination of the view axes, while in the near infrared, the reflectance increases with high inclination of the view axes. Size of the viewed area affects the reflectance of plant canopies through its effect on the variation coefficient. When the size of the pixel increases the coefficient of variability decreases.

Wind affects the plant canopy by changing its geometry. The size of this effect depends on the type of plant and the wind speed.

Target geometry and its conditions:- The reflectance of plant canopies is affected by type of soil cover, its percentage, and its optical properties. Crop row orientation and its relationship with the incident radiation and the viewing axis affects the soil \ vegetation ratio, and so affects the plant canopies reflectance. Canopy geometry is the total leaf inclination angle. This inclination angle varies from one crop to another, and its effect is dependent on the part of plant canopy which interacts with the incident radiation. So, the area of the sensed leaves is decided by their inclination angle.

3.8 Conclusion

The TM data used for this research are more suitable for agricultural land use mapping than MSS data. The reason is because fields in the study area are relatively small, and the spatial resolution of this data is relatively high (79m), while that of the TM data is 30m. Weather conditions of the images were ideal for optimising image interpretation and analysis despite some haze existed on the coast. Image filtering can be considered an important source of data which helps to understand the physical and morphological structure of the image.

CHAPTER FOUR

Chapter 4 : Image Classification

4.1 Introduction

Image classification is a major part of land use mapping in remote sensing. The accuracy of resultant land use maps depends very much on this part. Classification can be described as a form of pattern recognition. This recognition is of two types:- spatial and spectral. Spatial recognition involves analysis of pattern texture, size, shape, and location. Spectral pattern recognition involves the digital analysis of reflectance measurements of each pixel over different wavebands. These two types of pattern recognition can not be treated individually, and a combination of them improves the accuracy of classification. The main aim of classification is to group all pixels in an image into land use \ land cover classes and produce thematic land use maps.

In this study, a temporal pattern recognition is used. The three dates used in the study are of different seasons to improve the agricultural feature identification.

Two major techniques for digital image classification are normally used. One is called ***supervised classification*** and the other is called ***unsupervised classification.*** Implementation of these techniques is by software written for digital computers. The image processing system used for classification of the study area is called TERRAMAR MICROIMAGE (Terra-Mar, 1991).

4.2 Supervised Classification

This classification technique requires a training set of well-known conditions to the image analyst. These training fields are selected to be representative of the land cover types of the study area. They are allocated on their correspondent locations on an image. Each pixel is categorised to the class it most closely resembles. Pixels of dissimilar spectral properties are labelled as unknown and have the black colour. Percentage of unknown pixels reflects the representation of the training set used of the image classified. After the categorisation of each pixel to its class, the classified image can be produced in the form of a thematic map. Tables of statistical description of scenes and subscenes can be produced and analysed, or the classified image can be put into a Geographical Information System (GIS) for further analysis. Four major methods of supervised classification are normally used:-

1. Minimum-Distance to Mean Classifier:- The principle of this method is that each pixel in the image is classified to the nearest mean DN of a class in the training areas. The limitation of this classifier is that it is insensitive to different degrees of variance of the spectral properties of each class. So, this classifier is inappropriate for images of having classes close to one another and which have high variance such as scenes of intensive vegetation especially in the period of crop foliation.

2. Parallelepiped Classifier (Box Classifier):- Unlike the previous classifier, this classifier is sensitive to class variance since it takes into consideration the range of values in each class training set. The limitation of this classifier is that it is not sensitive to class correlation. So, this classifier does not take into consideration the problem of overlapping classes.

3. Parallelepiped Classifier with Stepped Box Borders:- This classifier is mostly the same as the previous one. The difference between them is that this classifier tries to overcome the problem of classes overlapping by stepping the box borders in the overlapped areas.

4. Maximum Likelihood Classifier:- This classifier method is the most popular classification method because it has the solution for the shortages of the previous methods;

(a) It calculates the mean vector of each class in each band.

(b) It calculates variance for each class, and

(c) It calculates correlation percentage for each class in the training set. These calculations are based on the assumption that the data are normally distributed. So, this classifier is described as "Guassian Classifier".

The principle of this classifier work is that it delineates ellipsoidal and equapropability contours in the scatter diagram, figure (4:1). It can be seen from the shape of the contours that this classifier is sensitive to both variance and covariance. The spread of pixels around each mean vector can be described using a probability function. Each pixel in the data set is allocated to the class which has the highest probability of membership. For example, the highest probability of pixel p2 membership in the figure is the class soil. "As every spectral response has a probability, however low, of representing a class, no pixels are left out in the cold" (Curran, 1985). For example, the lone pixel p1 in the figure below would be classified as urban.

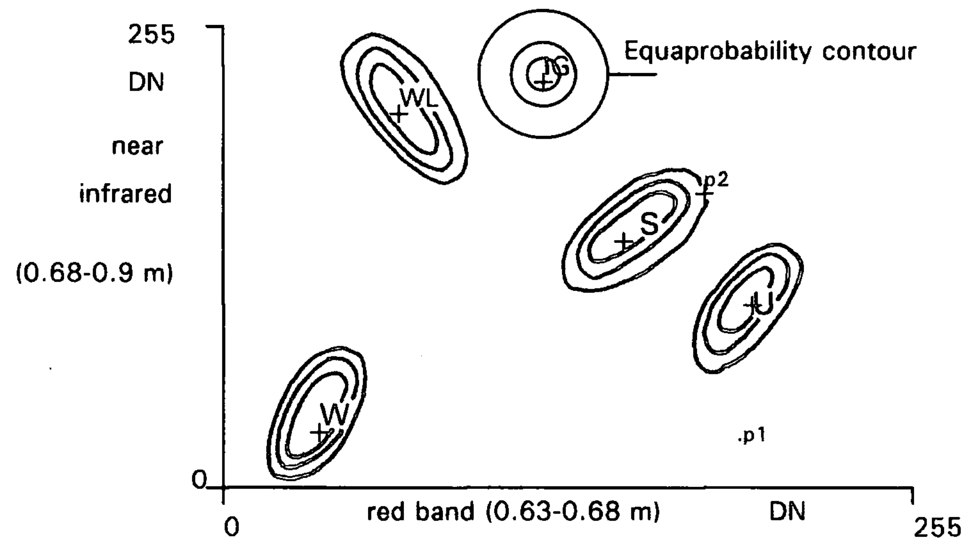


Figure (4:1): Principe of the Maximum Likelihood Classifier

Where W is water, WL is woodland, IG is improved grass, S is soil, U is urban, + is the mean vector, and p1 and p2 is pixel number.

4.3 Unsupervised Classification

While supervised classification uses training set as representative of image data, unsupervised classification divides the DNs into categories or groups. Each group consists of a number of pixels having homogeneous spectral properties, and well separated spectrally from other groups. Identity of these categories cannot be known unless compared with reference data such as maps or aerial photographs. So, the main difference between the supervised and the unsupervised classification is that in the supervised classification; the image is trained by field data, while in the unsupervised one; image digital data is applied to reference data. The advantage of the unsupervised classification over the supervised is that sometimes training set may miss some classes, especially when the scene contains numerous types of data, and in the case of multi-temporal studies. Some farmers do not keep records of land use for previous years. The unsupervised classification facilitate the recognition of these missing classes.

4.4 The Applied Method

The classification method applied on the study area is the ***Maximum Likelihood Classifier,*** and the reason for that in addition to the mentioned advantages of this classifier over other methods is;

(a) The study area is within County Durham, so it is easy to access to it to carry out the field work and establish training sets.

(b) Farmers are familiar with such research studies, so they mostly do not hesitate to cooperate.

(c) Farmers in most cases keep records of land use in previous years.

4.4.1 Training Set Selection

This part of image classification involves the following steps:-

1. Selection of farms:- Two farms in each study area were selected. The selection of these farms took into consideration; (a) location of farms is intended to be well distributed through the study area to represent different land use patterns, and different physical characteristics of the area which affects the spectral response of different agricultural crops. (b) It is presumed that fields surrounding belong to these farms, so farms of large size fields are selected to get pixels representative of different agricultural crops.

2. Ordnance Survey maps:- large scale OS maps for each study area at a large scale were plotted using ARC \ INFO package. These maps were digitised, edited and topologically built into the field mapping stage. Each date (of the three) is represented by a map to allocate the training fields on it. These maps contained administrative boundaries, field boundaries, and location of farms to be visited. In addition to parish maps, maps of fields outside parish boundaries were used in case farmers have farms outside the borders of the parish. Each training field was labelled by its land use type at each image acquisition date. Labelling these fields took the form of letters. For example, winter wheat is given the label '*ww*', and so on.

3. Methods of assigning training sets:- Three methods are used to allocate the training fields on maps. These methods are:-

(a) Interviewing farmers:- Two farmers in each parish were interviewed and all fields belonging to his farm were numbered on the three maps of the three study dates, then labelled with their actual land use at that date. Most farmers kept records for the years 1990 and 1992, and those who did not keep records for these two dates were able to remember crop type grown in these years. The problem rose for the year 1985; some farmers did not keep records of land use for this year and they hardly remember types of crops grown in that year. So, information obtained from these farmers were given a special sign for further verification. In addition, farmers are questioned about some specific conditions of crop growing. They are questioned about the agricultural calendar of some of uncommon crops in the region, such as oats, sheep rape, kale and swedes. They are questioned also about types of fertilisers they use, and the period of adding these fertilisers.

(b) Ordnance Survey maps:- This method was applied on the land cover types which have a relatively static status such as built-up areas, woodland, water bodies, rough grass, and moorland.

(c) Field Survey:- This method was carried out during the field mapping stage. It was used to verify the accuracy of the training areas selected by maps, and to record land use changes that have occurred in the area since the production of these maps; such as changes in field boundaries, and afforestation and deforestation activities. Notes are written about the detailed conditions of each area such as density and characteristics of location.

Each parish for each date is dealt with independently. This approach of data manipulation has the following advantages:- 1. The problem of the uncertainty of the accuracy of some training fields is overcome by applying what can be called a "spectral informational exchange". Training fields missed in one parish is detected by information of other parishes. 2. Conditions of one area such as atmospheric conditions, topographic variations, and cultivation conditions are not affected by other areas' conditions.

3. Processing smaller areas reduces spatial differences and creates a spatial and spectral homogeneous scene, and consequently facilitates classification process and improves its accuracy.

4. Training areas included in classification and their annotation key:- These training areas are of two types:-

1. Supervised training areas:- They are the areas which are assigned by one or more of the mentioned methods (interviewing farmers, maps, and field work). These training areas for the three dates are:-

Table (4:1): The supervised training classes included in image classification

No	Land use \ Land cover class	A. Key	No	Land use \ Land cover class	A. Key
1	Coniferous Woodland	CWL	12	Swedes and Kale	S+K
2	Deciduous Woodland	DWL	13	Sheep Rape	SR
3	Mixed Woodland	MWL	14	Improved Grass -temporary-	IG -T-
4	Winter Wheat	WW	15	Improved Grass -permanent-	IG -P-
5	Winter Barley	WB	16	Unimproved Grass	UG
6	Spring Barley	SB	17	Moorland	M
7	Winter Barley -Cut-	WB -cut-	18	Ploughed and Sown	P+S
8	Oats	O	19	Unimproved Grass + Coniferous W.	UG+CWL
9	Oilseed Rape	OSR	20	Quarries and Bare Soil	Q+BS
10	Oilseed Rape -Cut-	OSR -cut-	21	Sand	S
11	Linseed	LS	22	Water Bodies	W
			23	Urban areas (built-up areas)	U

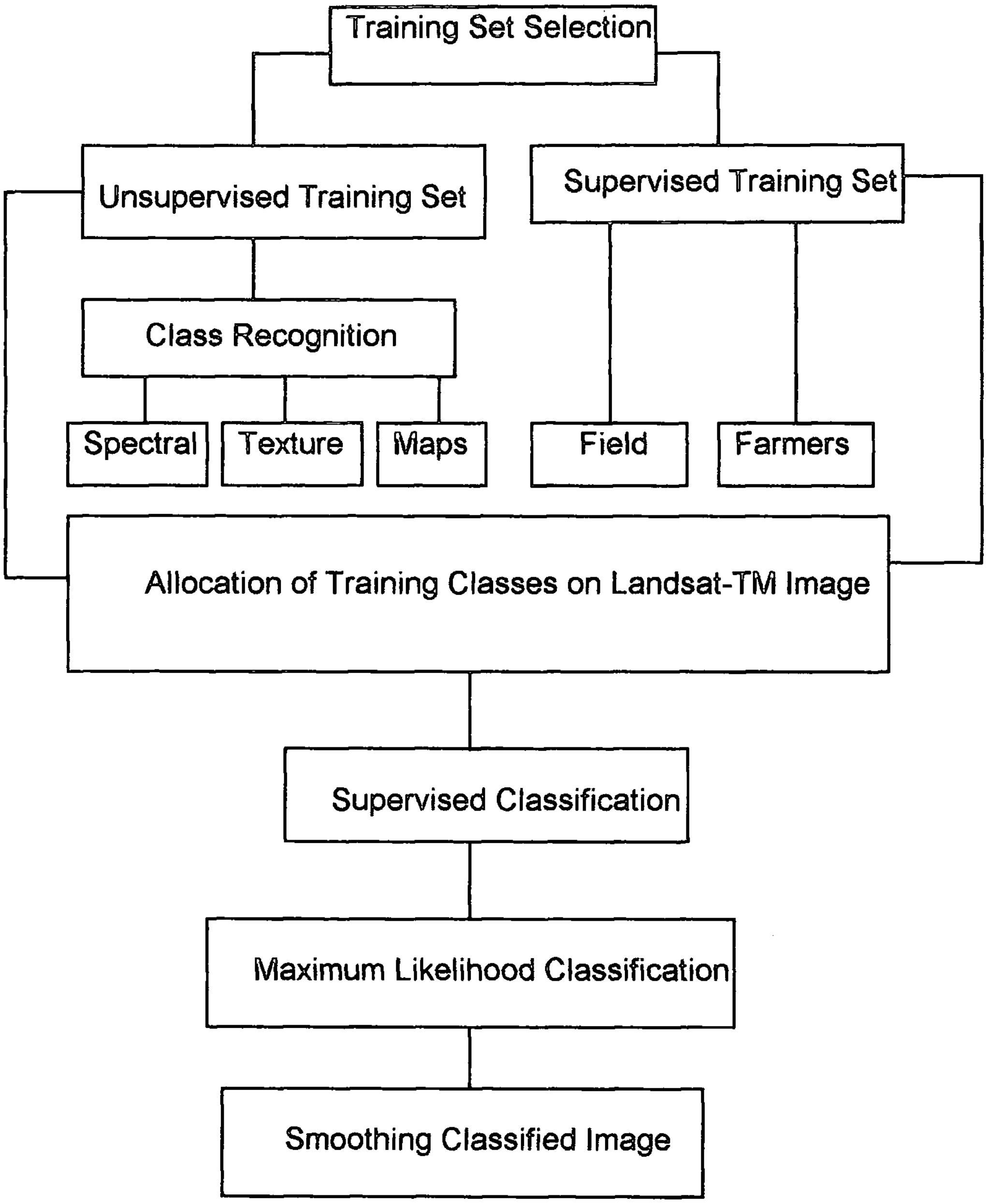


Figure (4:2): Flowchart for image classification

2. Unsupervised training areas:- They are the areas which are not considered in the supervised training set and have reflectance different from the supervised training set. They are treated as independent classes because images and reference maps show that they occupy full fields. Identification of the classes of these fields is achieved by three means:-

(a) spatial recognition, each unclassified field is compared with the reference data available mainly large scale maps(1:10,000), then given a grade of probability.

(b) spectral recognition; a statistical report including the minimum, the maximum, the mean, the standard diviation, and a matrix of variance\covariance for each unclassified field is produced. This statistical report is compared with the statistical report of each supervised training fields and given a grade of probability.

(c) textural recognition; texture or roughness of these unknown fields is compared with those of supervised training fields, then given a grade of probability.

(d) Grade average probability of the three probabilities is calculated for each unknown field, then assigned to the class fits it best. Table (4:2) illustrates the idea. Conditions of this field are as follows:- (1) It is a large field. (2) It is located in a flat topography. (3) It has a regular straight boundaries.

Table (4:2):- Methodology of unknown fields class detection

Class	Spatial Probability	Spectral Probability	Textural Probability	Average Probability %
Improved Grass	5	0	0	16.7
Arable Crops	8	0	0	26.7
Unimproved Grass	1	0	0	3.4
Urban (Built-up)	0	8	8	53.4
Woodland	0	0	0	0
Ploughed and Sown	5	7	7	63.4

(e) The weight of each factor can be decided according to its importance in the study area. In this example, the three factors are given equal weight; so calibration of the result is required. It can be seen from the average probability of this unknown field class that there is a competition between built-up class (53.4%) and the ploughed and sown class (63.4%) on this field. But details of both percentages can give the decision; 1. The spatial probability (0% for the built-up class, and 50% for the ploughed and sown class) provides a strong indication that it is an agricultural field. 2. The spectral and the textural probability is high for both classes but closer to built-up areas. 3. The spatial analysis decided that this unknown area is an agricultural field and has a texture and reflectance closer to buildings. So, this field is assigned as ploughed area. On the other hand, the probability of being this field ploughed for arable cropping more than grass sowing (26.7% and 16.7% respectively). The same procedure is applied on the rest of unknown fields.

Table (4:3):- Unsupervised training areas included in classification and their annotation key

No	Class	Annotation Key
1	Fallow	F
2	Bare Soil (light)	BS. light
3	Bare Soil (dark)	BS. dark
4	Spring Wheat	SW
5	Ploughed Land	P
6	Mixed Land Cover	MLC

*5. **Generalisation of similar classes:-*** Classes that have the same thematic description but do not have the same reflectance are given the same colour to be treated as one class in results analysis. These classes are:-

(a) Improved grass (temporary) and improved grass (permanent). They are classified as improved grass.

(b) Bare soil (light) and bare soil (dark). They are classified as bare soil.

*6. **Training areas allocation on image:-*** Training data collected by different methods mentioned are divided into two sets:-

(a) training areas for supervised classification.

(b) The rest collected data and the field mapping data are used for classification accuracy assessment. So, the accuracy assessment method will be the grid-by-grid overlay method combined with the deductive method (see ch. 5).

Availability of sufficient number of training fields for different categories varies from one crop or vegetation type to another. For the types of crops which are common in the region such as arable crops (cereals) and improved grass, it was possible to record a sufficient number of training areas for the purpose of training and testing. But for those crops not common in the region such as sheep rape, linseed, kale and swedes, it was not possible to collect enough sample data for both training and independent accuracy assessment.

Allocation of training areas in the imagery took into account the following considerations:-

1. Spatial distribution; from each farm visited one field for each class is selected, so each class is represented by two fields (when available) well distributed through the image.

2. Field size; largest fields of each class are selected to represent different conditions of fields as possible.

3. Tree density; this is applied on woodland. Training areas of this land cover classes are selected from areas of different densities to represent the land cover class as possible. Woodland in some study areas such as Edmundbyers are not dense enough and mixed with other kinds of land cover mainly unimproved grass, so this may affect its representation as a woodland class.

4. Class purity, this approach is applied on the built-up urban class. It was not possible to have pure pixels of built-up areas within the administrative boundaries of parishes, because the area is mainly agricultural. Built-up areas are mostly farm buildings, so they are surrounded with vegetational cover. This resulted in a textural and spectral confusion between these areas and ploughed and sown areas. To reduce the confusion between these two classes; one mixed training area from the parish and another pure

training area from outside the boundaries of the parish are selected. The ratio between the pure and the impure training areas was experimental.

Figure (4:3): Allocation of training areas on image (Satley)

4.4.2 Selection of Bands for Image Classification

This stage of image classification is a fundamental one, and to a great extent the success of classification depends on it. The optimum choice of wavebands for image classification varies according to the components of the scene, and the interaction of these components with these bands independently and together. The nature purpose of the study dictates the appropriate bands to be used, but, in general, this selection should achieve the following results:-

(a) Optimum spectral discrimination between different types of land cover, especially those of similar spectral properties.

(b) Optimum textural discrimination and good colour interpretability.

To achieve these two points in this multi-temporal study; ***first, correlation matrices of each study area for the three dates are studied. Second, correlation matrices of major land cover training areas are studied. Then the weakly correlated wavebands are selected.*** An example of subscene statistics is taken from the Hett subscene. The reason for selecting this subscene as an example is, (1) intensive agriculture exists in this area, and the main components of the study areas are agricultural. (2) most agricultural types are represented in this area. (3) main annual agricultural crops are represented over the three dates, so a study of agricultural seasonal change for a subscene can be carried out.

4.4.2.1 Statistics for Hett Subscene in Three Dates

FIGURE (4:4): MINIMUM, MAXIMUM, AND MEAN REFLECTANCE OF HETT SUBSCENE OF THE IMAGE OF MAY, 1985

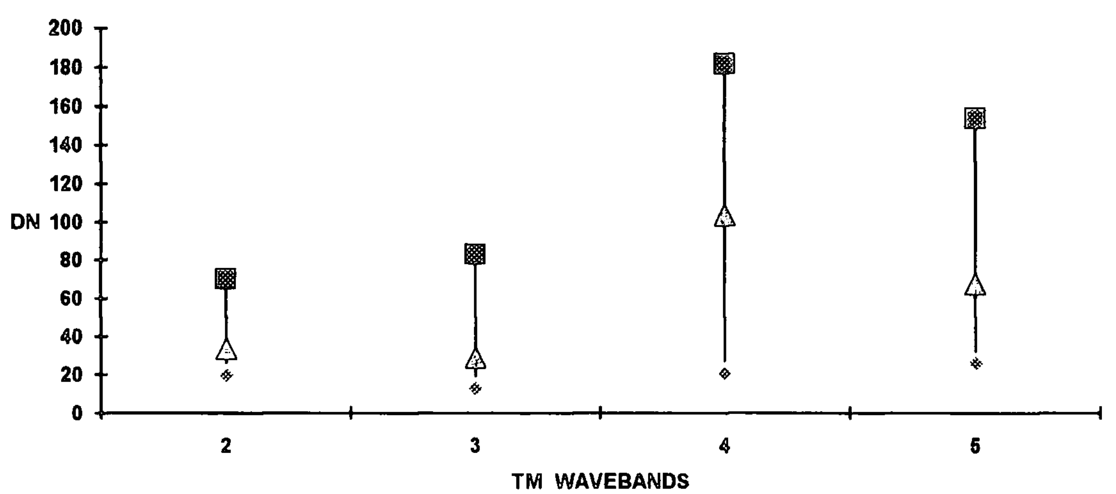


Table (4:4):- Wavebands correlation matrix for Hett subscene

of the image of May 1985

Band	2	3	4	5
2	1.0	0.84	- 0.20	0.52
3	0.84	1.0	- 0.41	0.56
4	- 0.20	- 0.41	1.0	- 0.19
5	0.52	0.56	- 0.19	1.0

FIGURE(4:6): MINIMUM, MAXIMUM, AND MEAN REFLECTANCE OF HETT SUBSCENE IN AUGUST, 1990

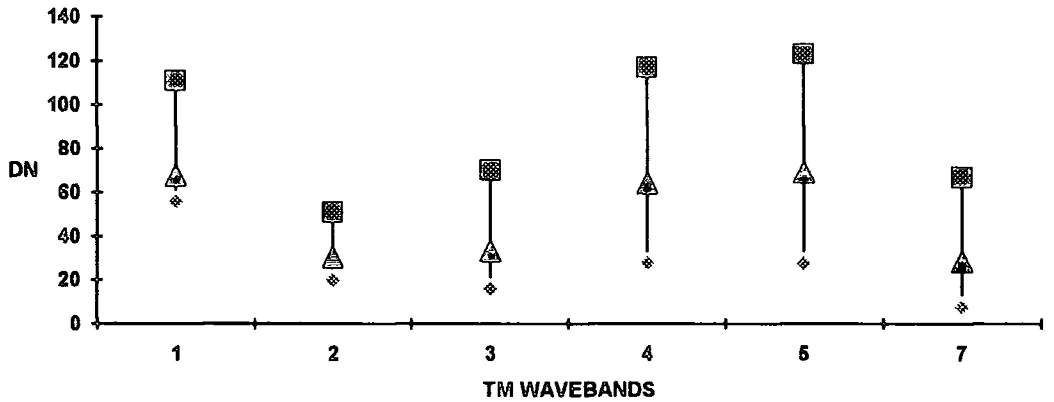
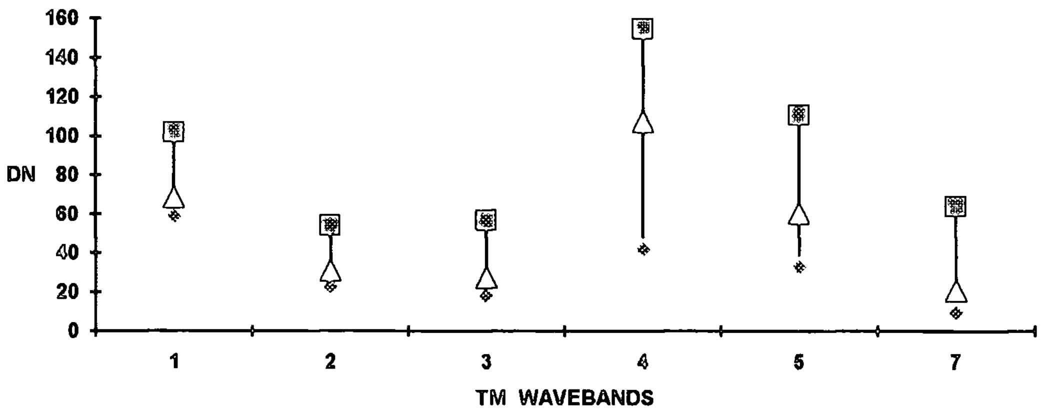


Table (4:5):- Wavebands correlation matrix for subscene of Hett for image of August 1990

Band	1	2	3	4	5	7
1	1.0	0.89	0.84	- 0.02	0.66	0.81
2	0.89	1.0	0.94	0.02	0.69	0.80
3	0.84	0.94	1.0	- 0.21	0.61	0.77
4	- 0.02	0.02	- 0.21	1.0	0.26	0.01
5	0.66	0.69	0.61	0.26	1.0	0.93
7	0.81	0.80	0.77	0.01	0.93	1.0



FIGURE(4:6): MINIMUM, MAXIMUM, AND MEAN REFLECTANCE OF HETT SUBSCENE FOR THE IMAGE OF JULY, 1992

Table (4:6):- Wavebands correlation matrix for Hett subscene of the image of July 1992

Band	1	2	3	4	5	7
1	1.0	0.68	0.76	- 0.41	0.54	0.82
2	0.68	1.0	0.96	0.05	0.36	0.50
3	0.76	0.96	1.0	- 0.15	0.33	0.59
4	- 0.42	0.05	- 0.15	1.0	0.02	- 0.47
5	0.54	0.36	0.33	0.02	1.0	0.75
7	0.82	0.50	0.59	- 0.47	0.75	1.0

Table (4:7):- Best bands for discrimination for three dates

	Best 2 bands						Best 3 bands						Best 4 bands						Best 5 bands					
Date \ Bands	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**3**	**4**	**5**	**7**
May 1985			+	+					+	+	+			+	+	+	+							
August 1990			+	+					+	+	+			+	+	+	+			+	+	+	+	+
July 1992	+			+			+		+	+			+		+	+	+		+		+	+	+	+
All dates			+	+					+	+	+			+	+	+	+			+	+	+	+	+

4.4.2.2 Statistics for Major Land Cover Types

Since land cover of relatively static annual status does not have a fundamental impact on wavebands correlation such as coniferous woodland; one date of these land cover types is considered in producing correlation matrix for these types. For annual agricultural crops and grass, correlation matrix for wheat in the three dates is produced as a representative of agricultural crops except oilseed rape for it has different spectral properties in its flowering stage.

Table (4:8):- Waveband correlation matrix for coniferous woodland

	1	2	3	4	5	7
1	1.0	0.63	0.59	0.68	0.71	0.62
2	0.63	1.0	0.68	0.88	0.83	0.79
3	0.59	0.68	1.0	0.64	0.75	0.77
4	0.68	0.88	0.64	1.0	0.88	0.77
5	0.71	0.83	0.75	0.88	1.0	0.91
7	0.62	0.79	0.77	0.77	0.91	1.0

Table (4:9):- Waveband correlation matrix for deciduous woodland

Band	1	2	3	4	5	7
1	1.0	0.34	0.32	0.16	0.41	0.41
2	0.34	1.0	0.68	0.63	0.79	0.70
3	0.32	0.68	1.0	0.48	0.73	0.76
4	0.16	0.63	0.48	1.0	0.67	0.52
5	0.41	0.79	0.73	0.67	1.0	0.88
7	0.41	0.70	0.76	0.52	0.88	1.0

Table (4:10):- Waveband correlation matrix for

wheat in May 1985

Band	2	3	4	5
2	1.0	0.37	0.16	0.06
3	0.37	1.0	0.22	0.38
4	- 0.16	0.22	1.0	0.35
5	0.06	0.38	0.35	1.0

Table (4:11):- Waveband correlation matrix for wheat in July 1992

Band	1	2	3	4	5	7
1	1.0	0.19	0.50	- 0.16	0.29	0.38
2	0.19	1.0	0.67	0.08	0.60	0.74
3	0.50	0.67	1.0	- 0.29	0.58	0.54
4	- 0.16	0.08	- 0.29	1.0	0.34	0.15
5	0.29	0.60	0.58	0.34	1.0	0.68
7	0.38	0.74	0.54	0.15	0.68	1.0

Table (4:12): Waveband correlation matrix for wheat in August 1990

Band	1	2	3	4	5	7
1	1.0	- 0.12	0.09	- 0.20	- 0.17	- 0.04
2	- 0.12	1.0	0.09	0.15	- 0.18	0.0
3	0.09	0.09	1.0	- 0.38	- 0.08	0.35
4	- 0.20	0.15	- 0.38	1.0	0.39	- 0.32
5	- 0.17	- 0.18	- 0.08	0.39	1.0	0.31
7	- 0.04	0.0	0.35	- 0.32	0.31	1.0

Table (4:13):- Waveband correlation matrix for oilseed rape in July 1992

(flowering peak)

Band	1	2	3	4	5	7
1	1.0	0.34	0.39	0.21	0.08	0.13
2	0.34	1.0	0.89	0.70	0.51	0.14
3	0.39	0.89	1.0	0.74	0.51	0.18
4	0.21	0.70	0.74	1.0	0.31	0.10
5	0.08	0.51	0.51	0.31	1.0	0.31
7	0.13	0.14	0.18	0.10	0.31	1.0

Table (4:14):- Waveband correlation matrix for bare soil

Band	1	2	3	4	5	7
1	1.0	0.19	0.64	- 0.61	0.25	0.62
2	0.19	1.0	0.47	0.39	0.51	0.34
3	0.64	0.47	1.0	- 0.37	0.34	0.67
4	- 0.61	0.39	- 0.37	1.0	- 0.15	- 0.52
5	0.25	0.51	0.34	- 0.15	1.0	0.64
7	0.62	0.34	0.67	- 0.52	0.64	1.0

Table (4:15):- Waveband correlation matrix for quarries

Band	1	2	3	4	5	7
1	1.0	0.95	0.94	0.78	0.81	0.82
2	0.95	1.0	0.99	0.85	0.83	0.85
3	0.94	0.99	1.0	0.85	0.81	0.84
4	0.78	0.85	0.85	1.0	0.82	0.77
5	0.81	0.83	0.81	0.82	1.0	0.95
7	0.82	0.85	0.84	0.77	0.95	1.0

Table (4:16):- Waveband correlation matrix for urban (built-up) areas

Band	1	2	3	4	5	7
1	1.0	0.62	0.42	- 0.1	- 0.09	0.27
2	0.69	1.0	0.86	0.27	0.21	0.54
3	0.42	0.86	1.0	0.30	0.33	0.61
4	- 0.10	0.27	0.30	1.0	0.71	0.55
5	- 0.09	0.21	0.33	0.71	1.0	0.76
7	0.27	0.54	0.61	0.55	0.76	1.0

Table (4:17):- Waveband correlation matrix for water bodies

Band	1	2	3	4	5	7
1	1.0	0.08	0.16	0.06	- 0.04	0.01
2	0.08	1.0	0.04	- 0.03	0.11	0.03
3	0.16	0.04	1.0	0.09	0.18	0.02
4	0.06	- 0.03	0.09	1.0	0.13	0.02
5	- 0.04	0.11	0.18	0.13	1.0	0.09
7	0.01	0.03	0.02	0.02	0.09	1.0

Table (4:18):- Best bands for discrimination of major classes of the study area

Land use \ Land Cover Class	Best 2 bands	Best 3 bands	Best 4 bands	Best 5 bands
Coniferous Wood	1, 3	1, 3, 4	1, 3, 4, 5	1, 2, 3, 4, 5
Deciduous Wood	1, 4	1, 3, 4	1, 2, 3, 4	1, 2, 3, 4, 7
Wheat (May)	2, 4	2, 4, 5	2, 3, 4, 5	2, 3, 4, 5, 7
Wheat (July)	3, 4	2, 3, 4	2, 3, 4, 5	2, 3, 4, 5, 7
Wheat (August)	3, 4	1, 3, 4	1, 2, 3, 4,	1, 2, 3, 4, 7
Oilseed Rape (flowering)	1, 5	1, 5, 7	1, 4, 5, 7	1, 3, 4, 5, 7
Bare Soil	1, 4	1, 3, 4	1, 3, 4, 5	1, 3, 4, 5, 7
Quarries	4, 7	1, 4, 7	1, 4, 5, 7	1, 3, 4, 5, 7
Urban (built-up) Areas	1, 4	1, 4, 5	1, 3, 4, 5	1, 3, 4, 5, 7
Water Bodies	1, 5	1, 2, 5	1, 2, 4, 5	1, 2, 4, 5, 7
ALL CLASSES	**1, 4**	**1, 3, 4**	**1, 3, 4, 5**	**1, 3, 4, 5, 7**

4.4.2.3 Summary of Band Selection

1. Correlation matrices of subscenes for the three dates emphasises that bands 2, 3, 4, and 5 are the best for discrimination.

2. Correlation matrices of different land cover classes of the study area emphasise that bands 1, 3, 4, and 5 are the best for discrimination.

3. Subscenes statistics for the three dates show that correlation between bands 2 and 3 on one hand, and between band 5 and 7 on the other hand is strong. So, the inclusion of these bands together in classification will not add much information and reduces the contrast between different agricultural features of the study area.

4. Despite the high divergence between band 1 and band 4; high scatter factor on band 1 and its sensitivity to atmospheric conditions reduces its efficiency for agricultural studies.

5. Despite the availability of band 6 in two of the three dates, this band is not used because of its low spatial resolution (120 m).

6. For the above mentioned reasons, it is found that, in general, bands 3, 4, and 5 are the best bands for image classification in the study areas for the three dates.

7. For areas of larger fields and more vegetation such as Hett; band 2 is added to the three bands mentioned in classification for its importance in biomass assessment.

8. It is found that in the areas of high spatial frequency, smaller fields, and more topographic variations such as Greencroft; scatter on bands 2 and 3 is relatively high. The use of these bands in classification resulted in a speckled, noisy image. So, these bands are replaced by band 7 taking into account the lowest probability limit for each training class.

4.4.3 Subscene Statistics Analysis for the Three Dates

Before making any spectral analysis for Hett subscene in the three dates, the crop calendar in County Durham emphasises the following fundamental agricultural concepts in the three dates:-

(a) In May: First, winter crops will be in the optimum foliation stage and crop leaves have their maximum coverage. Second, spring crops will be freshly sown, and soil participation in fields reflectance is more than that of vegetation. Thirdly, oilseed rape will be in the middle of the flowering stage. Fourthly, neither wheat or barley is in grain. Fifthly, deciduous trees will be in full leaf, but their leaves did not yet reach the maximum water content. So, in May, leaves of deciduous trees have a lighter tone. And lastly, temporary grass will be in the same stage of growth of cereals.

(b) In July: First, all cereal crops will be in the fourth quarter period of their growing season. This means that these crops at this stage are in grain and their leaves start yellowing rapidly, especially barley. Second, oilseed rape will be at its maximum flowering stage. Third, spring crops will have a maximum leaf coverage and contain more foliar moisture than winter crops, and lastly, deciduous trees leaves will be at the stage of their maximum water content and have a rough and dark surface.

(c) In August: First, most winter barley, oilseed rape, and temporary grass fields are harvested. Second, winter wheat and spring crops are still standing in the field. Third, deciduous trees will still be in full leaf, but the percentage of leaves dropped off starts to increase and leaves are in their roughest and darkest stage.

From these fundamental agricultural concepts, spectral analysis of subscene can be carried out:-

1. It is supposed that reflectance in the red band (0.63-0.69μm) for the subscene of May to be the least of the three subscenes, for leaf chlorophyll representation in this period reaches its peak. But, figures 4.4-4.6 show that the subscene of July has least reflectance in the visible red band for the three dates, despite the solar elevation of this scene being higher than that of the other two scenes. The explanation for this is first, the subscene of May contain fields which are freshly sown with spring crops, so the increase participation of soil in fields reflectance affected the pure vegetational appearance of the area. Second, the spring crops in July are in their maximum leaf coverage. Lastly, apart from arable crops; the chlorophyll representation of other types of land cover especially permanent grass is still high.

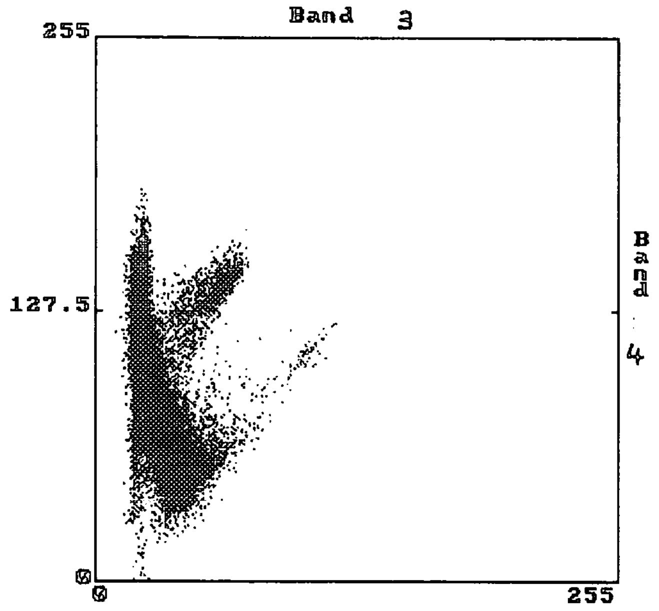
2. On the contrary, it is supposed that reflectance on band 4(0.79-0.90μm) to have the highest reflectance percentage in May, because it is sensitive to greenness. But for the same reasons mentioned in the first point, the maximum reflectance on band 4 is for the July 1992 subscene.

3. It can be seen from figures 4.4-4.6 also that reflectance on band 2(0.52-0.60μm) and band 5(1.55-1.75μm) increased by the increase of soil participation in fields reflectance.

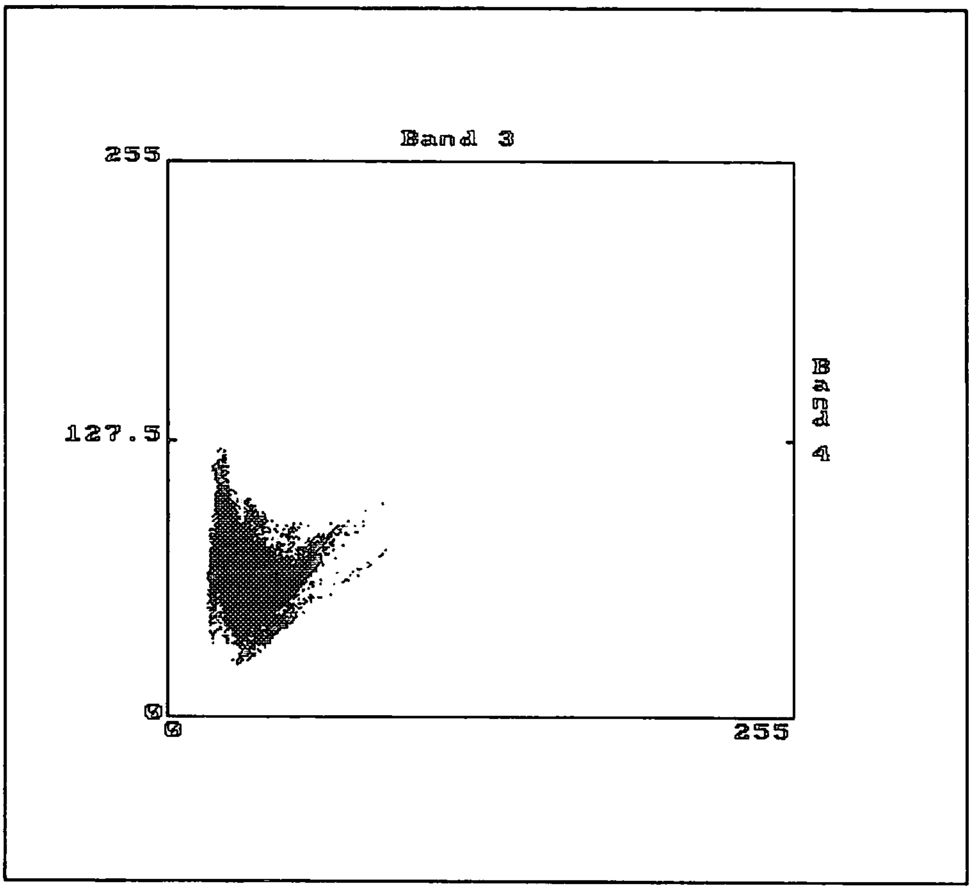
4. Reflectance in band 5(1.55-1.75μm); is highest over the scene of August. This can be explained by the fact that crop leaf water content at this stage is least, and soil and hay participation in fields reflectance is highest.

5. The scatter diagrams 4:7, 4:8, and 4:9 for Hett subscene show how reflectance on the infrared band 4 decreases from May and July to August.

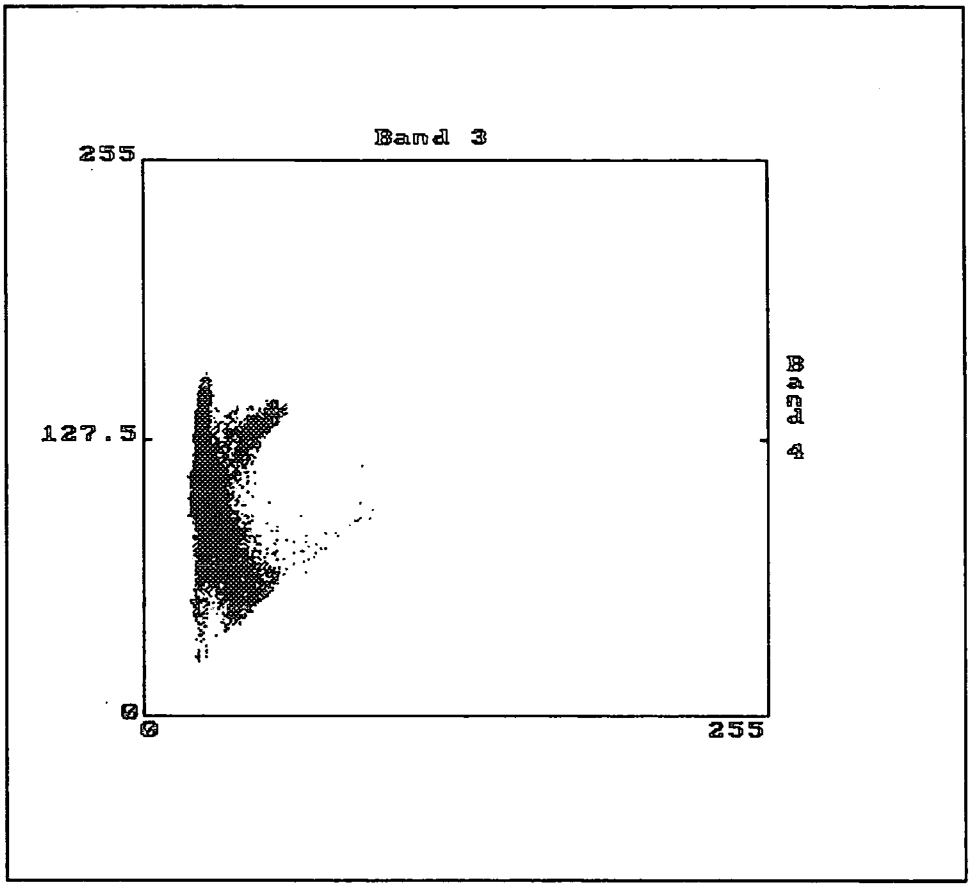
Figure(4:7): Scatter diagram for Hett subscene in May 1985



Figure(4:8): Scatter diagram for Hett subscene in Aug 1990



Figure(4:9): Scatter diagram for Hett subscene in July 1992



4.4.4 Analysis of Training Areas Statistics

Confusion may occur in training class analysis, because each training class has more than one reflectance value for each date (one to six values; where six is the number of the study areas). To avoid this confusion, the average reflectance of the means for each class over the six study areas is considered.

Example : $vr(cwl) = \frac{mr(cwl1) + mr(cwl2) + mr(cwl3) + mr(cwl4) + mr(cwl5) + mr(cwl6)}{6}$

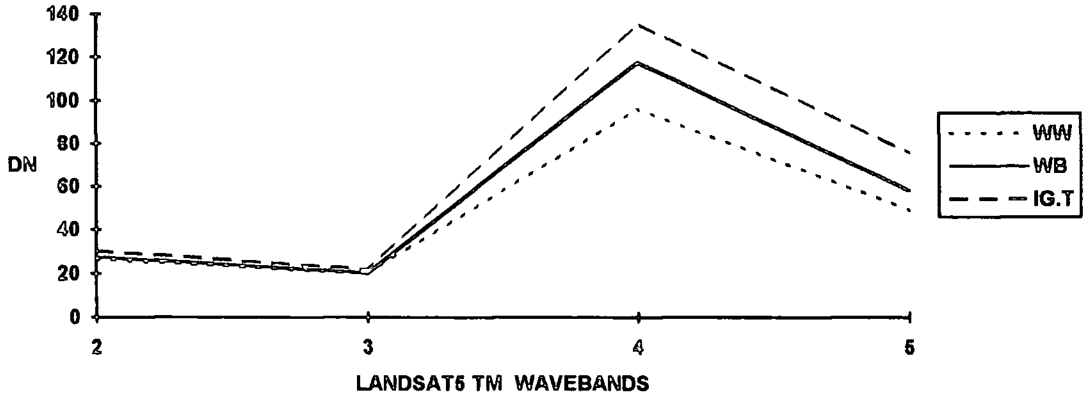
where vr(cwl) = average reflectance of coniferous woodland, mr(cwl1) = mean reflectance of coniferous woodland in the study area 1, and so on.

This generalisation of statistics offers the opportunity to carry out a temporal study for each training class, and the effect of spatial differences on the spectral properties of each class is represented equally.

4.4.4.1 *Analysis of the Study Area Training Statistics for the Image of 31st May 1985*

Statistics of this date show that a number of land cover types are spectrally overlapped especially in the visible domain of the spectrum. These land cover types are wheat, barley, and temporary grass. Thus the spectral and hence spatial discrimination between wheat and barley at this stage of growth is difficult. The reason for this difficulty is first, the accumulative temperature has not yet had a noticeable effect on these two crop types especially barley. Second, farmers are used to adding chemical fertilisers especially nitrogen in spring, so leaves of both are darkened. Wheat and barley are overlapped with temporary grass because these two cereal crops are still out of ears and the three types are in foliation stage, figure (4:10).

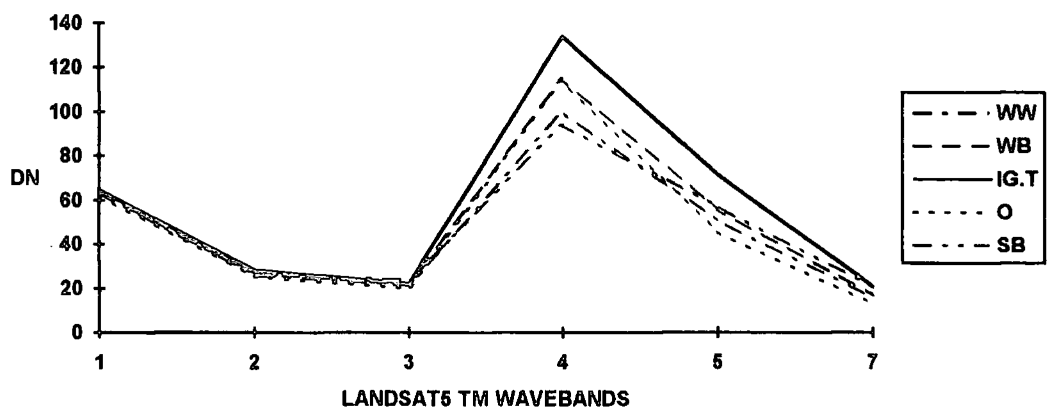
FIGURE (4:10): MEAN REFLECTANCE OF W.WHEAT, W. BARLEY, AND TEMPORARY GRASS IN MAY



4.4.4.2 *Analysis of the Study Area Training Statistics for the Image of 10th July 1992*

Discrimination between cereal crops and temporary grass for this date is better than that of May. This improvement in discrimination is due to the coarser texture of cereals resulted from grains and the rapid loss of leaf water content. There is still overlap between wheat and barley, but less than occurs in May. More overlap occurs between winter barley and oats on one hand and between winter wheat and spring barley on the other hand. Figure (4:11) shows how these classes are overlap especially in the visible wavebands.

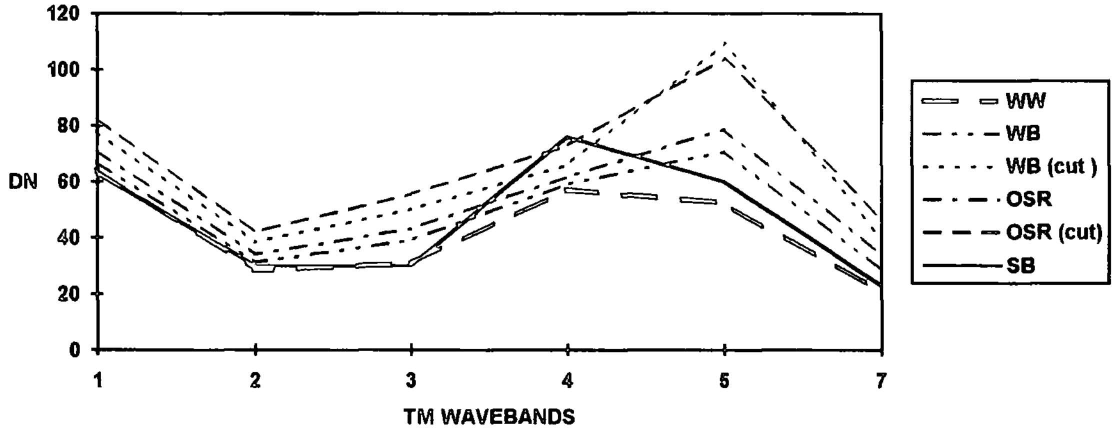
FIGURE (4:11): MEAN REFLECTANCE OF CEREAL CROPS AND IMPROVED GRASS (TEMPORARY) FOR THE TRAINING AREAS OF JULY, 1992



4.4.4.3 Analysis of the Study Area Training Areas for the Image of 1st, August 1990

Statistics of land cover classes for this date show that apart from grass, overlap occurs between cereals on one hand and cereals and oilseed rape on the other hand. At this stage, most barley and oilseed rape crops are harvested, so these training classes overlap spectrally. At this stage, wheat is not harvested, so the overlap occurs with not harvested barley. Figure (4:12) illustrates this overlap.

FIGUERE (4:12): MEAN REFLECTANCE OF CEREAL CROPS AND OILSEED RAPE IN AUGUST, 1990



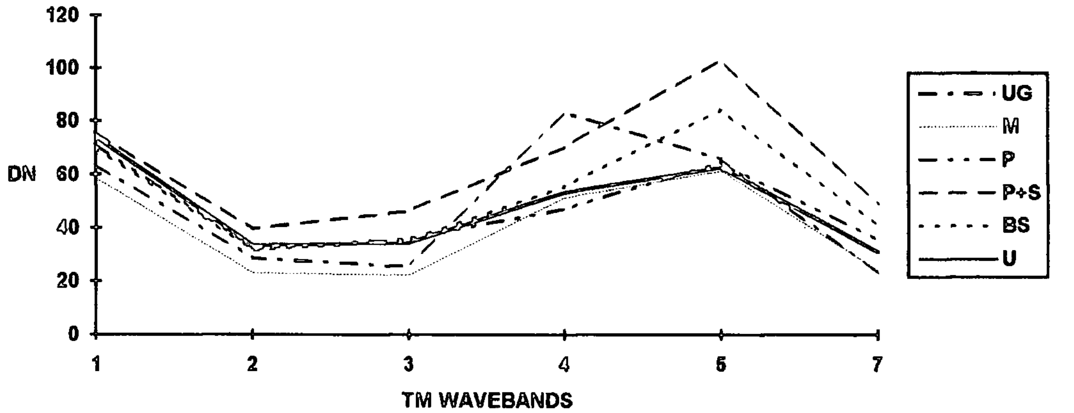
4.4.4.4 Training Classes Overlap Over the Three Dates

Spectral characteristics of training areas are fairly constant over the three dates are :

(a) unimproved grass (rough grass) overlaps with moorland.

(b) ploughed land, ploughed and sown land, bare soil, and urban (built-up) areas overlap spectrally. Figure (4:13) illustrates this overlap

FIGURE (4:13): TRAINING CLASSES OVERLAP OVER THE THREE DATES



4.4.5 Manipulation of Spectrally Overlapped Training Classes

1. Spatial manipulation:- reference data were used as a supporting tool for the discrimination between overlapping land cover types which their distribution is affected by local physical environment. Large scale maps were used. These maps contain field boundaries and altitudinal contour lines. Cereal crops are more likely to be grown in relatively large fields with flat terrain because steep topography and small fields hinder mechanical operations. Temporary grass can be grown in both situations. Permanent grass is more likely to be grown in steep areas because heavy mechanical operations are not needed. Reference data are useful in determining the probability of these overlapped training classes. The texture of cereal crops in May and July is rougher than that of temporary grass, and the leaf area coverage of grass is larger than that of cereals because grass is normally sown with less distance between rows and their leaves grow in all directions. Grass leaves in July stay green while cereal crops leaves start yellowing. The reason for that is that grass roots go deeper into the soil and create a net of continuous roots through the field. Reference data are also used to discriminate between unimproved grass and moorland. The existence of moorland in the study area is restricted to one parish, so this problem is manipulated easily. Spatial manipulation of soil and urban areas took a textural and tonal form in addition to reference data. In rural environment; built-up areas do not represent pure class, and grass is grown among and

surrounding these areas. So, this mixture of vegetation and buildings gave the urban class a lighter tone. The heterogenieity of the structure of urban class pixels gave it a discontinuous tone. On the other hand, soil cover is normally homogeneous and pure. So, soil has a continuous and darker tone.

2. Digital manipulation:- The prior probability is decided by an experimental procedure:

(a) In the first stage, all training classes are given equal prior probability.

(b) The overlapping classes are recorded associated with the approximate percentage of each class. For example, if 5 pixels of barley in the test area is assigned as wheat, and 10 pixels of wheat are assigned as barley; the prior probability of wheat is decreased more than that of barley. This procedure is applied to all the spectrally overlapped training classes.

It was found that the deciduous trees class for the image of May and July was over estimated and pixels of arable crops and temporary grass are assigned to this land cover class, especially in the limits of these fields where hedges gave these areas similar spectral response to deciduous trees. On the other hand, unimproved grass land cover class is underestimated over these two dates, because at this period this land cover type contains more foliar moisture. So, the prior probability for deciduous trees training class is decreased and that of unimproved grass is increased. For the image of August, this situation is converted.

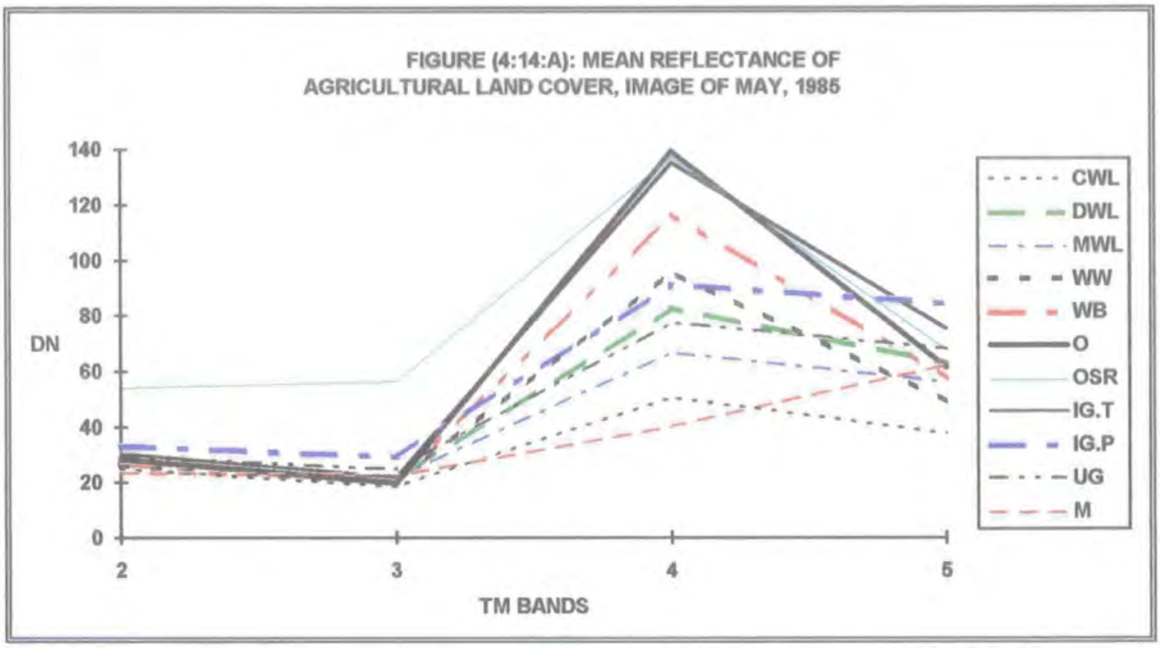


FIGURE (4:14:A): MEAN REFLECTANCE OF
AGRICULTURAL LAND COVER, IMAGE OF MAY, 1985
140
120
100
80
60
40
20
0
DN
2
3
4
5
TM BANDS
CWL
DWL
MWL
WW
WB
O
OSR
IG.T
IG.P
UG
M

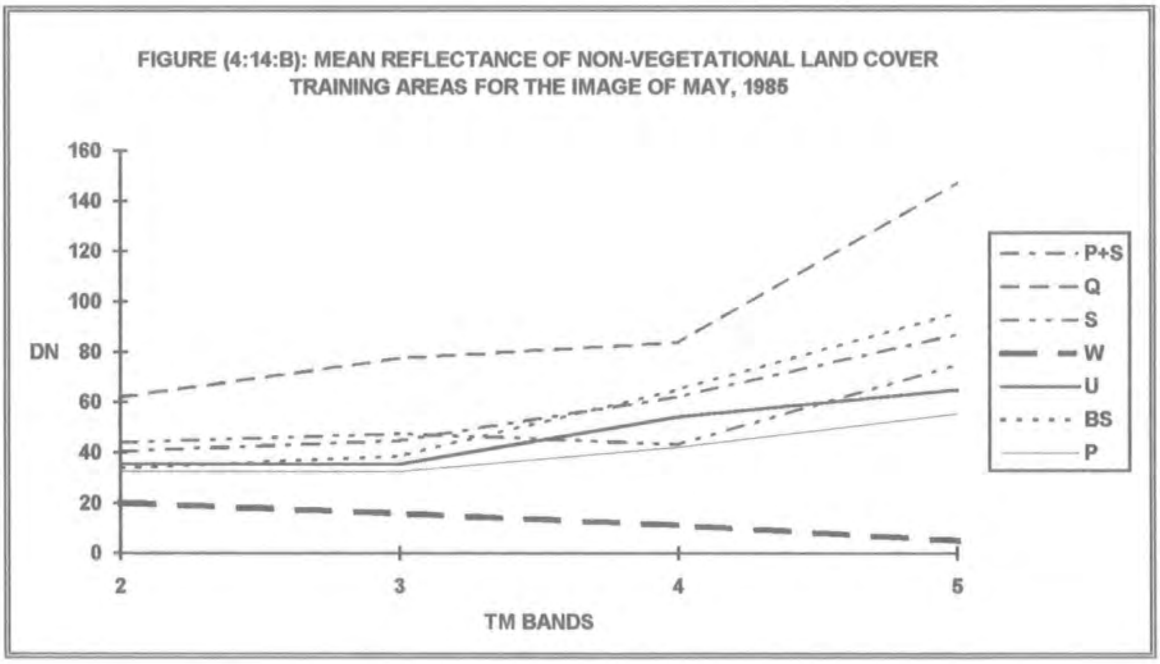


FIGURE (4:14:B): MEAN REFLECTANCE OF NON-VEGETATIONAL LAND COVER
TRAINING AREAS FOR THE IMAGE OF MAY, 1985
160
140
120
100
80
60
40
20
0
DN
2
3
4
5
TM BANDS
P+S
Q
S
W
U
BS
P

FIGURE (4:15:A): MEAN REFLECTANCE OF AGRICULTURAL AND VEGETATIONAL LAND COVER TRAINING AREAS FOR THE IMAGE OF JULY, 1992

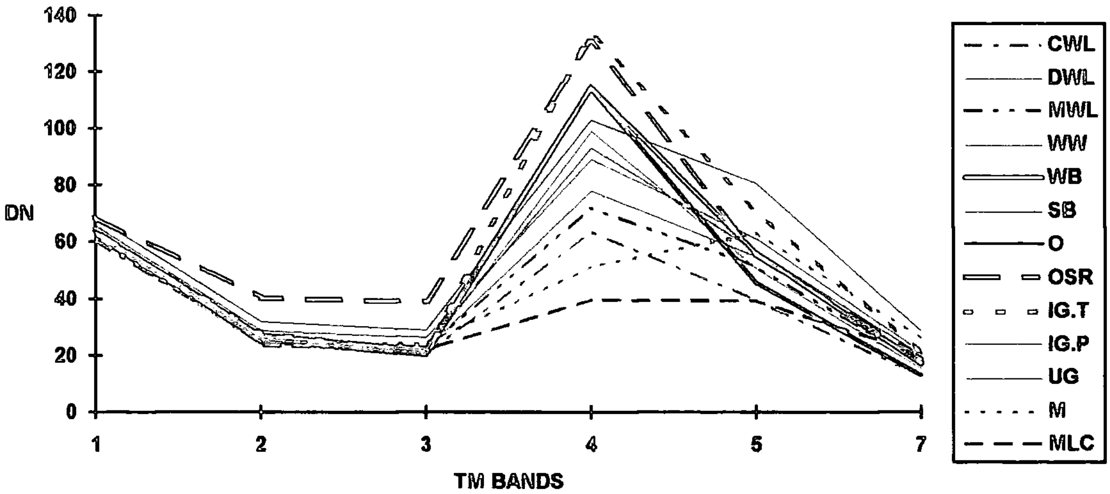


FIGURE (4:15:B): MEAN REFLECTANCE OF NON-VEGETATIONAL LAND COVER TRAINING AREAS FOR THE IMAGE OF JULY, 1992

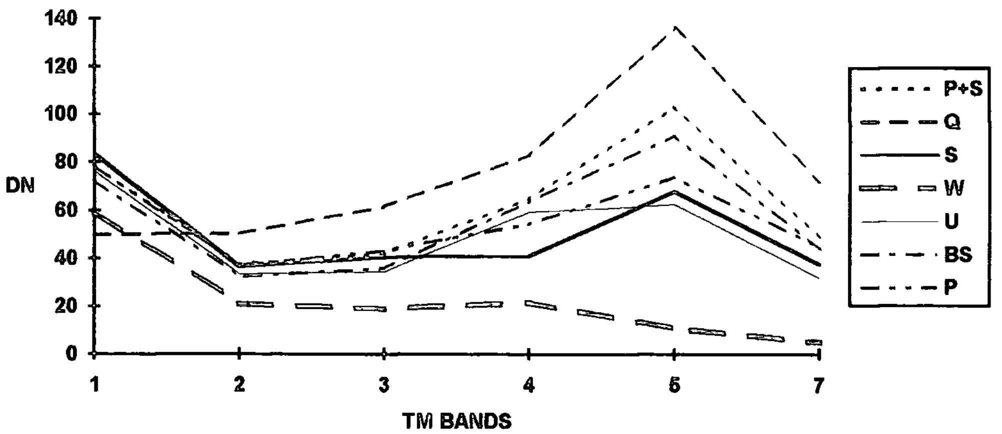


FIGURE (4:16:A): MEAN REFLECTANCE OF MAIN AGRICULTURAL AND VEGETATIONAL LAND COVER TRAINING AREAS FOR THE IMAGE OF AUGUST, 1990

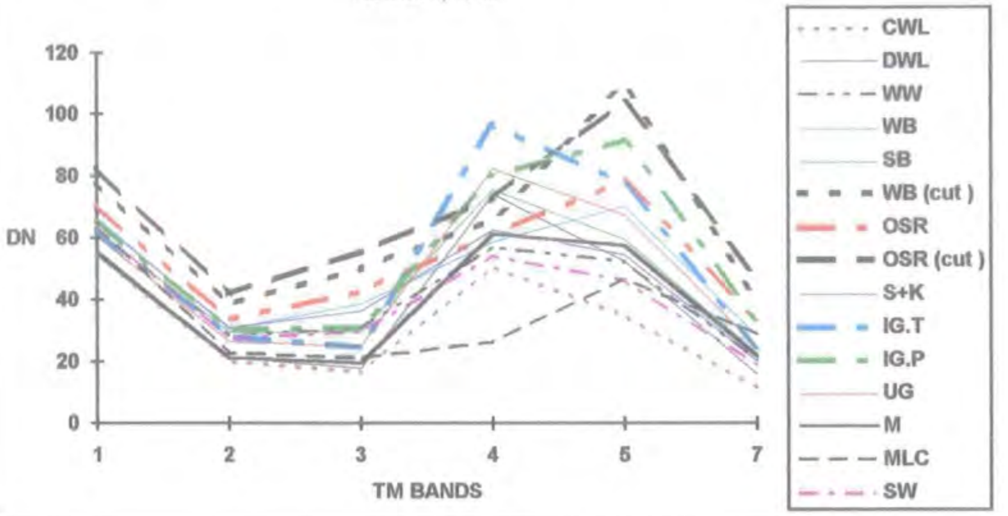
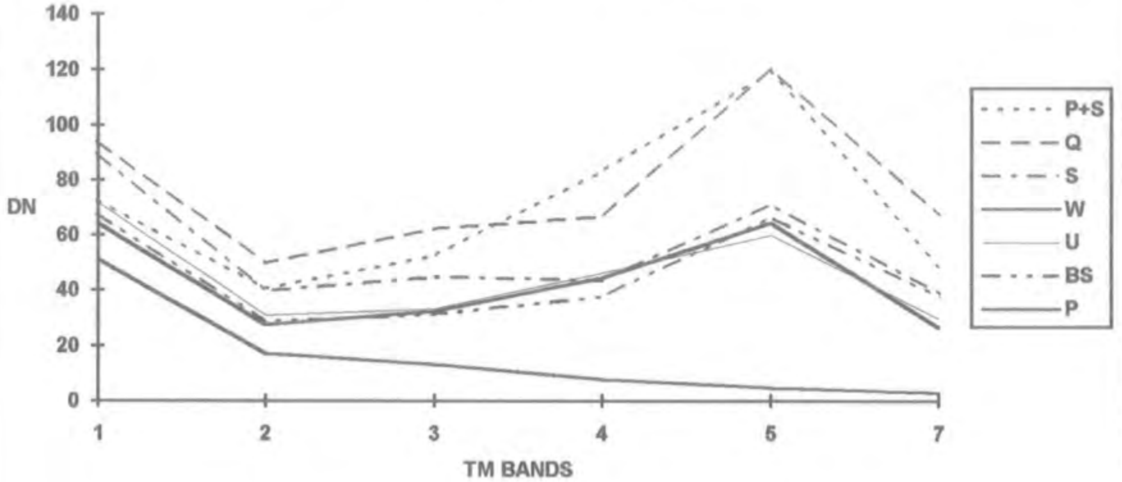


FIGURE (4:16:B): MEAN REFLECTANCE OF NON-VEGETATIONAL LAND COVER TRAINING AREAS FOR THE IMAGE OF AUGUST, 1990



4.4.7 Smoothing of Classified Images

Classified images normally contain isolated pixels of one class surrounded by a dominance of pixels of another class (salt and pepper). These isolated pixels may reduce the readability and the interpretability of images. The occurrence of these isolated pixels may due to the following factors:-

(a) spectral overlapping between land cover types in the image.

(b) topographic variations.

(c) small fields.

(d) edges, limits and linear features such as drains and roads.

(e) high spatial frequency of land cover types.

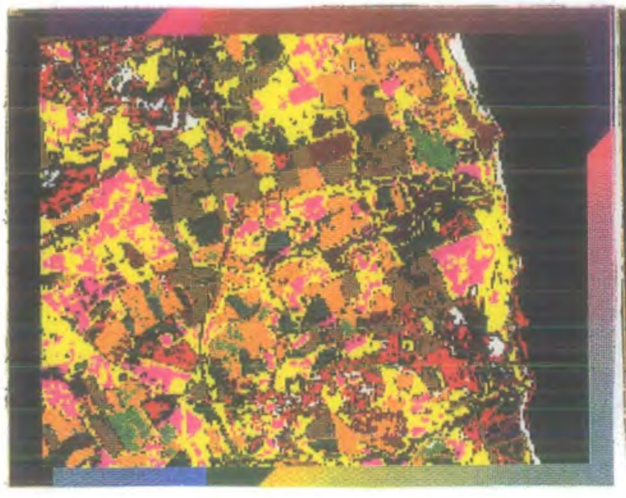
For land use mapping studies, this process is essential to produce maps which can be used cartographically. There are several techniques for filtering images, and each technique has a specific effect on classified image. So, the selection of filtering technique depends on the aim of filtering. In this case , the aim is to get rid of isolated pixels and produce cartographic maps without having a negative effect on the accuracy of the data. ***Median Smoothing*** is applied to the classified images to achieve the mentioned purposes. The principle on which this technique work is that it compares the spectral value of a pixel with its adjacent neighbours and assigns its location by a majority vote procedure. Size of kernel can be decided according to radiometric frequency of image. The more radiometric frequency is, the smaller the kernel size becomes.

Example:-

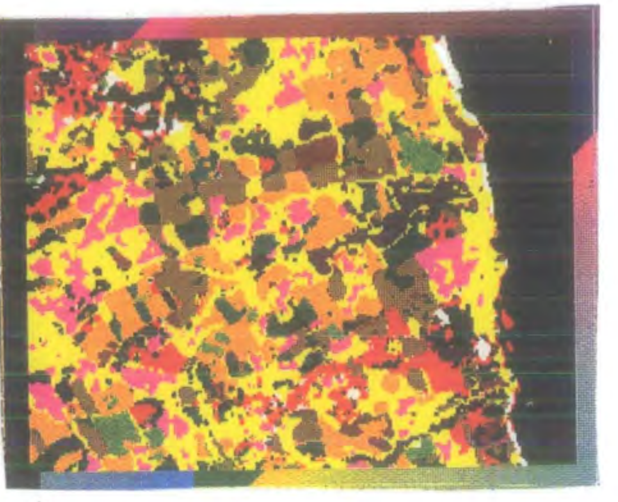
7	5	4
13	10	9
8	11	20

In this example a kernel of 3×3 pixels is used for the purpose of image smoothing, and the median in this example is 10. It can be seen from the kernel matrix that the median is not affected by extreme values such as the pixel which has the value 20. Figure (4:24) shows classified image before and after median smoothing.

Figure (4:17): Median smoothing for Hawthorn image, August, 1990. **(a) before smoothing (b) after smoothing**



a



b

4.5 Conclusion

Image classification represents a major part of land use mapping studies, and the accuracy of classified maps depends very much on this part. We have seen that image classification is not a solely automatic or systematic procedure. It involves many interrelated considerations, especially in agricultural image studies where land use \ land cover in a continuous change status. The integration of contextual or reference data in image interpretation and classification provides a good understanding of the micro-image conditions which affects the optical properties of different land cover types and consequently improves the classification accuracy. The awareness of factors which affects the spectral properties of land cover helps in the digital and visual interpretation of image information and classification accuracy.

CHAPTER FIVE

Chapter 5 : Image incorporation in Geographic Information System (GIS)

5.1 Introduction

Remotely sensed data can be integrated with other sources of information such as reference data in a GIS. These reference data can have two forms; contextual and arc. The full potential of both remote sensing and GIS cannot be achieved unless the two are integrated. The main principle of GIS is that it allows the overlaying of several types of information such as soil, topography, and then permits different kinds of analysis of this information. It also allows the merging of remotely sensed data from different dates to detect land use change. In this study, a GIS package called ARC \ INFO is used to analyse the remotely sensed data of the study area over the three dates of the study.

5.2 Image Geometric Correction

5.2.1 Data Input in GIS

For the purpose of the geometric correction of images by GIS, the following data are entered into the GIS:-

(a) Raw images of the study area. These images are stretched (histogram equalisation stretching) over three bands before they are transferred to GIS. The aim of this image stretching is to increase the clarity and sharpness of fine data such as fields limits, cross roads and woodland boundaries. This image data can then be used to select ground control points for image registration to a reference map.

(b) Classified images of the study area. These images are coded with land use classes used in the classification scheme.

(c) Land use maps of the study area. These maps represent land use classification of the study area for the year 1994. They are prepared by field survey method by the researcher. They contain fields boundaries, roads, and the administrative boundaries of each study area.

5.2.2 Principle of Image Geometric Correction

Despite the fact that the Landsat TM images are corrected for earth's curvature and rotation, satellite attitude errors and sensor non-linearities, they still contain significant geometric distortions. For some studies such as environmental studies, these do not have a significant effect on image analysis. However, these distortions are important for comparative studies with geometrically corrected maps and for multi-temporal analysis.

The geometric correction process involves the following steps:-

(1) Image registration to a reference map. Raw images of the study area are registered to maps having the British National Coordinates System (BNCS). The reason for using raw images rather than the classified ones is that the later images contain a kind of noise resulting from classification errors. So, it is difficult to find identical features as those in the raw images. The registration process involves the following points :-

(a) Choice of ground control points (gcps). Ground control points selected should be sharp, clear, not change very much by time, and be identical on both images and maps. The best examples of these gcp are cross roads, rivers bending, soil water edges, bridges, and woodland boundaries.

(b) Distribution of gcps. They must be well distributed through the image to distribute the registration errors through image equally.

(c) Number of gcps. A sufficient number of gcps must be used to improve the registration accuracy especially in the areas of considerable topographic variations. In this study the minimum number of gcps used for each parish subscene rectification was 6.

(d) Once the registration results are satisfactory, the raw image co-ordinate file is copied to the classified image co-ordinate file (the number of pixels and rows for both the raw and the classified image should be the same). This co-ordinate file is used for rectifying the classified image.

There are three main methods of resampling remotely sensed images; first, nearest neighbour, second, bilinear Interpolation, and third, cubic convolution.

The functionality of the first method is that it transfers the DN of the nearest pixel. In figure (5:1), the DN of pixel A is allotted to the neighbouring cell which is geographically correct. This method is suitable for agricultural studies because it does not alter the pixel DN value. Its disadvantage is that it disjoins the image and pixels offset by up to half a pixel (Curran, 1985). This method is used for the rectification of the study area. The other two methods are not used because they alter DN values.

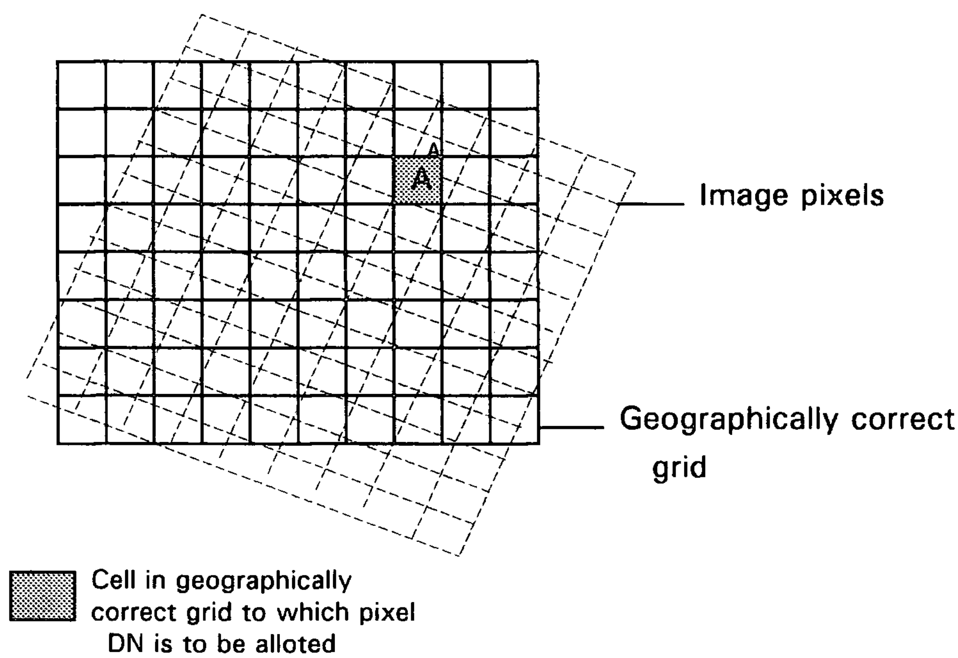


Figure (5:1): Principle of image rectification

(Adapted) from Curran, 1985

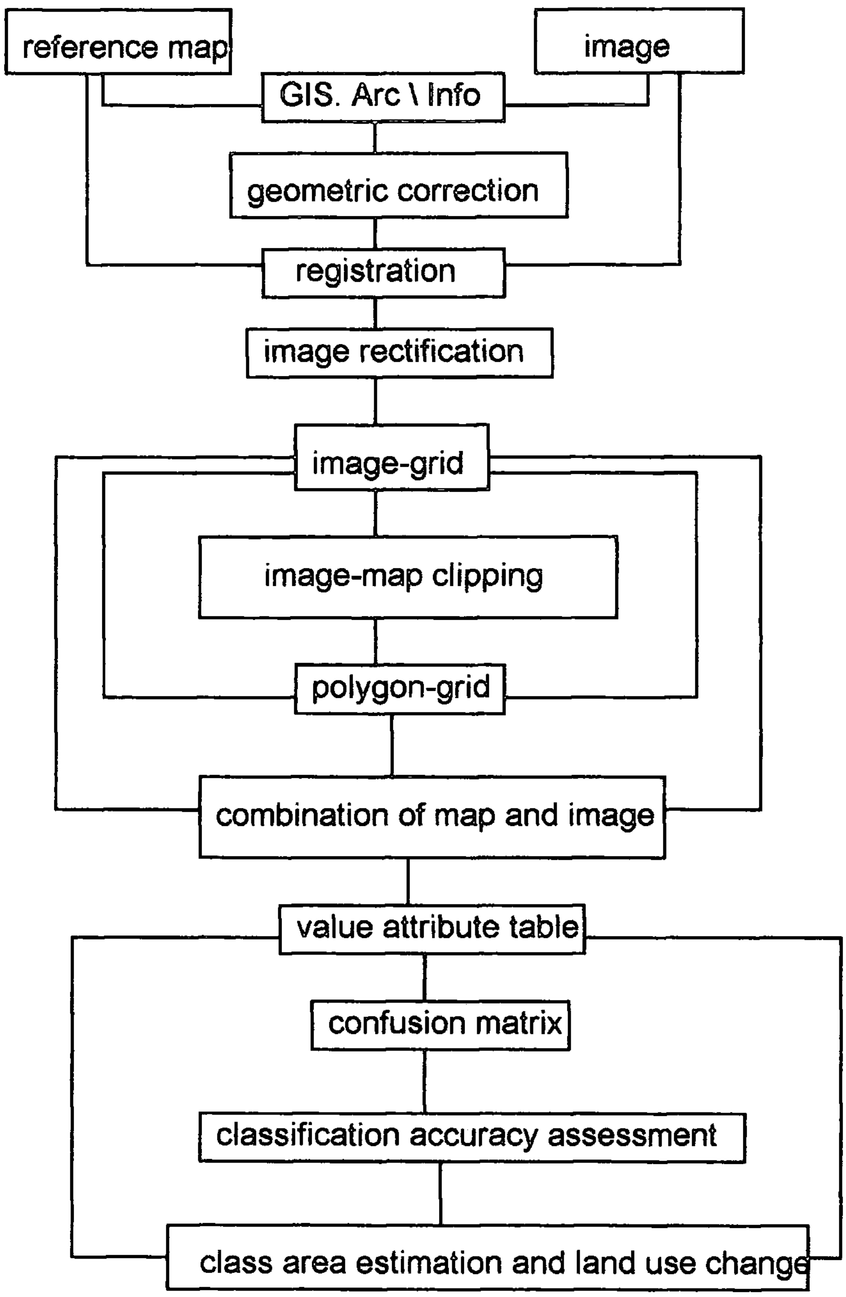
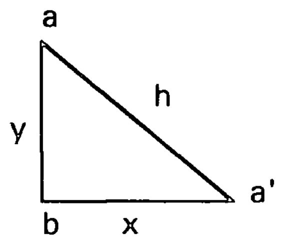


Figure (5:2):- Flowchart of image integration in a Geographical Information System (ARC / INFO).

5.2.3 Image Geometric Correction Results

Geometric correction accuracy is measured by the value of The Root of the Mean Square Error (RMSE). This value can be scaled either by metres or a percentage of pixel size. This error represents a displacement of the location of gcp on image in *x* and *y* away from their true location on the ground. The following equation illustrates this term.



Where **a** is the true location of the gcp1, **a'** is location of the gcp 1 on image after the geometric correction, **x** is the error of a' in x axis, **y** is the error of a' in y axis, and **h** is the straight distance between location of the gcp 1 on earth and image.

$$h = \sqrt{x^2 + y^2}$$

$$h^2 = h \times h$$

$$\bar{h}^2 = \frac{h^2 1 + h^2 2 + \ldots h^2 n}{n}$$

$$rmse = \sqrt{\bar{h}^2}$$

Where h^2 is the square error, $\bar{h}^2$ is the mean square error, **n** is the number of the gcp used in image rectification, and $\sqrt{\bar{h}^2}$ is the root of the mean square error.

Table (5:1):- Geometric correction accuracy for images of the study area (rmse, % pixel)

Date / Image	Hawth.	Hett	Wack.	Green.	Satley	Edmund.
1985	0.39	0.37	0.31	0.45	0.51	0.58
1990	0.48	0.49	0.37	0.43	0.71	0.51
1992	0.61	0.35	0.52	0.45	0.37	0.64

Table (5:2):- Geometric correction accuracy of the study area images (% Pixel)

1985 Image	1990 Image	1992 Image
0.44	0.50	0.49

5.2.4 Factors that Affect Rectification Accuracy

The results of the geometric correction show that the level of accuracy varies from one study area to another and also from one date to another. These variations can be due to the following factors:-

(1) Digitising errors:- These errors can result from different sources, such as;

(a) Conversion of data from vector format to raster format. Raster format is the arrangement of data into equal grids, while vector format represents the true shape of polygons. So, this conversion involves a process of omission and commission. The percentages of omission and commission are not necessarily equal. Also, this data conversion means a kind of relocation of data especially in the boundaries of polygons.

(b) Spacing between sequence vertices. The smaller the spacing the more accurate data representation becomes. This problem appears for data with twisting arcs, such as rivers, water bodies, and woodland boundaries. This phenomena is more frequent in areas of rough terrain such as Greencroft, Satley, Edmundbyers, and along dales in other study areas.

(c) Map joins. Five study areas out of six share more than one sheet, and data in these sheets do not fit together perfectly. So, joining data from different sheets to produce one map results in some distortion of the data especially in the joining areas.

(2) Map scale. The scale of maps to which images are registered are not the same for all study areas. The scale for Hett, Wackerfield, and Greencroft is 1: 10, 000, while that of Hawthorn, Satley, and Edmundbyers is 1: 25, 000. The ***rmse*** for the former set of maps

is less than that of the later set. The average *rmse* of the three dates for Hett, Wackerfield, and Greencroft is 0.4, 0.4, and 0.44 pixel respectively, while the rmse for Hawthorn, Satley, and Edmundbyers is 0.49, 0.53, and 0.58 pixel respectively. So, larger scale maps allow more accurate registration of gcp to images.

(3) General topography. The results of geometric correction show that areas of considerable topographic variations such as Satley and Edmundbyers are less accurate than flat areas such as Hett and Wackerfield. For Greencroft, although its topography varies considerably, the large scale of the map used (1: 10, 000) improved its geometric results. On the contrary, despite the relatively flat topography of Hawthorn, its smaller scale (1: 25, 000) reduced its geometric correction accuracy.

(4) Solar elevation. It can be seen from the geometric correction results over the three dates that the image of August 1st was less accurate than the other dates (0.5 pixel). Lower solar elevation resulted in a compression of the radiometrical data, shadowing, and more bidirectional reflectance. So, some spatial distortion of data occurred, and consequently reduced the clarity of data separation points.

(5) The agricultural nature of the study area, where field limits are obscured by agricultural cover, especially in the areas where adjacent fields are of the same land cover type.

(6) The uneven distribution of gcps through the image. Sometimes it was not possible to find precise and distinctive locations all over the image because the study areas are not large.

5.3 Classification Accuracy Assessment

There are several methods for assessing image classification accuracy. Each method has both advantages and disadvantages. These methods can be summarised as follows;

(1) Tests based on independent samples.

(2) Tests based on grid-by-grid overlay or polygon-by-polygon overlay.

(3) Classification area estimates versus area estimates obtained by other methods.

The first option involves the statistical sampling of individual areas of known land cover types. These areas are designated as test fields. This accuracy assessment method is preferred to other methods for large area studies where time and cost are important.

The second option involves a grid-by-grid comparison of the classified image in question with a reference map. The advantage of this method is that; (a) it assesses the accuracy of all pixels in each land use \ land cover class, (b) it gives the overlapping of each class with other classes, (c) it allows a more effective, comprehensive, and accurate interpretation of classification accuracy results, and (d) it is appropriate for small study areas.

This method has also some limitations, (a) it is not applicable for large study areas, (b) the reference map should be more accurate than the evaluated one, (c) the reference map should be updated, (d) considerations should be taken into account whenever land use \ land cover has changed between the two mapping dates, and (e) both maps should have similar minimum mapping units and classification scheme.

The third option, (area estimates), can be used when the location of individual pixels is not important. Therefore, this method is suitable for studies in which the spatial arrangement of pixels is not crucial.

In this study the grid-by-grid classification accuracy assessment was adopted, because it is suitable for small study areas, and the field mapping of the study area has already been done by the author. So, field maps can be used as a basis for image classification accuracy assessment. The following procedures were undertaken for the application of this method:-

(1) Classified and rectified images are converted to ARC \ INFO grids.

(2) The reference maps are also converted to grids. The grid size for both images and maps is the same, so at this stage, both images and maps have the same minimum mapping units.

(3) Both images and reference maps have the same classification scheme.

(4) To discriminate between image classes numbers and those of the reference map, the map class numbers are multiplied by 100. So, a map class which had the number 1 becomes class number 100, while class 1 on the image remains the same.

(5) A combination of the reference maps and evaluated images is made for the study areas over the three dates.

(6) The reference maps represent land use classification of the study areas in February, 1994 which was derived from field work done by the author.

To overcome the problem of land use change affecting the accuracy assessment procedure, the following points are taken into consideration:-

(a) Land use \ land cover types which have a relatively constant status and do not change drastically, such as woodland, water bodies, moorland, unimproved grass and urban areas did not represent a considerable problem. The reference maps can work properly for accuracy assessment of these classes.

(b) Land use \ land cover types which change drastically through time and are governed by crop rotation such as improved grass, cereals, and oilseed rape do affect this method of accuracy assessment. To overcome this problem, accuracy assessment of these crop types is based on the following basis:-

(1) The crop calendar in County Durham (see ch. 1).

(2) The spectral properties of each crop over the three dates (see ch. 4).

(3) The spectral similarity of crops.

It has been seen in ch. 4 that first, in May, the crops which spectrally overlap greatly are wheat with barley on one hand, and these crops with temporary grass on the other hand. Second, in July, these crops still overlap but less than in May. Third, in August, temporary grass does not overlap cereal crops, so accuracy assessment of grass at this time is not affected. Cereal crops overlap in August, especially those at the same stage at growth. At this time, cereal crops and oilseed rape have different conditions, and these conditions are:- (a) most winter barley crop is harvested, (b) none of the wheat crop and spring barley is harvested, and (c) some oilseed rape is harvested.

From these conditions, it can be seen that overlapping occurs mostly between spring wheat and winter wheat, spring barley and winter wheat, and harvested barley and harvested oilseed rape. The ploughed, the ploughed and sown, and urban areas overlap over the three dates.

On the basis of these concepts the accuracy assessment is carried out. This example illustrates and clarifies the procedure.

Example:- A combination between image land use classes in August and reference map classes is made, and this combination gave the following results:-

350, 200, 1

50, 100, 1

30, 300, 1

5, 1400, 1

8, 500, 1

Where the left column represents number of pixels, the middle column represents a land use class on the reference map, the right column represents a land use class on image, 1 is winter wheat on image, 200 is temporary grass, 100 is spring wheat, 300 is ploughed and sown, 1400 is winter wheat, and 500 is deciduous woodland. The following land use classes are included in the image classification scheme:-

(1) winter wheat, (2) winter barley, (3) spring barley, (4) temporary grass, (5) quarries, (6) water bodies, and (7) deciduous woodland.

A combination of results shows that the greatest overlap of winter wheat is with temporary grass which is unreasonable, because in August, winter wheat will be dry while temporary grass will be green. So, and because this overlap is the highest of all, these pixels are registered as the correctly classified winter wheat. The second combination result shows that winter wheat overlapped spring wheat by 50 pixels, but this class does not exist in the image classification scheme. So, this overlap will be either with winter barley or spring barley. But in August, most winter barley is harvested and does not overlap winter wheat greatly, so this overlap is assigned to spring barley, and the third overlap is assigned to winter barley. The last overlap between winter wheat and deciduous woodland on both the image and reference map is realistic because this class is relatively constant.

This classification accuracy assessment method is applied to all dates for the study area. The limitation of this method is that a kind of misdistribution of misclassified pixels may occur, especially within the highly overlapped crops. However, this method does not affect the resultant accuracy of each class and that of generalised classification accuracy for broad land use classes such as arable crops class (cereals), improved grass (temporary and permanent), and so on.

5.3.1 Classification Accuracy Assessment Results

(1) Accuracy Assessment Results for Image of 1985*

Table (5:3) :- Classification accuracy assessment for Hawthorn

Class	1	2	3	4	5	6	7	8	9	10	T	C	%
1	245	0	10	0	9	0	10	40	0	6	320	245	76.6
2	6	289	0	6	10	3	10	0	0	0	324	289	89.2
3	6	0	542	0	125	0	118	0	0	3	794	542	68.3
4	0	6	0	119	0	4	0	0	4	2	135	119	88.1
5	11	0	11	0	664	0	23	0	0	7	716	664	92.7
6	0	0	0	0	0	375	0	0	0	8	383	375	97.9
7	16	0	15	0	20	0	891	0	0	6	948	891	94
8	157	0	29	25	31	0	60	1768	4	100	2170	1768	81.5
9	3	4	0	1	4	0	2	2	84	24	121	84	69.4
10	0	0	0	23	0	0	0	0	0	9	32	9	28.1

Where 1 is mixed woodland, 2 is quarries and bare soil, 3 is temporary grass, 4 is sand, 5 is winter barley, 6 is oilseed rape, 7 is winter wheat, 8 is permanent grass, 9 is ploughed and sown land, 10 is urban areas, T is the total number of pixels included in accuracy assessment for each class, C is the correctly classified pixels, and % is the percentage accuracy of each class.

Total number of pixels for all classes = **5943**, Total number of pixels correctly classified = **4986**

Overall classification accuracy based on pixels number = **83.9 %,** overall classification accuracy based on number of classes = **78.6**

* Reference map classes are in rows, and image classes are in columns.

Table (5:4) :- Classification accuracy assessment for Hett

Class	1	2	3	4	5	6	7	8	9	10	T	C	%
1	474	0	0	0	1	2	0	0	0	0	477	474	98.1
2	0	1033	0	5	31	0	0	3	38	1	1111	1033	92.7
3	0	17	452	50	0	0	0	34	11	0	564	452	80.1
4	0	13	0	43	44	0	0	0	12	4	116	43	37.1
5	0	79	0	11	608	5	0	8	51	0	762	608	79.8
6	0	0	0	3	0	490	27	28	0	0	548	490	89.4
7	0	0	0	0	0	19	62	11	0	0	92	62	67.4
8	0	0	0	9	0	12	6	21	0	0	48	21	43.8
9	0	80	0	4	57	0	0	4	550	0	695	550	79
10	0	0	0	2	0	0	0	0	0	11	13	11	84.6

Where 1 is oilseed rape, 2 is winter barley, 3 is permanent grass, 4 is deciduous woodland, 5 is temporary grass, 6 is ploughed and sown land, 7 is ploughed land, 8 is urban areas, 9 is winter wheat, and 10 is coniferous woodland, (see the previous table for other abbreviations).

Total number of pixels for all classes = **4426**, Total number of correctly classified pixels = **3734.**

Overall classification accuracy based on number of pixels = **85.2 %**.

Overall classification accuracy based on number of classes = **75.2 %.**

Table (5:5):- Classification accuracy assessment for Wackerfield

Class	1	2	3	4	5	6	7	8	T	C	%
1	227	0	0	0	0	0	2	1	230	227	98.7
2	0	91	6	30	0	0	1	1	129	91	70.5
3	6	0	183	32	27	0	2	7	257	183	71.2
4	0	18	0	814	0	0	9	0	841	814	96.8
5	0	14	34	33	757	19	24	0	881	757	85.9
6	0	0	0	0	8	304	4	0	316	304	96.2
7	0	0	0	0	8	0	10	19	37	10	27
8	0	0	2	2	3	5	14	216	242	216	89.3

Where 1 is oilseed rape, 2 is oats, 3 is winter barley, 4 is winter wheat, 5 is temporary grass, 6 is permanent grass, 7 is urban areas, and 8 is ploughed and sown land.

Total number of pixels for all classes = **2933.** Total number of correctly classified pixels = **2602.**

Overall classification accuracy based on number of pixels = **88.7 %.**

Overall classification accuracy based on number of classes = **79.5 %.**

Table (5:6):- Classification accuracy assessment for Greencroft

Class	1	2	3	4	5	6	7	8	9	10	T	C	%
1	411	38	0	10	8	28	0	0	14	38	547	411	75.1
2	0	662	5	36	40	23	1	0	0	24	770	662	86.1
3	0	0	51	0	0	2	0	0	11	4	68	51	75
4	0	6	0	278	40	1	0	0	44	0	369	278	75.3
5	0	12	1	40	220	0	0	0	33	1	307	220	71.7
6	0	24	0	0	0	78	25	8	30	1	166	78	47
7	0	9	0	0	0	16	47	4	0	0	76	47	61.8
8	0	0	0	0	0	18	14	482	0	1	515	482	93.6
9	35	189	1	101	65	37	8	0	3105	61	3602	3105	86.2
10	18	117	12	0	0	29	0	0	10	600	786	600	76.3

Where 1 is permanent grass, 2 is deciduous woodland, 3 is coniferous woodland, 4 is winter barley, 5 is winter wheat, 6 is urban areas, 7 is fallow, 8 is ploughed and sown land, 9 is temporary grass, and 10 is unimproved grass.

Total number of pixels for all classes = **7206**. Total number of correctly classified pixels = **5934**

Overall classification accuracy based on number of pixels = **82.3 %**. Overall classification accuracy based on number of classes = **74.8 %.**

Table (5 :7):- Classification accuracy assessment for Satley

class	1	2	3	4	5	6	7	8	9	10	11	T	C	%
1	201	37	9	4	15	0	0	0	0	10	25	301	201	66.8
2	42	509	21	7	3	0	0	0	0	14	10	604	509	83.9
3	5	2	131	14	0	0	0	0	0	3	0	155	131	84.5
4	31	14	82	1055	40	0	0	0	0	5	21	1248	1055	84.5
5	20	22	108	82	1875	0	0	9	0	34	103	2253	1875	83.2
6	13	6	4	2	10	528	25	8	56	41	27	720	528	73.3
7	1	0	0	0	0	0	259	0	0	14	4	278	259	93.2
8	3	2	3	1	4	3	0	307	0	9	2	334	307	91.9
9	24	16	0	0	0	44	19	0	324	13	2	442	324	73.3
10	8	10	0	0	0	50	5	0	33	116	0	222	116	52.2
11	109	242	44	26	141	15	21	15	0	170	6808	7591	6808	89.7

Where 1 is coniferous woodland, 2 is deciduous woodland, 3 is winter wheat, 4 is winter barley, 5 is temporary grass, 6 is ploughed and sown land, 7 is quarries and bare soil, 8 is oilseed rape, 9 is ploughed land, 10 is urban areas, and 11 is permanent grass.

Total number of pixels for all classes = **14146**

Total number of correctly classified pixels = **12111**

Overall classification accuracy based on number of pixels = **85.6 %.**

Overall classification accuracy based on number of classes = **79.7 %.**

Table (5:8):- Classification accuracy assessment for Edmundbyers

Class	1	2	3	4	5	6	7	8	9	T	C	%
1	352	26	5	62	0	53	10	0	4	512	352	68.8
2	19	518	53	47	0	27	23	0	50	737	518	70.3
3	108	78	3400	80	0	166	102	0	196	4130	3400	82.3
4	188	138	50	1901	0	175	57	0	44	2553	1901	74.5
5	6	2	4	0	766	34	0	0	2	814	766	94.1
6	49	17	5	95	0	7672	7	0	3	7848	7672	97.8
7	9	3	3	35	0	132	34	0	1	217	34	15.7
8	2	1	0	3	0	0	0	1433	0	1439	1433	99.6
9	20	43	110	113	0	156	26	0	1245	1713	1245	72.7

Where 1 is coniferous woodland, 2 is deciduous woodland, 3 is temporary grass, 4 is unimproved grass, 5 is bare soil, 6 is moorland, 7 is urban areas, 8 is water bodies, and 9 is permanent grass.

Total number of pixels for all classes = **19963**.

Total number of correctly classified pixels = **17321**.

Overall classification accuracy based on number of pixels = **86.8 %**.

Overall classification accuracy based on number of classes = **75.1 %**.

(2) Classification Accuracy Assessment Results for Image of 1990*

Table (5:9):- Classification accuracy assessment for Hawthorn

Class	1	2	3	4	5	6	7	8	9	10	11	12	13	T	C	%
1	215	17	0	0	1	0	0	0	0	0	0	0	0	233	215	92.3
2	40	925	50	0	12	0	0	5	14	0	0	0	0	1064	925	88.4
3	0	0	21	0	0	2	3	4	0	0	0	0	0	30	21	70
4	0	3	2	212	10	15	14	2	0	13	0	3	8	282	212	75.2
5	15	10	7	0	259	39	30	0	0	0	0	8	10	371	259	69.8
6	0	0	190	0	196	1620	33	17	0	0	25	6	6	2093	1620	77.4
7	10	19	39	0	60	142	965	4	11	0	0	9	10	1260	965	76.6
8	0	0	12	1	0	0	0	67	0	13	0	0	0	93	67	72
9	20	32	48	18	8	0	0	3	468	0	0	0	0	597	468	78.4
10	0	0	10	7	1	0	0	0	0	37	0	0	0	54	37	68.5
11	0	0	0	0	2	13	0	0	0	0	40	0	0	55	40	72.7
12	0	0	61	6	12	0	0	0	0	0	0	1015	58	1152	1015	88.1
13	0	0	23	3	43	0	0	0	0	0	0	86	698	853	698	81.8

Where 1 is oilseed rape (cut), 2 is winter barley (cut), 3 is urban, 4 is quarries and bare soil, 5 is mixed woodland, 6 is temporary grass, 7 is permanent grass, 8 is sand, 9 is oilseed rape, 10 is ploughed land, 11 is swedes and kale, 12 is winter wheat, and 13 is spring wheat.

Total number of pixels for all classes = **8189.** Total number of correctly classified pixels = **6542.**

Overall classification accuracy based on number of pixels = **80.6 %**.

Overall classification accuracy based on number of classes = **77.8 %**.

* Reference map classes are in rows, and image classes are in columns.

Table (5:10):- Classification accuracy assessment for Hett

Class	1	2	3	4	5	6	7	8	9	10	11	12	13	14	T	C	%
1	238	0	9	0	3	0	0	7	35	0	0	0	5	0	297	238	80.1
2	0	284	0	0	2	0	39	0	0	0	0	19	16	31	391	284	72.6
3	0	0	726	0	39	0	0	0	0	0	0	0	37	0	802	726	90.5
4	0	0	34	1108	64	0	0	0	0	0	0	0	55	0	1261	1108	87.8
5	0	0	54	0	61	0	0	0	0	7	8	0	11	6	147	61	41.5
6	0	0	7	0	18	12	0	0	0	1	0	0	4	0	42	12	28.6
7	0	25	0	0	0	0	434	0	0	0	0	0	0	0	459	434	94.6
8	0	0	0	0	7	1	0	66	0	0	0	0	3	0	77	66	85.7
9	15	0	0	0	2	0	0	2	285	0	20	0	0	0	324	285	88.5
10	0	17	0	0	11	0	0	0	9	340	6	5	25	6	419	340	81.2
11	20	0	0	0	1	0	0	0	40	0	663	0	6	0	730	663	90.8
12	0	0	0	0	1	0	0	0	0	0	0	398	11	29	439	398	90.7
13	0	0	17	0	3	0	0	41	0	0	0	0	32	0	93	32	34.4
14	24	0	0	0	3	0	0	0	18	0	2	52	19	787	905	787	87

Where 1 is winter wheat, 2 is winter barley (cut), 3 is temporary grass, 4 is permanent grass, 5 is deciduous woodland, 6 is coniferous woodland, 7 is oilseed rape (cut), 8 is fallow, 9 is spring barley, 10 is linseed, 11 is spring wheat, 12 is oilseed rape, 13 is urban, and 14 is winter barley.

Total number of pixels for all classes = **6386**

Total number of correctly classified pixels = **5434**

Overall classification accuracy based on number of pixels = **85.1 %**.

Overall classification accuracy based on number of classes = **75.3 %**.

Table (5:11):- Classification accuracy assessment for Wackerfield

Class	1	2	3	4	5	6	7	8	9	10	11	12	13	T	C	%
1	502	2	0	0	1	0	0	0	12	0	36	0	0	553	502	90.8
2	0	330	0	0	0	0	3	8	0	4	0	3	3	351	330	94
3	0	0	108	0	0	1	0	0	0	0	0	0	0	109	108	99.1
4	0	0	0	3	0	0	0	0	0	0	0	0	2	5	3	60
5	0	0	0	0	50	0	0	0	0	0	2	0	0	52	50	96.2
6	0	0	11	0	0	526	5	0	0	0	5	0	0	547	526	96.2
7	0	0	0	8	1	16	716	0	0	0	43	50	12	846	716	84.6
8	0	13	0	1	7	0	0	522	0	26	35	0	0	605	522	86.4
9	2	0	0	0	0	0	0	0	42	0	0	0	2	46	42	91.3
10	0	0	0	0	1	0	0	1	0	60	4	0	0	66	60	90.9
11	0	0	1	1	0	1	1	7	0	0	2	2	2	17	2	11.8
12	0	0	0	4	5	0	10	0	0	0	43	403	60	525	403	76.8
13	0	0	0	0	3	0	32	0	0	0	8	30	382	455	382	84

Where 1 is permanent grass, 2 is swedes and kale, 3 is oilseed rape, 4 is unimproved grass, 5 is coniferous woodland, 6 is winter barley, 7 is winter wheat, 8 is temporary grass, 9 is ploughed and sown, 10 is linseed, 11 is urban, 12 is spring barley, and 13 is spring wheat.

Total number of pixels for all classes = **4172**.

Total number of correctly classified pixels = **3446**.

Overall classification accuracy based on number of pixels = **87.4 %**.

Overall classification accuracy based on number of classes = **81.7 %**.

Table (5:12):- Classification accuracy assessment for Greencroft

Class	1	2	3	4	5	6	7	8	9	10	11	12	13	T	C	%
1	15	5	0	0	0	0	0	0	0	4	0	0	0	24	15	62.5
2	8	452	80	7	4	9	7	17	24	92	0	10	0	710	452	63.7
3	3	5	1978	5	4	3	5	18	20	97	0	10	0	2148	1978	92.1
4	2	4	0	98	0	10	0	8	0	0	0	4	0	126	98	77.8
5	0	0	0	0	80	0	1	0	3	0	0	0	0	84	80	95.2
6	2	2	0	33	0	344	0	24	7	0	0	17	0	429	344	80.2
7	2	25	0	11	61	22	1022	30	27	0	0	3	0	1203	1022	85
8	5	8	41	0	0	2	0	70	1	40	0	2	0	169	70	41.4
9	7	53	15	13	21	19	35	51	1373	6	2	8	0	1603	1373	85.7
10	13	320	80	9	6	8	39	53	117	2509	0	7	0	3161	2509	79.4
11	0	0	0	0	0	0	0	10	0	0	8	0	0	18	8	44.4
12	3	5	0	0	0	0	0	4	4	0	0	126	0	142	126	88.7
13	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	100

Where 1 is coniferous woodland, 2 is deciduous woodland, 3 is permanent grass, 4 is oilseed rape, 5 is oilseed rape (cut), 6 is winter barley, 7 is winter barley (cut), 8 is urban, 9 is unimproved grass, 10 is temporary grass, 11 is mixed land cover, 12 is winter wheat, and 13 is quarries.

Total number of pixels for all classes = **9819**.

Total number of correctly classified pixels = **8077.**

Overall classification accuracy based on number of pixels = **82.2 %**.

Overall classification accuracy based on number of classes = **76.6 %**.

Table (5:13):- Classification accuracy assessment for Satley

Class	1	2	3	4	5	6	7	8	9	10	11	12	13	T	C	%
1	429	0	14	0	0	12	0	17	0	0	0	0	15	487	429	88.1
2	4	956	30	0	0	15	0	17	0	0	0	97	11	1225	956	78
3	13	0	70	0	0	8	0	11	0	0	0	0	4	106	70	66
4	0	0	0	166	0	0	0	5	0	0	0	0	0	171	166	97.1
5	0	0	0	0	13369	157	50	327	560	0	0	0	112	14575	13369	91.7
6	0	0	0	0	20	179	0	7	20	0	0	0	23	249	179	71.9
7	0	0	0	0	20	11	874	67	10	2	0	0	3	987	874	88.6
8	0	0	0	0	9	0	0	9	10	0	0	0	0	28	9	32.1
9	0	0	0	0	29	66	29	17	614	0	0	0	2	779	614	78.8
10	0	0	0	0	0	0	0	1	0	117	0	3	0	121	117	96.7
11	0	0	0	0	0	2	0	1	0	0	68	0	0	71	68	95.8
12	0	77	16	0	0	0	0	10	0	0	0	214	0	317	214	67.5
13	4	6	8	0	3	63	6	15	0	0	3	0	648	756	648	85.7

Where 1 is spring barley, 2 is winter barley, 3 is winter wheat, 4 is sheep rape, 5 is permanent grass, 6 is coniferous woodland, 7 is quarries and bare soil, 8 is urban, 9 is temporary grass, 10 is winter barley (cut), 11 is swedes and kale, 12 is oilseed rape, and 13 is deciduous woodland. Total number of pixels for all classes = **19872**. Total number of correctly classified pixels = **17713**.

Overall classification accuracy based on number of pixels = **89.1 %**.

overall classification accuracy based on number of classes = **79.8 %**.

Table (5:14):- Classification accuracy assessment for Edmundbyers

Class	1	2	3	4	5	6	7	8	9	10	11	12	T	C	%
1	1423	0	0	0	0	0	0	0	0	0	0	0	1423	1423	100
2	0	7400	226	207	237	210	81	0	0	183	0	0	6544	7400	86.6
3	0	24	217	1	0	23	12	0	0	5	0	0	282	217	77
4	7	10	12	401	6	97	59	0	0	16	0	0	608	401	66
5	2	8	4	28	537	35	50	0	0	8	0	0	672	537	79.9
6	26	57	200	234	186	3348	245	0	0	71	0	0	4367	3348	76.7
7	23	20	41	142	92	206	10516	0	0	54	0	0	11094	10516	94.8
8	0	0	0	0	0	19	62	658	0	4	0	0	743	658	92.2
9	0	0	0	0	0	0	0	1	262	0	0	0	263	262	99.6
10	0	20	8	21	0	52	200	31	30	65	0	0	427	65	15.2
11	2	0	0	2	0	0	0	10	14	10	841	0	879	841	95.7
12	9	0	0	5	5	23	0	0	0	9	0	127	178	127	71.3

Where 1 is water bodies, 2 is temporary grass, 3 is permanent grass, 4 is coniferous woodland, 5 is deciduous woodland, 6 is unimproved grass, 7 is moorland, 8 is bare soil (dark), 9 is bare soil (light), 10 is urban, 11 is ploughed and sown land, and 12 is oilseed rape. Total number of pixels for all classes = **29480**. Total number of correctly classified pixels = **25795**. Overall classification accuracy based on number of pixels = **87.5 %**. Overall classification accuracy based on number of classes = **79.6 %**.

(3) Classification Accuracy Assessment for Image of 1992[*]

Table (5:15):- Classification accuracy assessment for Hawthorn

Class	1	2	3	4	5	6	7	8	9	T	C	%
1	500	8	10	9	8	0	0	0	0	532	500	93.5
2	0	766	63	3	26	2	0	3	0	863	766	88.8
3	0	32	1097	16	20	32	0	45	0	1242	1097	88.3
4	0	30	38	340	12	0	0	3	0	423	340	80.4
5	0	0	0	28	16	0	36	0	0	80	16	20
6	0	1	5	0	2	307	2	0	5	322	307	95.3
7	0	8	8	3	0	0	115	0	0	134	115	85.8
8	0	9	9	84	7	1	0	209	0	319	209	65.5
9	10	15	13	80	300	0	16	151	1749	2343	1749	74.9

Where 1 is oilseed rape, 2 is winter barley, 3 is winter wheat, 4 is temporary grass, 5 is urban, 6 is quarries and bare soil, 7 is sand, 8 is mixed woodland, and 9 is permanent grass.

Total number of pixels for all classes = **6249**. Total number of correctly classified pixels = **5099**. Overall classification accuracy based on number of pixels = **81.6 %**. Overall classification accuracy based on number of classes = **76.9 %**.

[*] Reference map classes are in rows, and image classes are in columns.

Table (5:16):- Classification accuracy assessment for Hett

Class	1	2	3	4	5	6	7	8	9	10	T	C	%
1	324	0	0	0	0	0	0	0	8	0	332	324	97.6
2	0	999	2	0	0	31	0	29	35	61	1157	999	86.3
3	0	0	2	0	0	0	0	0	0	0	2	2	100
4	0	0	0	84	10	0	0	0	17	0	111	84	75.7
5	0	0	0	11	183	0	0	0	26	3	233	193	82.8
6	0	32	1	0	0	1861	0	35	58	15	2002	1861	93
7	0	7	0	6	1	0	142	0	20	16	192	142	74
8	0	27	0	0	0	51	0	574	1	3	656	574	87.5
9	0	0	0	18	10	0	0	0	13	4	45	13	28.9
10	0	23	1	0	0	0	0	0	12	33	69	32	47.8

Where 1 is oilseed rape, 2 is temporary grass, 3 is coniferous woodland, 4 is ploughed and sown land, 5 is fallow, 6 is winter wheat, 7 is permanent grass, 8 is winter barley, 9 is urban, and 10 is deciduous woodland. Total number of pixels for all classes = **4799**.

Total number of correctly classified pixels = **4224**.

Overall classification accuracy based on pixel number = **88 %**. Overall classification accuracy based on number of classes = **77.2 %**.

Table (5:17):- Classification accuracy assessment for Wackerfield

Class	1	2	3	4	5	6	7	8	9	T	C	%
1	301	40	0	6	26	9	0	0	0	382	301	78.8
2	114	1047	2	16	5	26	0	0	0	1210	1047	86.5
3	5	5	38	3	0	0	0	0	1	52	38	73.1
4	0	0	7	26	0	2	7	0	11	53	26	49.1
5	22	32	0	0	150	0	2	0	0	207	150	72.5
6	4	0	0	6	0	24	0	0	0	34	24	70.6
7	0	0	0	2	0	0	106	0	0	108	106	98.1
8	0	2	0	7	0	0	1	359	0	369	359	97.3
9	20	3	0	11	0	6	0	8	544	592	544	91.3

Where 1 is temporary grass, 2 is winter wheat, 3 is coniferous woodland, 4 is urban, 5 is oats, 6 is unimproved grass, 7 is ploughed and sown land, 8 is oilseed rape, and 9 is permanent grass.

Total number of pixels for all classes = **3007**. Total number of correctly classified pixels = **2595**.

Overall classification accuracy based on number of pixels = **86.3 %**. Overall classification accuracy based on number of classes = **79.7 %**.

Table (5:18):- Classification accuracy assessment for Greencroft

Class	1	2	3	4	5	6	7	8	9	10	11	12	T	C	%
1	708	20	41	7	9	0	0	0	0	0	15	32	832	708	85.1
2	29	926	30	35	7	0	0	0	0	0	9	0	1036	926	89.4
3	94	21	2561	8	6	0	3	0	5	0	21	64	2783	2561	92
4	2	36	7	708	61	0	0	0	0	0	8	1	823	708	86
5	1	4	0	22	41	0	0	0	0	0	1	0	69	41	59.4
6	1	0	0	0	0	26	0	0	0	0	0	0	27	26	96.3
7	1	0	0	3	0	0	62	0	0	0	0	0	66	62	93.9
8	0	0	1	0	0	0	0	18	0	0	4	0	23	18	78.3
9	1	0	0	0	0	0	0	0	29	0	0	0	30	29	96.7
10	0	0	0	0	0	0	0	0	0	11	0	0	11	11	100
11	17	0	0	0	0	0	0	0	87	33	70	5	212	70	33
12	109	10	33	15	10	0	0	2	0	0	62	641	882	641	72.7

Where 1 is deciduous woodland, 2 is temporary grass, 3 is permanent grass, 4 is winter barley, 5 is winter wheat, 6 is quarries and bare soil, 7 is oilseed rape, 8 is mixed land cover, 9 is ploughed and sown land, 10 ploughed land, 11 is urban, and 12 is unimproved grass.

Total number of pixels for all classes = **6771**. Total number of correctly classified pixels = **5801**.

Overall classification accuracy based on number of pixels = **85.7 %**. Overall classification accuracy based on number of classes = **75.6 %**.

Table (5:19):- Classification accuracy assessment for Satley

Class	1	2	3	4	5	6	7	8	9	10	11	T	C	%
1	93	1	0	0	0	0	0	0	0	0	0	94	93	98.9
2	3	5510	20	130	141	32	39	27	144	230	15	6291	5510	87.6
3	0	0	450	0	0	0	23	0	0	0	0	473	450	95.1
4	0	12	0	503	43	25	10	9	12	10	0	624	503	80.6
5	0	0	0	12	209	71	2	4	6	0	0	304	209	68.8
6	0	0	0	2	11	78	5	6	3	0	0	105	78	74.3
7	0	0	0	0	0	0	4	0	0	0	10	14	4	28.6
8	0	3	0	0	0	0	3	234	44	2	0	286	234	81.8
9	0	7	8	3	32	0	13	112	482	0	0	657	482	73.4
10	3	93	11	50	63	73	126	54	116	2635	0	3224	2635	81.7
11	0	0	18	0	0	2	24	4	2	4	634	688	634	92.2

Where 1 is oilseed rape, 2 is temporary grass, 3 is quarries and bare soil, 4 is winter barley, 5 is winter wheat, 6 is spring barley, 7 is urban, 8 is coniferous woodland, 9 is deciduous woodland, 10 is permanent grass, and 11 is ploughed and sown land.

Total number of pixels for all classes = **12760**. Total number of correctly classified pixels = **10832**

Overall classification accuracy based on number of pixels = **84.9 %**. Overall classification accuracy based on number of classes = **78.5 %**.

Table (5:20):- Classification accuracy assessment for Edmundbyers

Class	1	2	3	4	5	6	7	8	9	10	11	12	13	T	C	%
1	1671	7	7	0	0	0	0	0	0	5	0	0	0	1690	1671	98.9
2	11	356	0	9	4	0	0	59	0	95	6	0	0	540	356	65.9
3	10	5	273	10	9	0	0	60	0	112	10	0	0	489	273	55.8
4	0	5	4	905	50	0	0	3	0	55	12	0	0	1034	905	87.5
5	0	11	5	93	1505	0	0	103	0	35	26	0	0	1778	1505	84.6
6	0	0	0	1	0	8	0	0	0	0	0	0	0	9	8	88.9
7	0	4	0	0	0	0	31	0	0	0	2	0	0	37	31	83.8
8	5	31	6	1	0	0	0	8020	0	93	9	30	0	8165	8020	98.2
9	3	14	1	0	0	0	0	0	124	0	6	0	21	196	124	63.3
10	28	245	287	85	93	0	0	224	0	4090	174	0	0	5226	4090	78.3
11	8	12	11	30	40	0	0	16	0	63	51	0	0	231	51	22.1
12	6	11	46	0	21	0	0	0	0	0	0	1890	0	1974	1890	95.7
13	2	0	0	0	0	0	0	0	2	0	0	0	228	232	228	98.3

Where 1 is water bodies, 2 is coniferous woodland, 3 is deciduous woodland, 4 is temporary grass, 5 is permanent grass, 6 is oilseed rape, 7 is winter barley, 8 is moorland, 9 is ploughed and sown land, 10 is unimproved grass, 11 is urban, 12 is bare soil (light), and 13 is bare soil (dark). Total number of pixels for all classes = **21601**. Total number of correctly classified pixels = **19152**. Overall classification accuracy based on number of pixels = **88.7%**. Overall classification accuracy based on number of classes = **73%**.

5.3.2 Image Classification Accuracy Assessment Generalisation

It has been seen from the detailed image classification that an agricultural crop may have more than one land cover condition. For example, winter barley and oilseed rape in August have two different land cover conditions (harvested and not harvested), improved grass has two different land cover conditions (temporary and permanent), and so on. So, classification accuracy assessment can be simplified as follows:-

(1) Classification Accuracy Assessment Generalisation for the Image of May 1985.

Number of classes included in the classification scheme for this image is 18 classes. So, classes of the same agricultural family are put together in one class. These generalised classes are:-

(a) Deciduous woodland, coniferous woodland, and mixed woodland are combined in a **woodland** class (WL).

(b) Temporary grass and permanent grass are combined in an improved grass class (IG).

(c) Winter barley, winter wheat, and oats are combined in an arable (cereal) class (A).

This generalisation process resulted in the following land use \ land cover classes:-

(1) woodland, (2) improved grass, (3) arable (cereals), (4) oilseed rape, (5) quarries and bare soil, (6) urban areas, (7) sand, (8) unimproved grass, (9) moorland, (10) water bodies, (11) ploughed land, (12) ploughed and sown land, (13) bare soil, and (14) fallow.

Table (5:21):- Generalised classification accuracy assessment results of the six study areas for the image of May 1985 (%).

NO.	*CLASS*	HAW.	HETT	WACK.	GREEN.	SAT.	EDMUND.
1	WL	76.6	38.8	-	85.7	87	73.3
2	IG	78.9	79.9	90.9	85.9	88.2	84.7
3	A	93.4	94.1	95.7	85.5	91.4	-
4	U	28.1	43.8	27	47	52.2	15.7
5	Q+BS *	89.2	-	-	-	93.2	-
6	UG	-	-	-	76.3	-	74.5
7	M	-	-	-	-	-	97.8
8	W	-	-	-	-	-	99.6
9	F	-	-	-	61.6	-	-
10	P+S	69.4	89.4	89.3	93.6	73.3	-
11	OSR	97.9	98.1	98.7	-	91.9	-
12	S	88.1	-	-	-	-	-
13	BS	-	-	-	-	-	94.1
14	P		67.4	-	-	73.3	-
	P. A.	**85.1**	**87.1**	**92.6**	**84.2**	**86.9**	**88.5**
	C. A.	**77.7**	**73.1**	**80.3**	**76.5**	**81.3**	**77.1**

Where P. A. is classification accuracy based on number of pixels, and C. A. is classification accuracy based on number of classes. *See annotation key for classes in Ch. 4.*

* These two classes are put in one class in the parishes which have both classes, and separated in the parishes which have only one of them.

(2) Classification Accuracy Assessment Generalisation for the Image of August 1990.

It can be seen that number of classes included in the classification scheme of this image is the highest (25 classes). The reason for this is that at this time the fields are cultivated with both spring and winter crops, and some winter crops such as winter barley and oilseed rape have two land cover conditions as mentioned earlier in this chapter. So, in addition to the previous class generalisations, the following generalisations have been made:-

(a) spring and winter cereals are included in an arable (cereals) class (A).

(b) harvested and not harvested oilseed rape classes are included in an oilseed rape class (OSR).

Table (5:22):- Generalised classification accuracy assessment results of the six study areas for the image of August 1990 (%).

NO.	CLASS	HAW.	HETT	WACK.	GREEN.	SATLEY	EDMUND.
1	WL	69.8	47.6	96.2	65.4	90.8	75.9
2	IG	82	90.5	88.4	87.9	94.9	89.1
3	A	91.2	92.9	94.5	79.4	84.2	-
4	U	70	34.4	11.8	41.4	32.1	15.2
5	UG	-	-	-	85.7	-	76.7
6	M	-	-	-	-	-	94.8
7	W	-	-	-	-	-	100
8	OSR	84.7	92.7	99.1	84.8	67.5	71.3
9	S	72	-	-	-	-	-
10	Q+BS	75.2	-	-	100	88.6	-
11	BS	-	-	-	-	-	91.6
12	MLC	-	-	-	44.4	-	-
13	P+S	-	-	91.3	-	-	95.7
14	P	68.5	-	-	-	-	-
15	S+K	72.7	-	94	-	95.8	-
16	LS	-	81.2	90.9	-	-	-
17	S.R	-	-	-	-	97.1	-
18	F	-	85.7	-	-	-	-
	P. A.	**84.6**	**89.1**	**92.5**	**83.3**	**92.8**	**88.5**
	C. A.	**76.2**	**75**	**83.3**	**73.6**	**81.4**	**78.9**

Where P. A. is classification accuracy based on number of pixels, and C. A. is classification accuracy based on number of classes. *See annotation key for classes in Ch. 4.*

Table (5:23):- Generalised classification accuracy assessment results of the six study areas for the image of July 1992 (%).

NO.	CLASS	HAW.	HETT	WACK.	GREEN.	SATLEY	EDMUND.
1	WL	65.5	49.3	73.1	85.1	92.5	61.6
2	IG	78.7	85.1	88.8	92.6	89	90.8
3	A	93	94.8	87.1	93.3	92.4	83.8
4	U	20	28.9	49.1	33	28.6	22.1
5	UG	-	-	70.6	72.7	-	78.3
6	M	-	-	-	-	-	98.2
7	W	-	-	-	-	-	98.9
8	OSR	93.5	97.6	97.3	93.9	98.9	88.9
9	Q+BS	95.3	-	-	96.3	95.1	-
10	BS	-	-	-	-	-	96
11	P+S	-	75.7	98.1	96.7	92.2	63.3
12	F	-	82.8	-	-	-	-
13	S	85.8	-	-	-	-	-
	P. A.	**84.4**	**90**	**88.2**	**87.4**	**89.9**	**89.3**
	C. A.	**76**	**73.5**	**80.6**	**84.8**	**84.1**	**78.2**

TABLE (5:24):- TOTAL CLASSIFICATION ACCURACY ASSESSMENT RESULTS FOR MAJOR LAND USE \ LAND COVER TYPES OF THE STUDY AREA OVER THE THREE IMAGE DATES (%)

NO	CLASS	MAY 1985	AUGUST 1990	JULY 1992
1	WOODLAND	78.9	76.1	76.9
2	IMPROVED GRASS	85.6	90.8	88.3
3	ARABLE (CEREALS)	93.4	89.3	92.5
4	OILSEED RAPE	97.1	85.1	96
5	QUARRIES + BARE SOIL	92.8	88.2	95.8
6	URBAN AREAS	37.1	29.7	28.3
7	SAND	88.1	72	85.8
8	UNIMPROVED GRASS	74.9	79.1	77.4
9	MOORLAND	97.8	94.8	98.2
10	WATER BODIES	99.6	100	98.9
	P. A.	87.6	88.9	88.7
	C. A.	84.7	80.5	83.8

Where P. A. is classification accuracy based on number of pixels, and C. A. is classification accuracy based on number of classes. *See annotation key for classes in Ch. 4.*

From the classification accuracy results it can be seen that number of classes included in the classification scheme affects this accuracy. So, generalisation of classes improves classification accuracy for it avoids the overlap which occurs between land use \ land cover classes of the same agricultural family. Another important point to notice from this study is that classification accuracy based upon pixel numbers is considerably better than that based upon class numbers. The reason for this is that classes with poor accuracy such as the urban class do not represent a large number of pixels in agricultural areas on one hand, and on the other hand, classes with good accuracy such as improved grass and moorland represent a large number of pixels in the study area as a whole. So, when considering class accuracy; urban class will have the same weight as improved grass and moorland classes, and consequently this reduces the overall classification accuracy apart from its low representation in the study area.

5.3.3 Interpretation of Classification Accuracy Results for the Three Image Dates

From classification accuracy results, it can be seen that,

(a) Classification accuracy of the six study areas over the three image dates is affected negatively by the low accuracy of the built-up class. This class is inaccurate because urban areas in County Durham consist of individual and separated farm houses, and spaces between these houses are normally planted with permanent grass. So, purely urban areas are rare in such an environment. On the other hand, the roads in rural areas are normally narrow (less than 10 m or less than half a pixel). This means roads and buildings are assigned to the dominant adjacent land cover types or to an unknown class, and consequently the number of unclassified pixels rises. Confusion matrices show that the urban class overlaps most other classes.

(b) The good accuracy achieved for the improved grass class which represents between 40-55% of the study area improved the classification accuracy based upon pixel numbers over the three dates.

(c) Water bodies achieved the highest accuracy over the three dates for it is highly spectrally separated from other land cover types.

(d) The oilseed rape class achieved much higher accuracy in the May and July images than the image of August (more than 96%). The reason for that is in these dates, oilseed rape will be in the flowering stage, and so well spectrally separated from other land cover types, while in August; it overlaps winter barley.

(e) The woodland class did not achieve high accuracy results, because this land cover type is mostly mixed with improved grass in the eastern agricultural region and unimproved grass in the western agricultural region. In some cases such as Hett, the woodland class represents only a narrow strip with a railway passing through and by the forest.

(f) The sand in the coastal area represented by Hawthorn in the image of August 1990 did not achieve as high an accuracy as the other two dates. It can be seen that the number of pixels assigned to this class in this image date is considerably less than the other two dates. This can be explained by the high sea tides that occurred on the 1st August 1990. So, the fine textured sand adjacent to water boundaries are covered with water, and only the rough textured area of this land cover type is visible. This area consists mainly of escarpments, sandstone, and gravel which have spectral properties similar to urban areas and rough soil. So, a certain number of sand pixels are assigned to urban or ploughed classes.

(g) The unimproved grass class accuracy is affected by its overlap with the moorland class. So, a certain number of moorland pixels are assigned to this class, and consequently the area of unimproved grass class is overestimated considerably.

(h) The moorland class achieved high accuracy because, firstly, it mainly overlaps with the unimproved grass class only. Secondly, it represents a relatively high percentage of the study area, and thirdly, it exists in only one of the six study areas (Edmundbyers).

(i) The classification accuracy of the improved grass class increases from spring to summer. This explains the increasing contrast between this class and cereal class from May to August.

(j) The classification accuracy of cereal crops decreases from spring to summer. The reason for that is because fields in summer will have both spring and winter crops on one hand, and winter barley has two land cover conditions (harvested and not harvested). However in May, the spring crops will be mostly soil.

(k) The classification accuracy of quarries and the bare soil class is high because it is well spectrally separated from other land cover types.

5.3.4 Factors that Affect Image Classification Accuracy

The image classification operation cannot be separated from other image processing operations and other conditions related to it. All these operations and conditions represent one unit and every part of this unit have affected other parts, starting from image acquisition conditions to that of image classification. So, the following factors may affected classification accuracy of the study area:-

(1) Data Acquisition Errors. These errors can be divided into two major types, (a) Natural error such as atmospheric conditions and topographical variations effects. This type of errors cannot be controlled. For example, some haze in the subscene of Hawthorn of the image of August 1990 affected the visibility of its data. (b) Human error. This error includes the original error of data used and that results from processing this data.

(2) Image Spatial Filtering. Image smoothing aims to get rid of isolated pixels to produce readable cartographic maps, and so it generalises classified image data. This process in some way alters the original pixel value. Errors such as displacement of original field boundaries or loss of some image data may occur. In the case of this study, and in the eastern region study areas; classification accuracy is enhanced by image filtering. The reason for this is that in this region field sizes are relatively large, and the terrain is flat. While in the central and the western regions; where terrain is relatively rough and field sizes are smaller, image filtering resulted in a loss of some data along drains and field boundaries. So, it can be said that image smoothing enhances classification accuracy in large fields and flat terrain areas, and loses some data in small field and rough terrain areas.

(3) Geometric Correction Errors (rmse). Manipulation of more than one type of data in the form of layers in GIS requires precise registration between these data layers. The imperfect registration of classified images to reference maps resulted in a kind of spatial disagreement between reference maps and classified images. So, when classified images are combined with reference maps, this spatial disagreement between the reference and the evaluated layers results in misclassification.

(4) Mixed Pixels. It has been seen that the classification accuracy of the urban class for all dates is very poor because these pixels are mixed with other land cover types. Sometimes, the maximum likelihood classifier could not assign these pixels to a certain class. Mixed pixels exist also in borders of polygons.

(5) Method of Accuracy Assessment. The accuracy assessment applied on this study is not solely a grid-by-grid method because it involves a kind of deduction of the distribution of misclassified pixels between the highly overlapping classes such as cereal crop classes. These errors may affect the classification accuracy results of these classes.

(6) Subjectivity of Researcher. This kind of error is one of the most difficult sources of error to estimate, because it varies from one researcher to another. In addition to that, the method of data interpretation and analysis affects considerably the classification accuracy.

5.4 Conclusion

The general results of geometric correction can be considered satisfactory in terms of the registration of images to reference maps. The achievement of this relatively high accuracy may be due to the successful selection of ground control points, the small size of the study areas, the relatively large scale maps used for image registration (1:10, 000 and 1:25, 000) and homogeneity of the terrain in the areas. But results do not reflect the real geometric accuracy because reference map accuracy is affected by different factors, such as digitising and data conversion errors. On the other hand, the classification accuracy based on pixel numbers was more than 85% over all dates, and that based on number of classes was more than 80%. The best date for improved grass classification was August, and in May and July for cereal crops.

For more efficient, realistic, and accurate evaluation of classification accuracy; more research and investigation is required for the documentation of the sources of errors and the possibility of integrating these errors into GIS.

CHAPTER SIX

Chapter 6: Area Estimation and Land Use Change by Satellite Remote Sensing

6.1 Introduction

Nowadays, remote sensing is not only used for crop area estimation and land use change detection, but also for estimating crop yields. This development in remote sensing capability goes beyond local and national levels to a global scale. One fundamental aim of this study is to verify the capability of remote sensing for estimating and detecting land use types and land use change trends in the study area in comparison with other methods of land use mapping.

6.2 Area Estimation for Land Use Classes Over the Three Image Dates

The three images of the study area are integrated in a GIS to detect the number of the pixels assigned to each land use \ land cover class. Estimation of each land use class area is done by multiplying the number of pixels in each class by the square of pixel size. The result in this case will be in square metres. To convert the square metre to the area in hectares , the result is divided by 10, 000. So, the equation for area estimation is:-

$$\text{ha } 1 = \frac{p^2 \times \text{np } 1}{10,000}$$

Where ha 1 is hectare area of class 1, p^2 is pixel size square, np 1 is number of pixels in class 1, and 10,000 is the hectare area in metres squared.

Pixel size varies from one date to another and from one study area to another. The field of view determines the pixel size for different dates, and the relative location of each study area compared to field of view determines the pixel size of each. The calculation of pixel size was done by converting the images to grids.

Table (6:1):- pixel size (m) of the six study areas over the three image dates

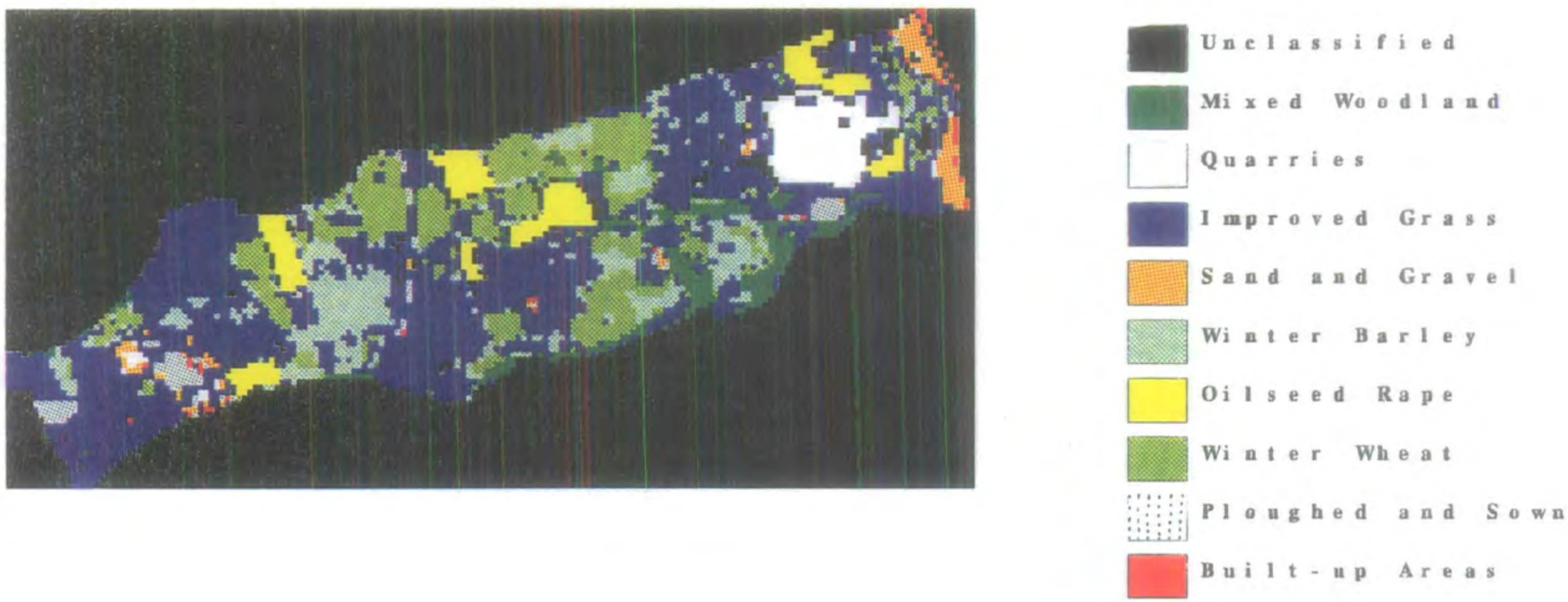
	Hawthorn	Hett	Wackerfield	Greencroft	Satley	Edmundbyers
1985	29.929	30.748	30.343	30.165	30.12	29.905
1990	25.209	25.415	25.453	25.105	25.214	25.394
1992	29.669	31.327	30.446	30.244	30.341	29.776

Table (6:2):- Class area estimation of the six study areas for the image of May 1985 (detailed classification), ha\ %

NO.	CLASS	HAW.	HETT	WACK.	GREEN.	SAT.	EDMUND.
0	UN.	25.26\ 4.8	57.77\ 11.4	12.98\ 4.3	26.93\ 4	59.06\ 4.3	125.63\ 6.1
1	MWL	29.2\5.1	-	-	-	-	-
2	Q+BS	28.48\ 4.9	-	-	-	25.67\ 1.9	-
3	IG.T	71.12\ 12.3	80.64\ 15.9	83.97\ 27.6	342.85\ 50.5	205.93\ 15.2	460.48\ 22.3
4	S	12.18\ 2.1	-	-	-	-	-
5	WB	64.4\ 11.2	105.22\ 20.8	24.31\ 8	33.85\ 5	113.58\ 8.4	-
6	OSR	34.57\ 6.0	48.22\ 9.5	23.75\ 7.8	-	30.39\ 2.3	-
7	WW	85\14.7	65.71\ 13	77.89\ 25.6	28.21\ 4.2	14.15\ 1.1	-
8	IG.P	212.64\ 36.8	64.19\ 12.7	29\ 9.5	50.32\ 7.4	691.38\ 51.1	154\ 7.5
9	P+S	11.2\1.9	52.09\ 10.3	22.93\ 7.5	47.68\ 7	67.4\ 5	-
10	U	3.76\ 0.7	5.77\ 1.1	3.68\ 1.2	15.1\ 2.2	21.1\ 1.6	19.76\ 1
11	DWL	-	17.3\ 3.4	-	72.52\ 10.7	55.61\ 4.1	66.89\ 3.2
12	CWL	-	1.23\ 0.2	-	6.28\ 0.9	28.12\ 2.1	45.88\ 2.2
13	P	-	8.89\ 1.8	-	-	40.19\ 3	-
14	O	-	-	25.96\ 8.5	-	-	-
15	F	-	-	-	7\ 1	-	-
16	UG	-	-	-	47.68\ 7	-	281.88\ 13.7
17	M	-	-	-	-	-	706.05\ 34.2
18	BS						73.33\ 3.6
19	W	-	-	-	-	-	129.05\ 6.3
	TOTAL	**577.81 ha**	**507.03 ha**	**304.47 ha**	**678.3 ha**	**1352.62 ha**	**2062.95 ha**
		100%	**100%**	**100%**	**100%**	**100%**	**100%**

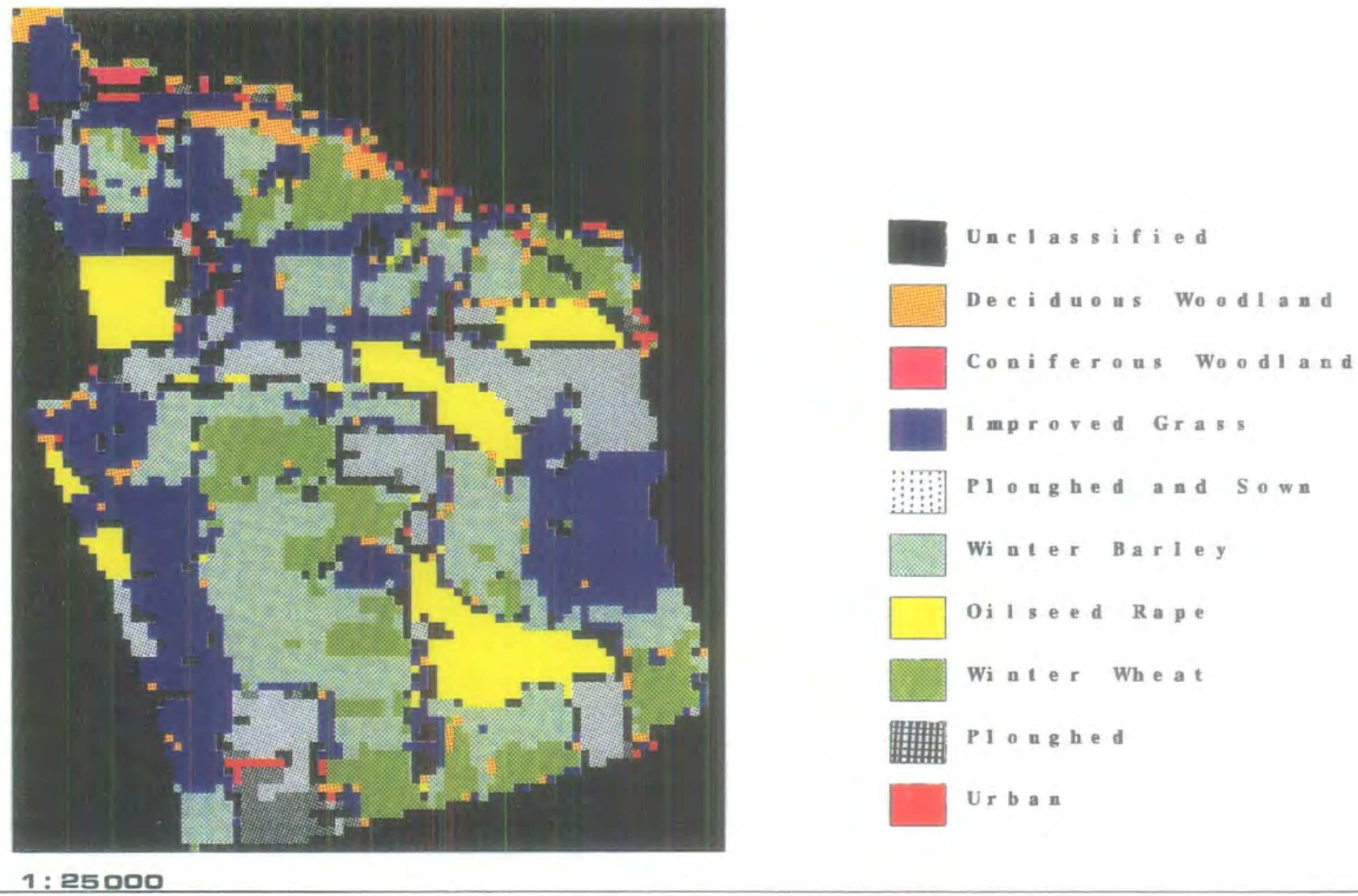
UN. is unclassified pixels class.

Hawthorn Landuse Map of Landsat5 TM Image (31/5/85)

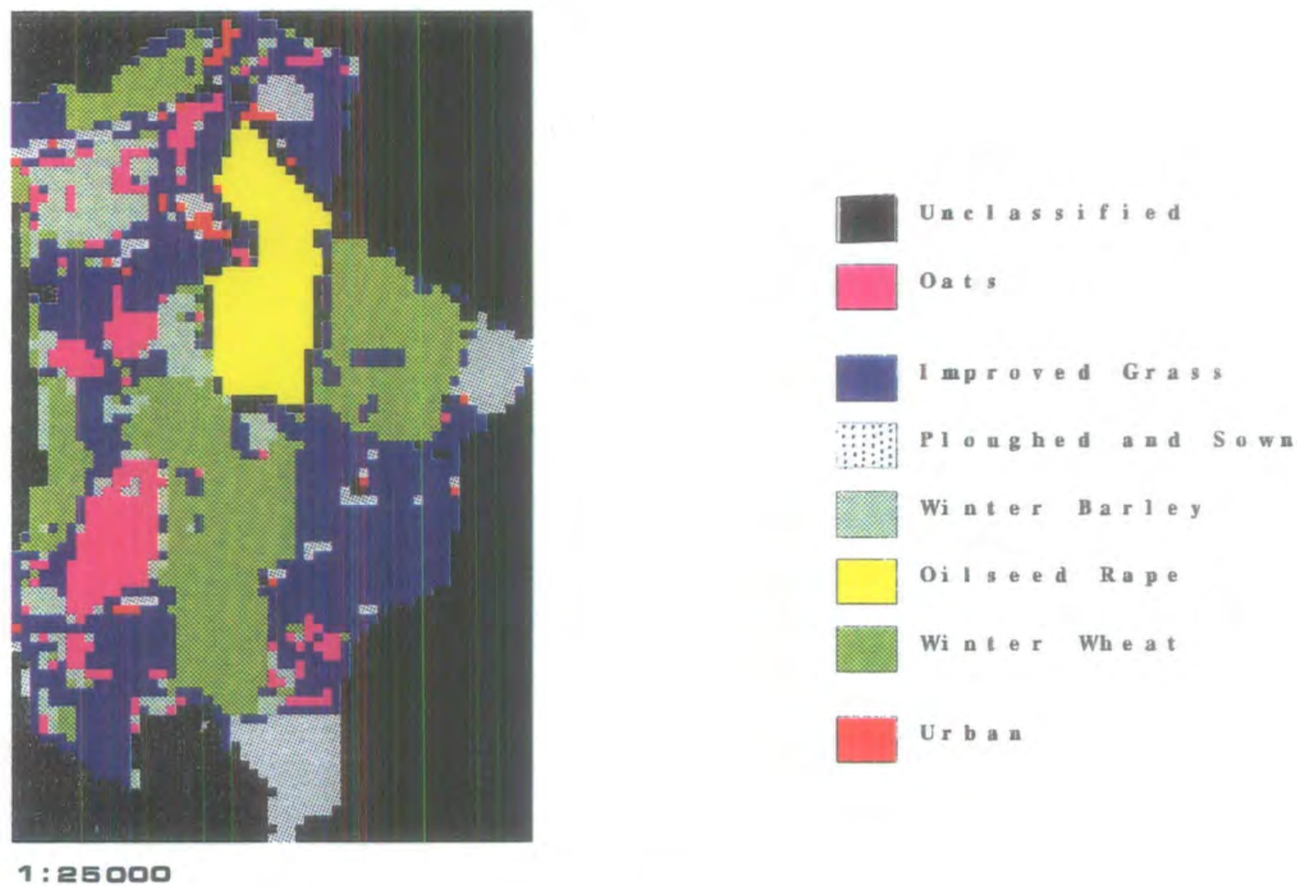


Scale 1 : 40,000

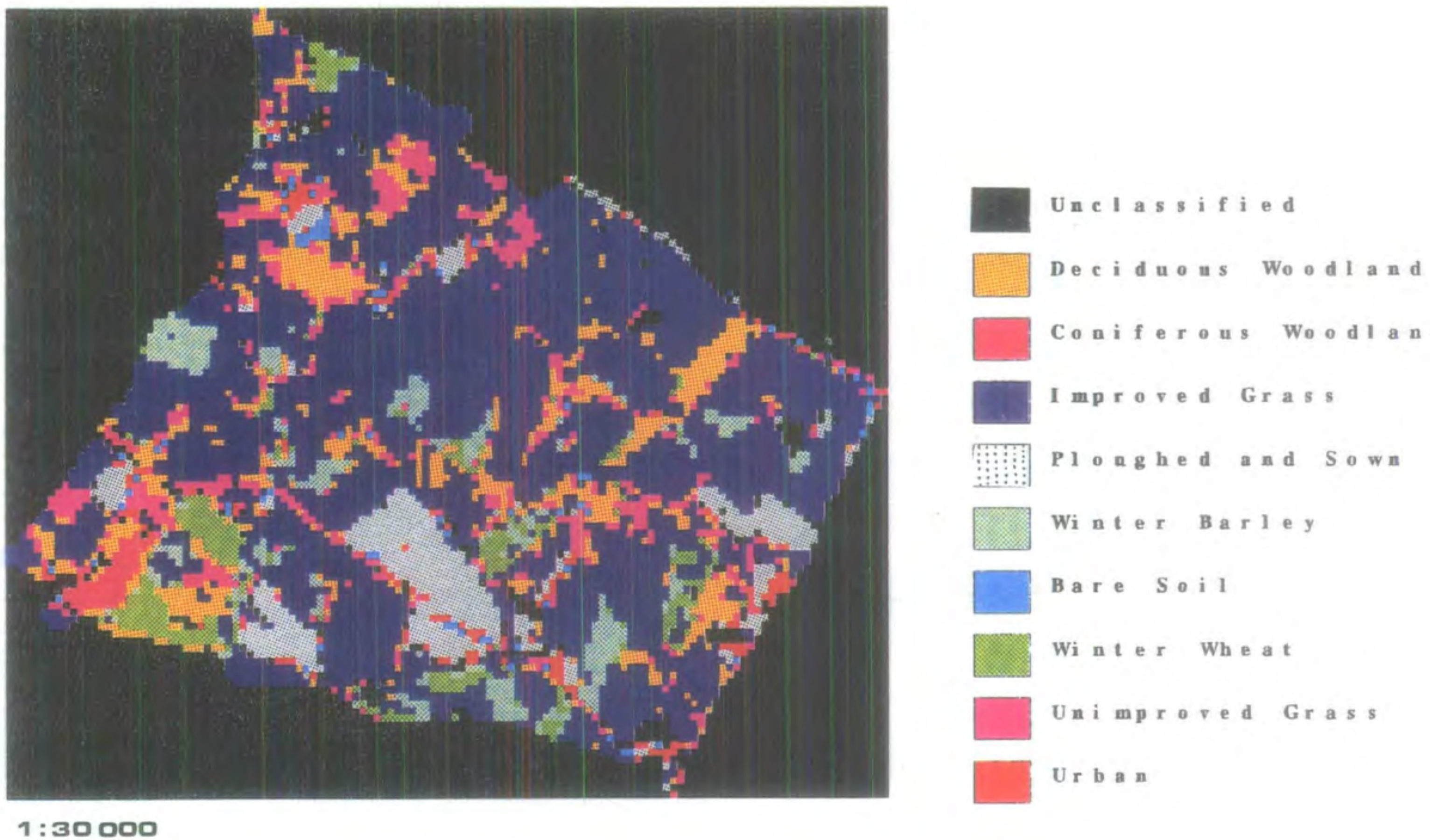
Hett Landuse Map of Landsat-5TM Image (31/5/85)



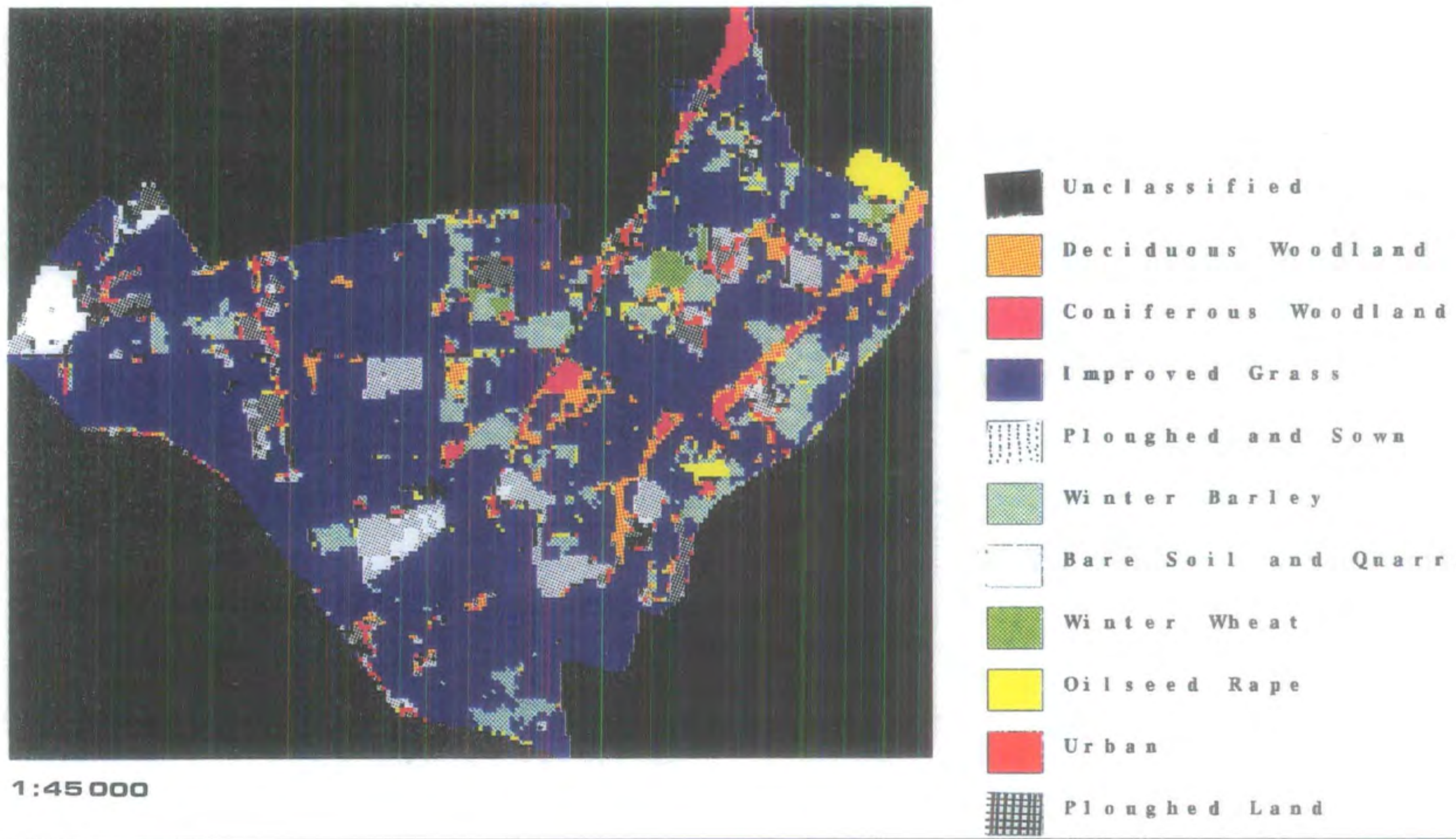
Wackerfield Landuse Map of Landsat-5TM Image (31/5/85)



Greencroft Landuse Map of Landsat-5TM Image (31/5/85)



Satley Landuse Map of Landsat-5TM Image (31/5/85)



Edmundbyers Landuse Map of Landsat-5TM Image (31/5/85)

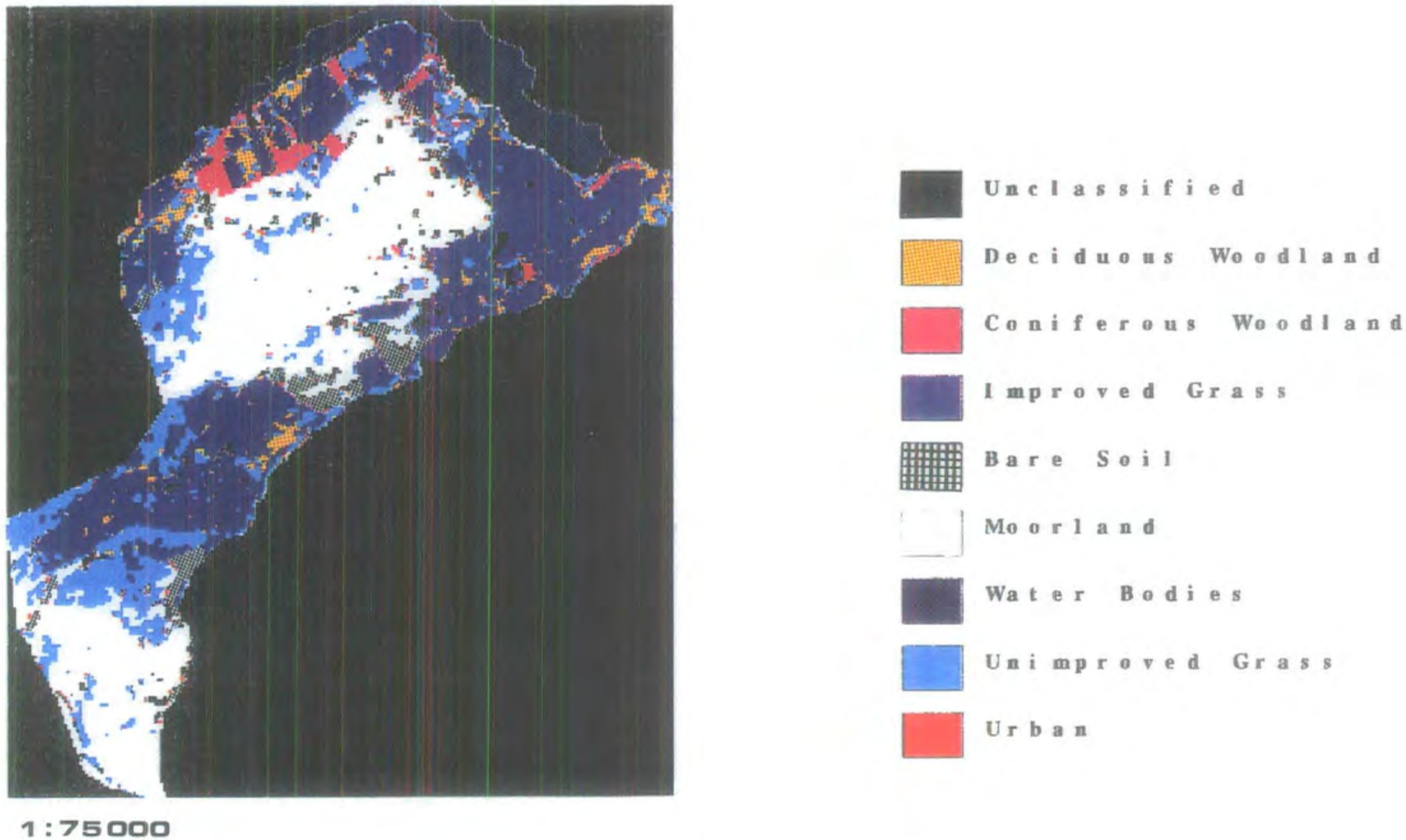
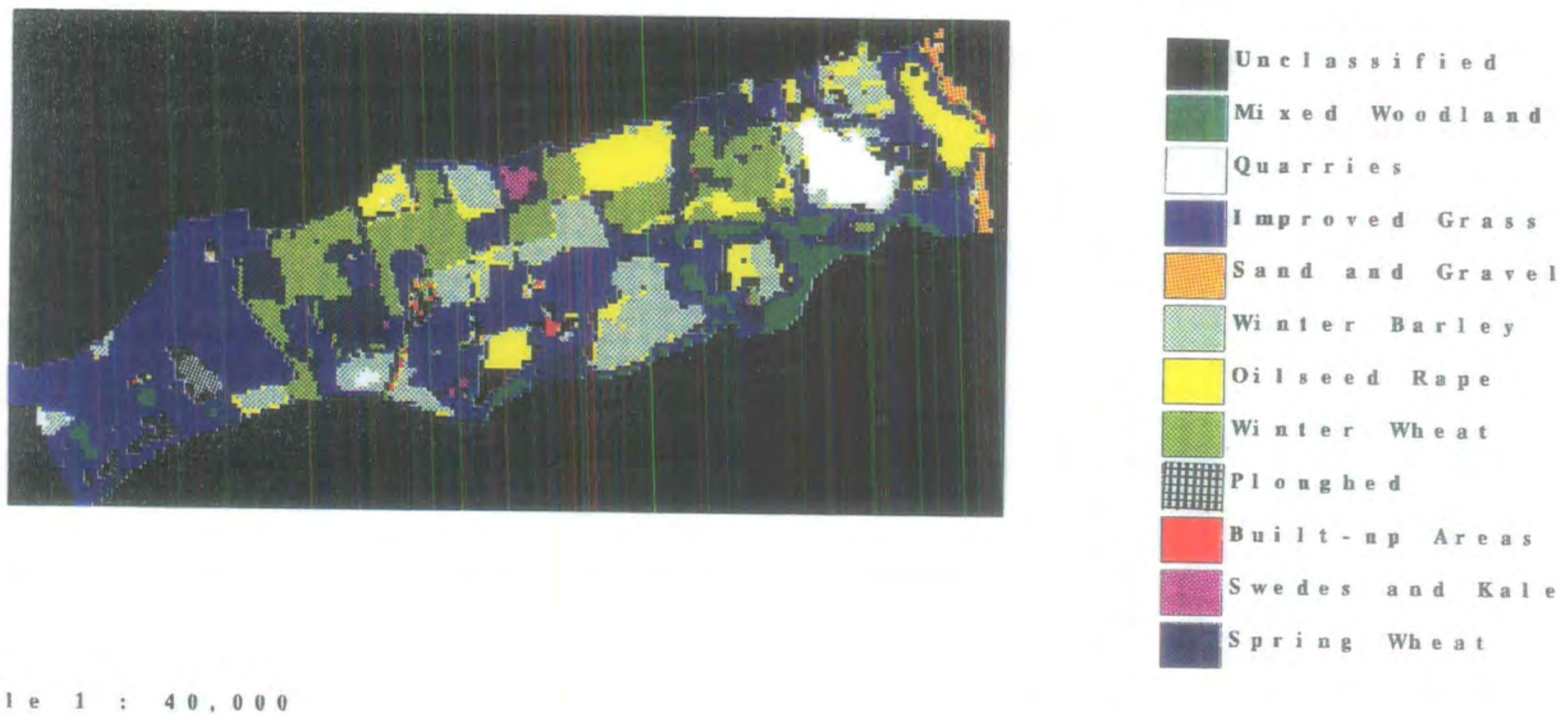


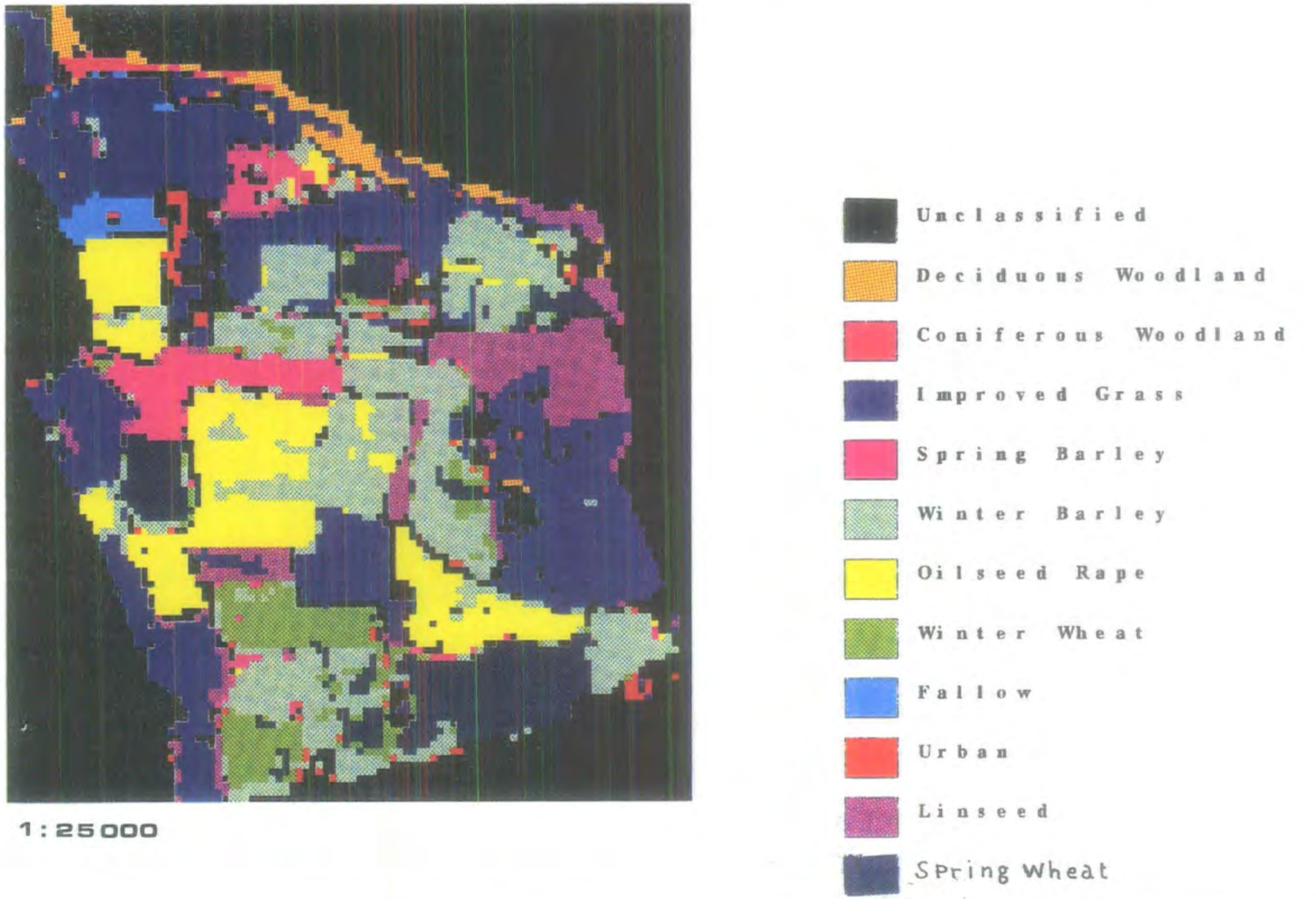
Table (6:3):- Class area estimation of the six study areas for the image of August 1990, (detailed classification), ha\ %

NO.	CLASS	HAW.	HETT	WACK.	GREEN.	SAT.	EDMUND.
0	UN.	59.8\ 10.4	63.24\ 12.46	29.61\ 9.7	51.05\ 7.5	83.47\ 6.2	158.26\ 7.7
1	OSR-CUT	14.49\ 2.5	29.65\ 5.8	-	5.36\ 0.8	-	-
2	WB	-	58.5\ 11.3	-	27.23\ 4	71.34\ 5.3	-
3	U	1.84\ 0.3	6.72\ 1.3	1.1\ 0.4	10.97\ 1.6	1.78\ 0.1	27.8\ 1.4
4	Q+BS	17.22\ 3	-	-	0.13\ 0.02	62.87\ 4.6	-
5	MWL	24.09\ 4.2	-	-	-	-	-
6	IG.T	135.62\ 23.5	53.42\ 10.5	39.65\ 13	202.2\ 29.8	935.11\ 69	553.58\ 26.8
7	IG.P	79.56\ 13.8	88.55\ 17.5	37.71\ 12.4	136.21\ 20.1	49.77\ 3.7	18.25\ 0.9
8	S	5.18\ 0.9	-	-	-	-	-
9	OSR	36.99\ 6.4	28.36\ 5.6	7.O6\ 2.3	7.94\ 1.2	23.27\ 1.7	11.8\ 0.6
10	P	3.43\ 0.6	-	-	-	-	-
11	S+K	3.11\ 0.5	-	22.94\ 7.5	-	4.64\ 0.3	-
12	WW	74.48\ 12.9	25.9\ 5.1	54.88\ 18	9.27\ 1.4	6.8\ 0.5	-
13	SW	53.64\ 9.3	41.66\ 8.2	29.54\ 9.7	-	-	-
14	CWL	-	2.78\ 0.6	3.43\ 1.1	1.64\ 0.2	16.15\ 1.2	39.21\ 1.9
15	WB-CUT	68.13\ 11.8	37.07\ 7.3	35.96\ 11.8	77.02\ 11.3	7.69\ 0.6	-
16	F	-	4.97\ 1	-	-	-	-
17	SB	-	20.93\ 4.1	34.27\ 11.3	-	31.85\ 2.4	-
18	LS	-	35.33\ 7	4.92\ 1.6	-	-	-
19	UG	-	-	0.32\ 0.1	102.36\ 15.1	-	283.43\ 13.7
20	MLC	-	-	-	1.98\ 0.3	-	-
21	DWL	-	10.33\ 2	-	46.26\ 6.8	49.27\ 3.6	42.5\ 2.1
22	M	-	-	-	-	-	715.52\ 34.7
23	W	-	-	-	-	-	91.9\ 4.5
24	S.R	-	-	-	-	10.87\ 0.8	-
25	P+S	-	-	2.98\ 1	-	-	56.75\ 2.8
	BS	-	-	-	-	-	64.94\ 3.1
	TOTAL	**577.58**	**507.43**	**304.37**	**679.62**	**1354.88**	**2063.88**
		100	**100**	**100**	**100**	**100**	**100**

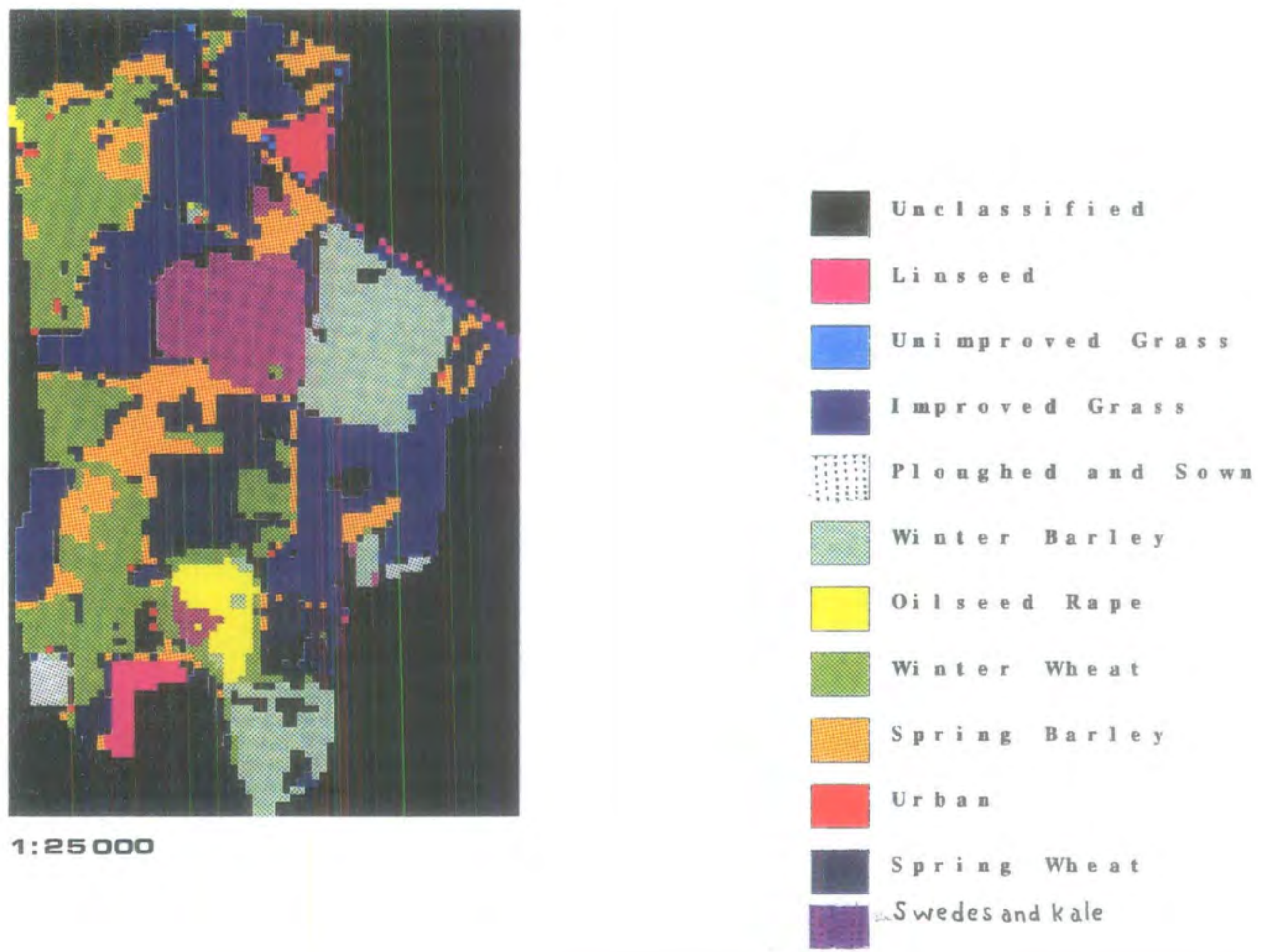
Hawthorn Landuse Map of Landsat-5-TM Image (1/8/90)



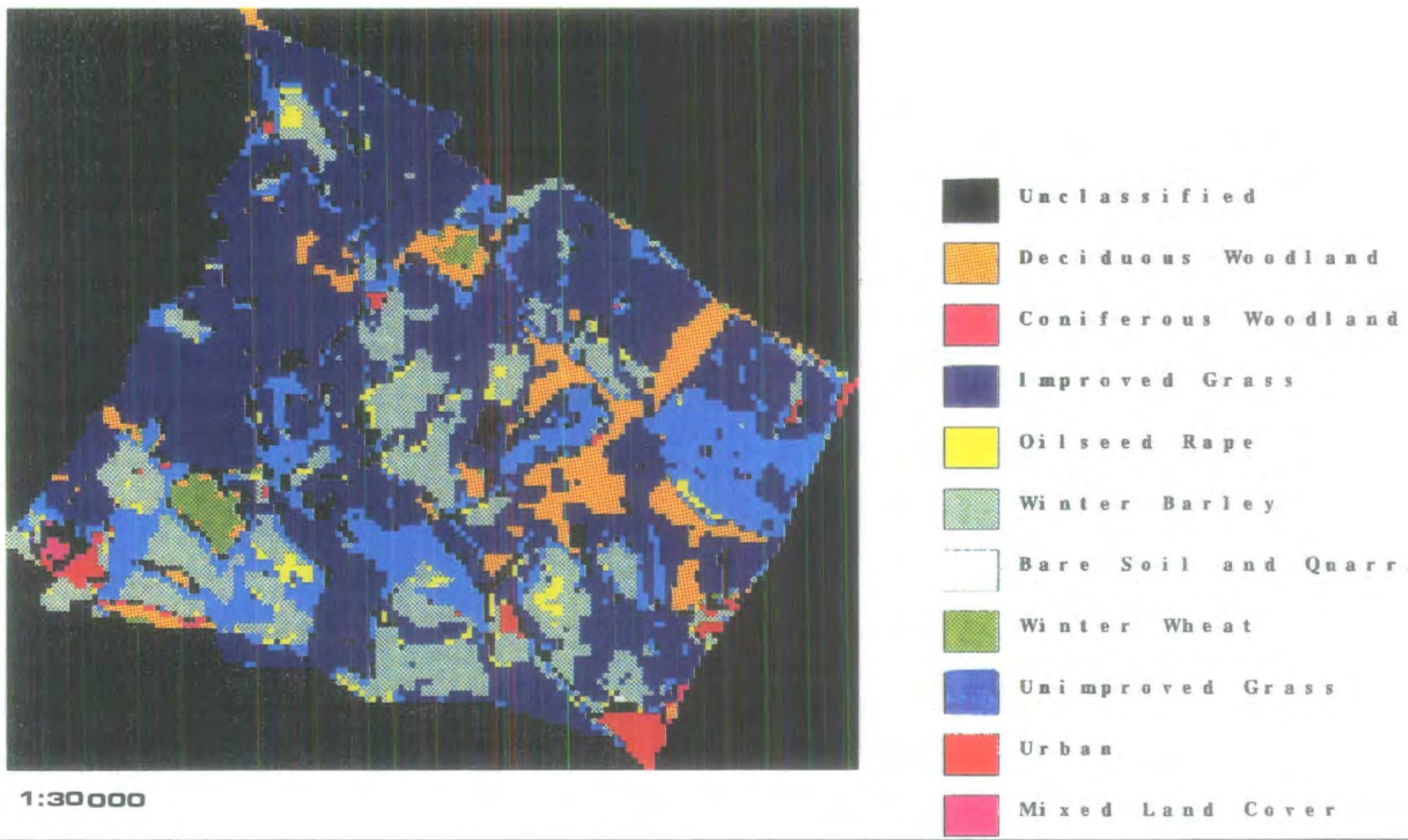
Hett Landuse Map of Landsat-5TM Image (1/8/90)

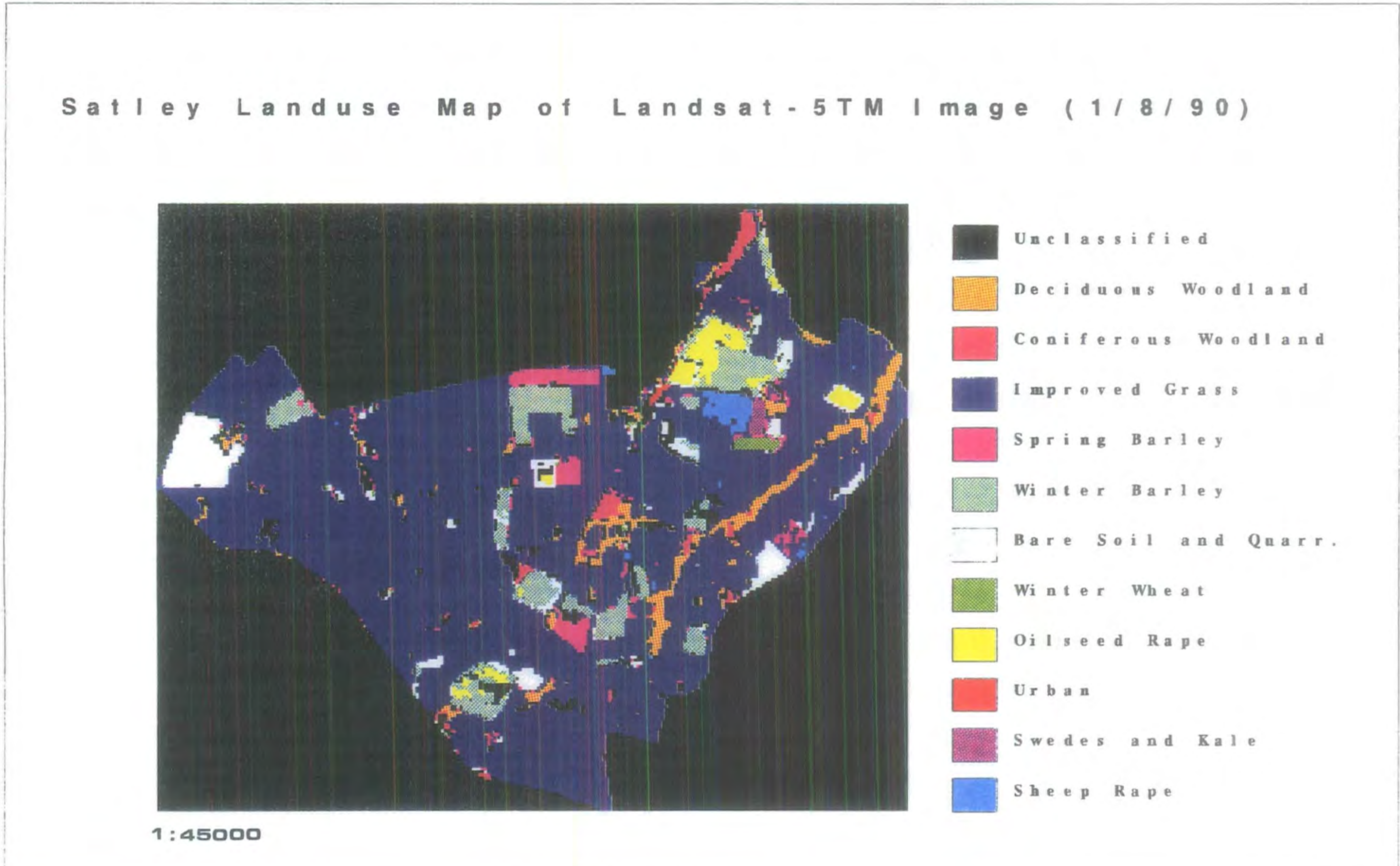


Wackerfield Landuse Map of Landsat-5TM Image (1/8/90)



Greencroft Landuse Map of Landsat-5TM Image (1/8/90)




Satley Landuse Map of Landsat-5TM Image (1/8/90)
Unclassified
Deciduous Woodland
Coniferous Woodland
Improved Grass
Spring Barley
Winter Barley
Bare Soil and Quarr.
Winter Wheat
Oilseed Rape
Urban
Swedes and Kale
Sheep Rape
1:45000

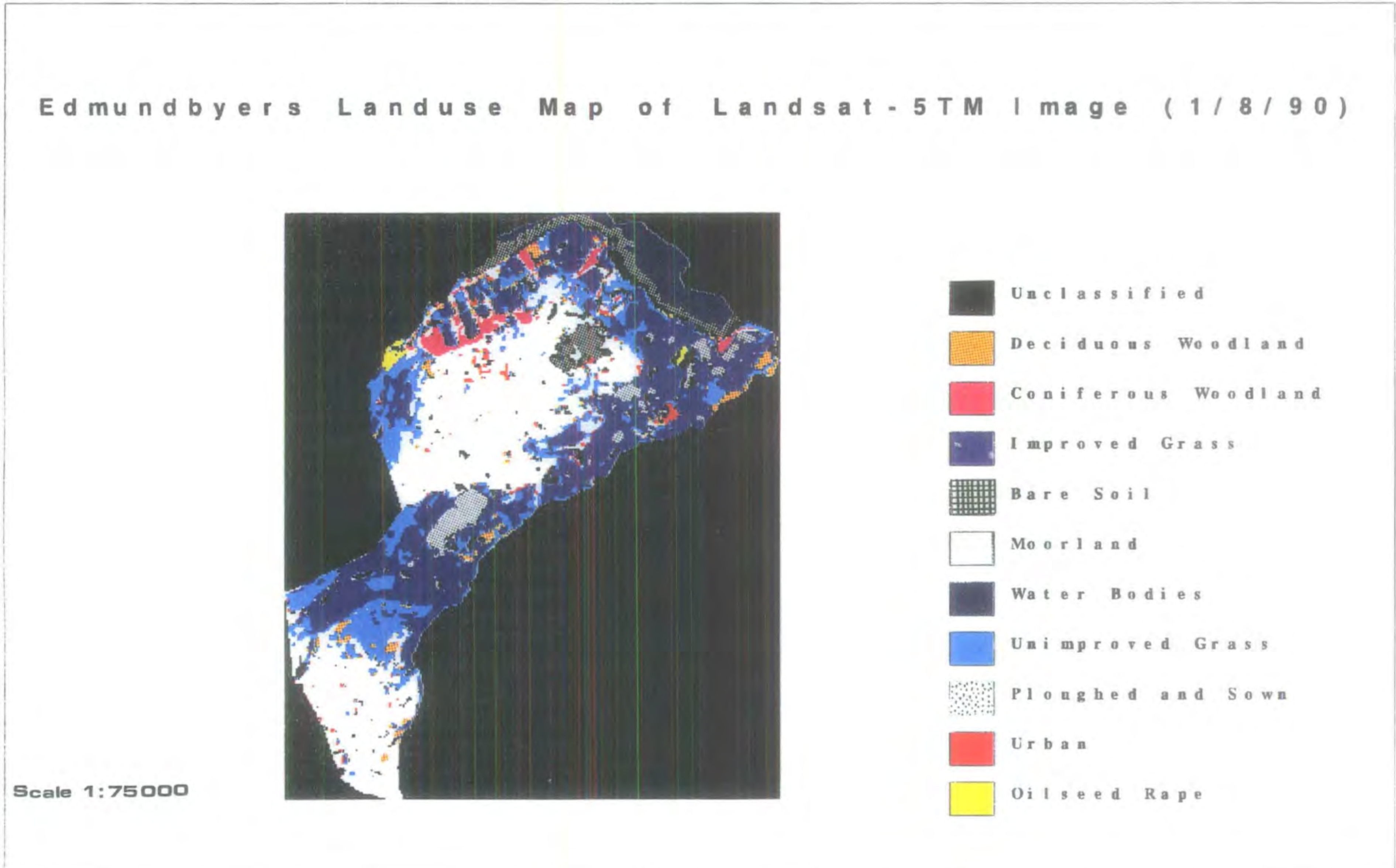
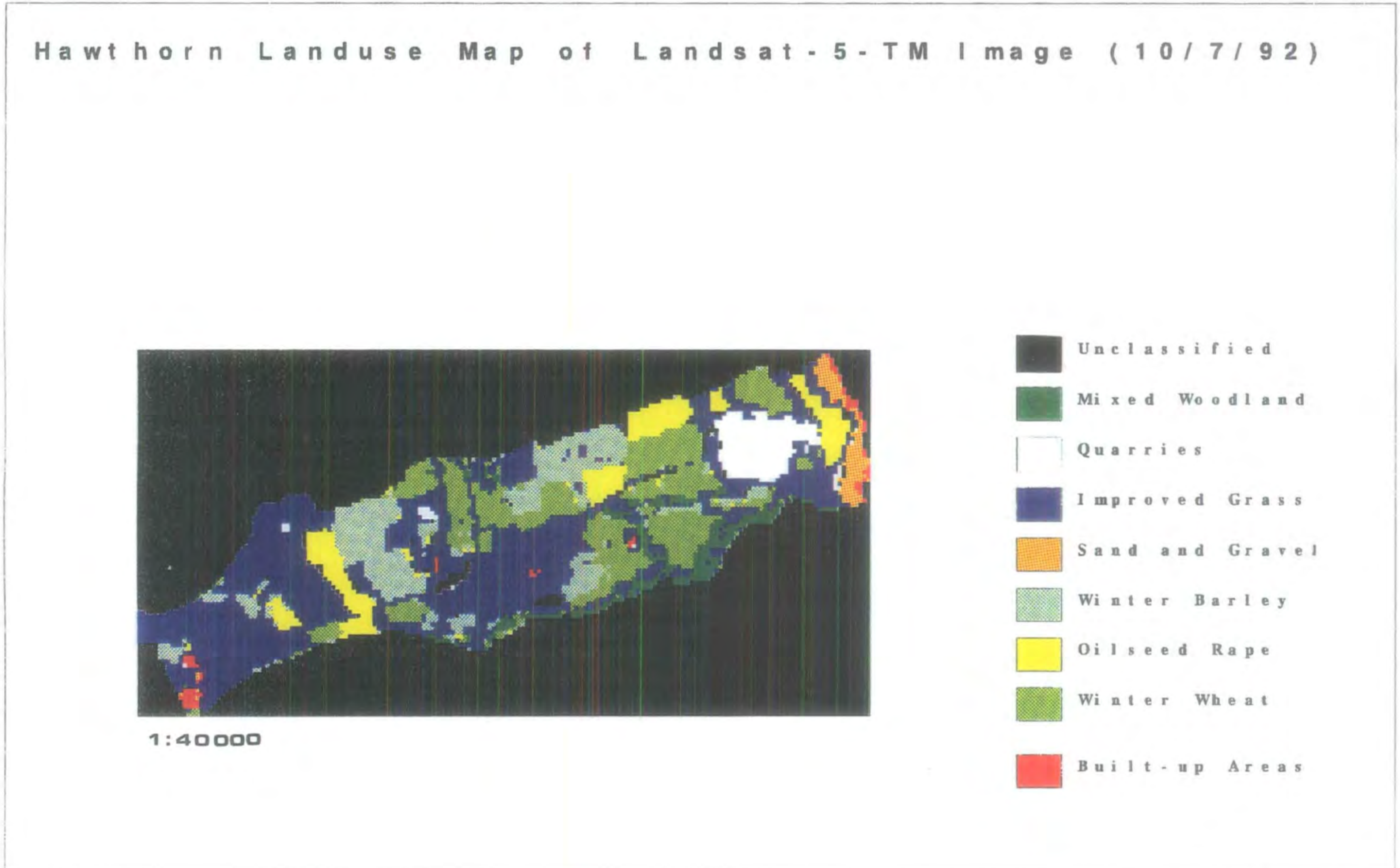
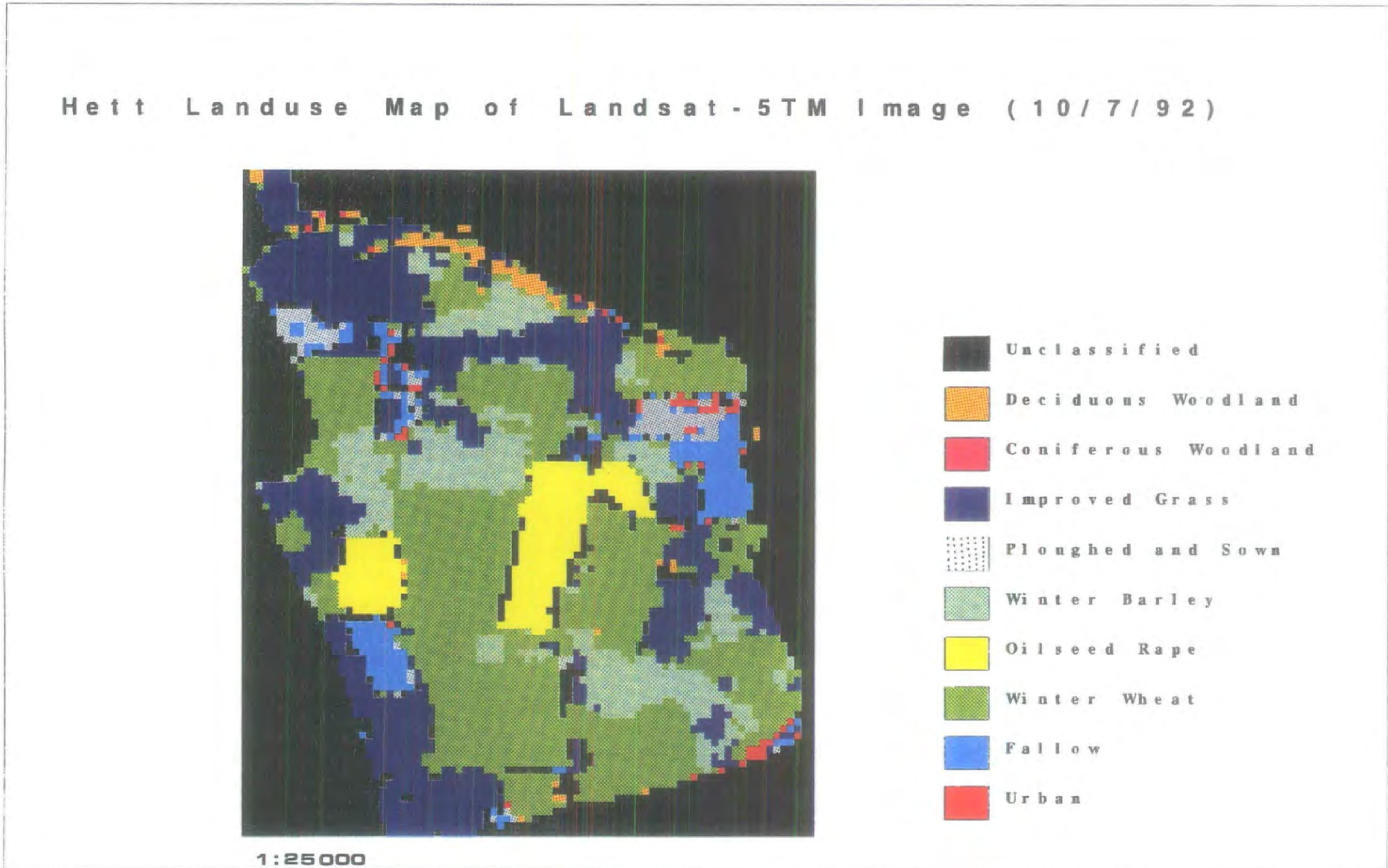

Edmundbyers Landuse Map of Landsat-5TM Image (1/8/90)
Unclassified
Deciduous Woodland
Coniferous Woodland
Improved Grass
Bare Soil
Moorland
Water Bodies
Unimproved Grass
Ploughed and Sown
Urban
Oilseed Rape
Scale 1:75000

Table (6:4):- Class area estimation of the six study areas for the image of July 1992, (detailed classification), ha\ %

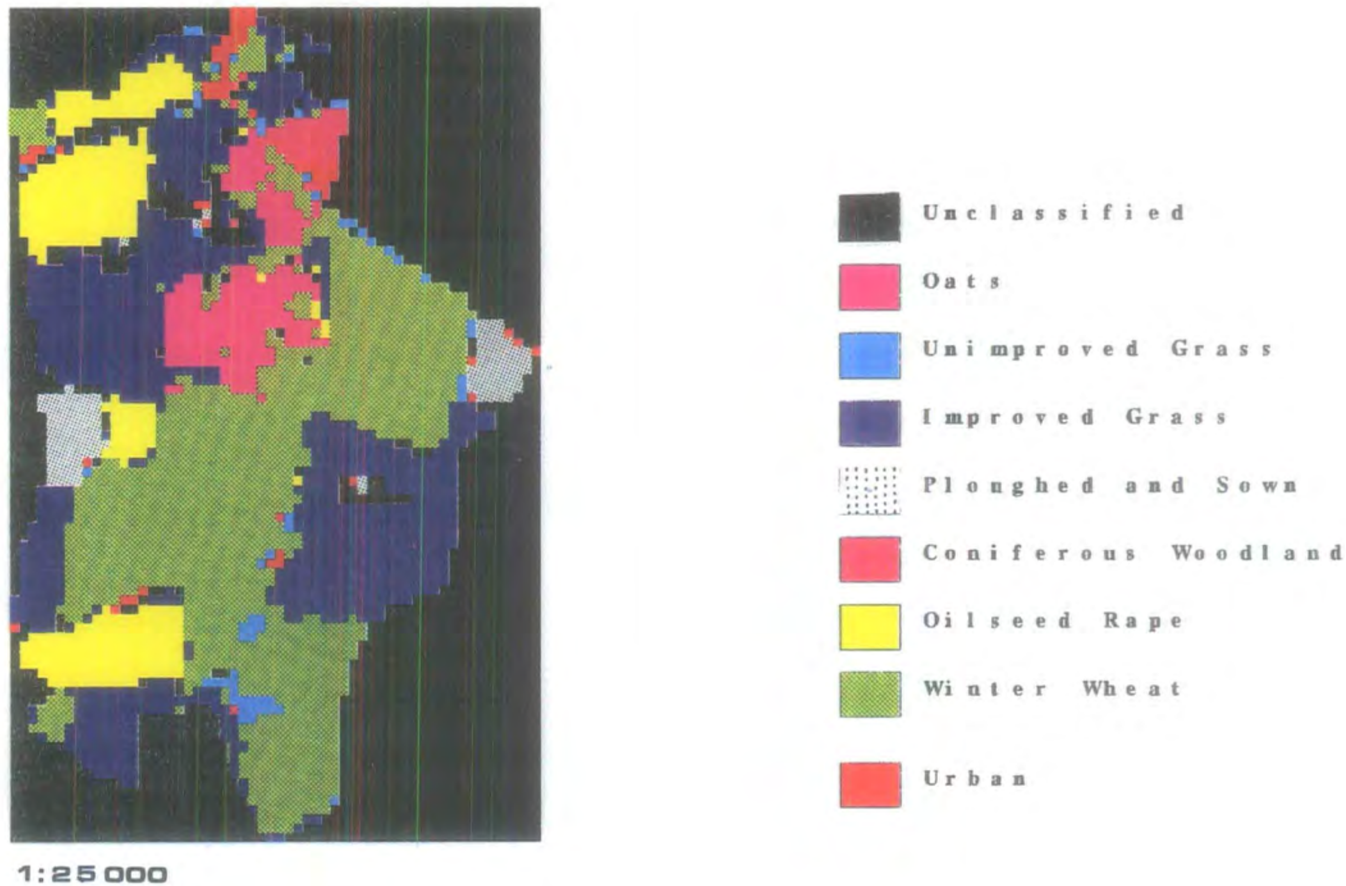
NO	CLASS	HAW.	HETT	WACK.	GREEN.	SAT.	EDMUND.
0	UN.	17.16\ 3	37.78\ 7.4	19.37\ 6.39	47.47\ 7	180.16\ 13.3	140.17\ 6.8
1	OSR	47.35\ 8.2	32.58\ 6.4	34.21\ 11.3	6.04\ 0.9	8.65\ 0.6	0.8\ 0.04
2	WB	77.55\ 13.4	66.44\ 13.1	-	76.47\ 11.3	57.45\ 4.2	3.3\ 0.2
3	WW	106.94\ 18.5	193.43\ 38.1	112.82\ 37.2	6.31\ 0.9	28.08\ 2.1	-
4	IG.T	37.41\ 6.5	111.2\ 21.9	36.52\ 12	95.4\ 14.1	580.25\ 42.9	95.4\ 4.6
5	IG.P	215.47\ 37.3	18.84\ 3.7	55.71\ 18.4	256.39\ 37.8	300.67\ 22.2	157.64\ 7.6
6	U	7.13\ 1.2	5.79\ 1.1	5.1\ 1.7	21.04\ 3.1	1.38\ 0.1	20.66\ 1
7	Q+BS	28.34\ 4.9	-	-	2.47\ 0.4	43.64\ 3.2	-
8	S	11.95\ 2.1	-	-	-	-	-
9	MWL	28.78\ 5	-	-	-	-	-
10	CWL	-	0.2\ 0.1	4.82\ 1.6	-	26.24\ 1.9	36.63\ 1.8
11	DWL	-	7.26\ 1.4	-	76.46\ 11.3	54.13\ 4	54.95\ 2.7
12	P+S	-	10.99\ 2.2	10.01\ 3.3	2.74\ 0.4	63.8\ 4.7	17.64\ 0.9
13	F	-	22.96\ 4.5	-	-	-	-
14	O	-	-	19.1\ 6.3	-	-	-
15	UG	-	-	5.65\ 1.9	84.43\ 12.5	-	464.58\ 22.5
16	MLC	-	-	-	2.1\ 0.3	-	-
17	P	-	-	-	1\ 0.2	-	-
18	SB	-	-	-	-	9.67\ 0.7	-
19	W	-	-	-	-	-	150.19\ 7.3
20	BS						196.47\ 9.5
21	M	-	-	-	-	-	725.5\ 35.2
	TOTAL	**578.08**	**507.46**	**303.31**	**678.6**	**1354.12**	**2063.93**
		100	**100**	**100**	**100**	**100**	**100**

Hawthorn Landuse Map of Landsat-5-TM Image (10/7/92)

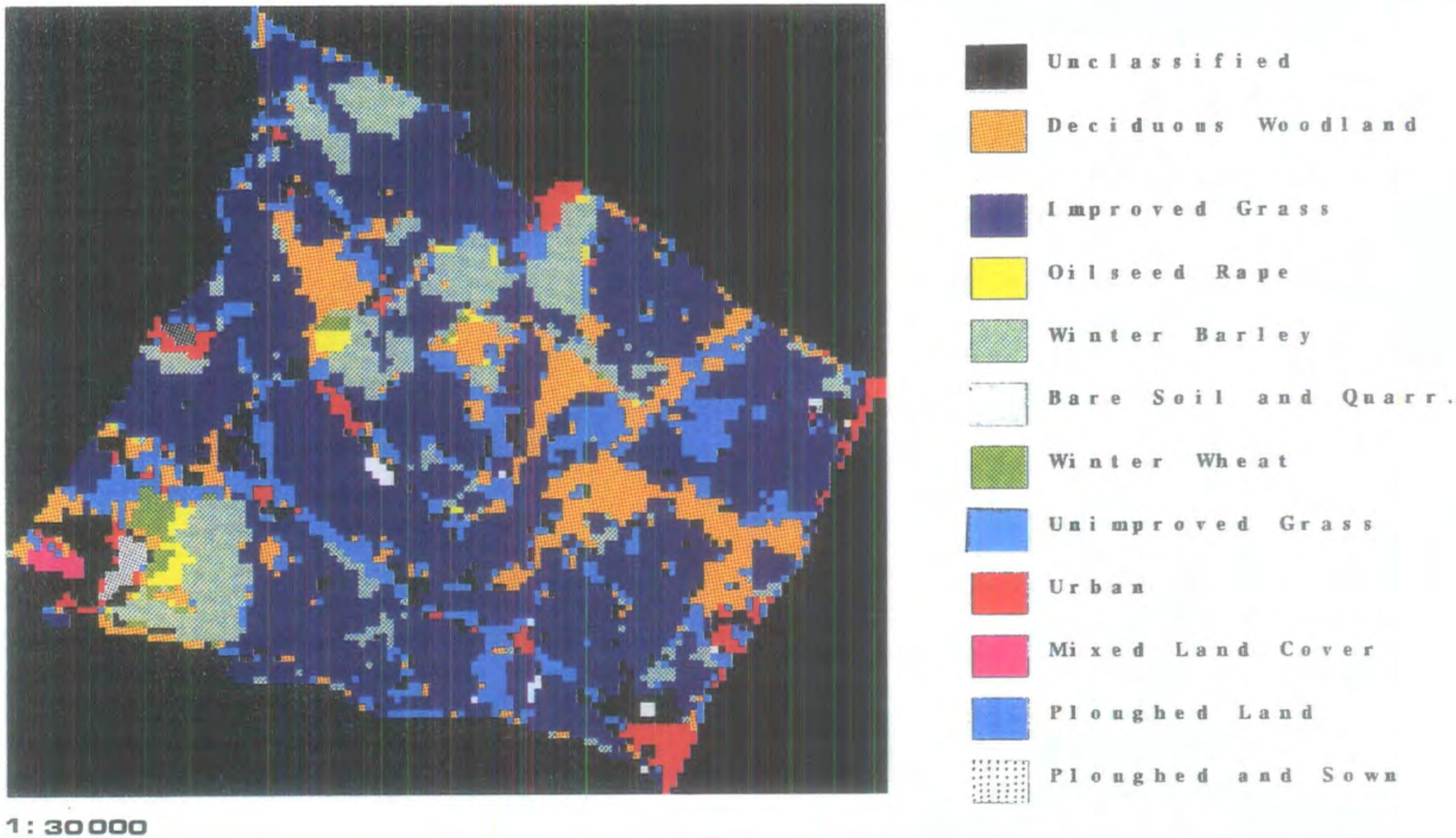



Hett Landuse Map of Landsat-5TM Image (10/7/92)
1:25000
Unclassified
Deciduons Woodland
Coniferous Woodland
Improved Grass
Ploughed and Sown
Winter Barley
Oilseed Rape
Winter Wheat
Fallow
Urban

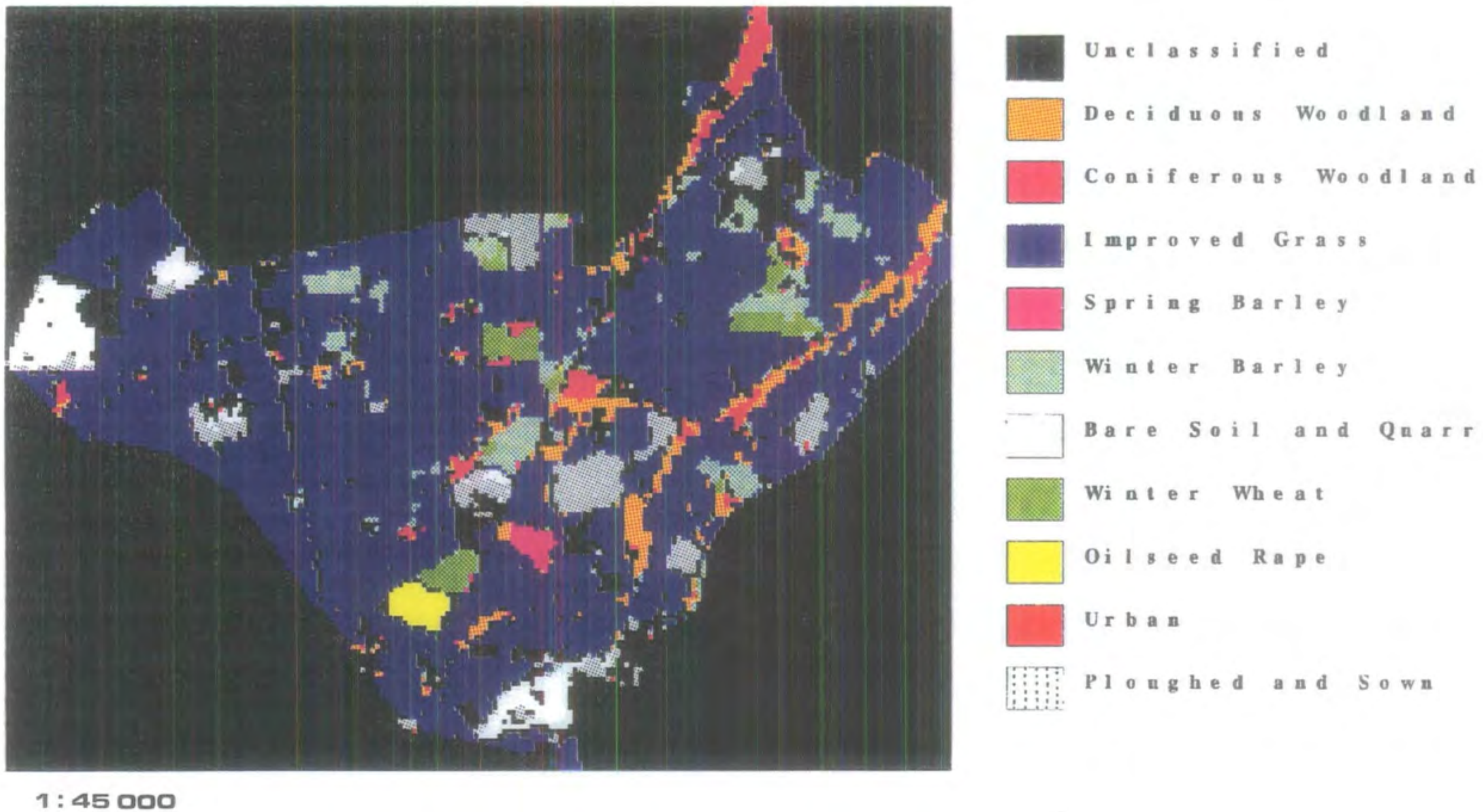
Wackerfield Landuse Map of Landsat-5TM Image (10/7/92)



Greencroft Landuse Map of Landsat-5TM Image (10/7/92)



Satley Landuse Map of Landsat-5TM Image (10/7/92)



Edmundbyers Landuse Map of Landsat-5TM Image (10/7/92)

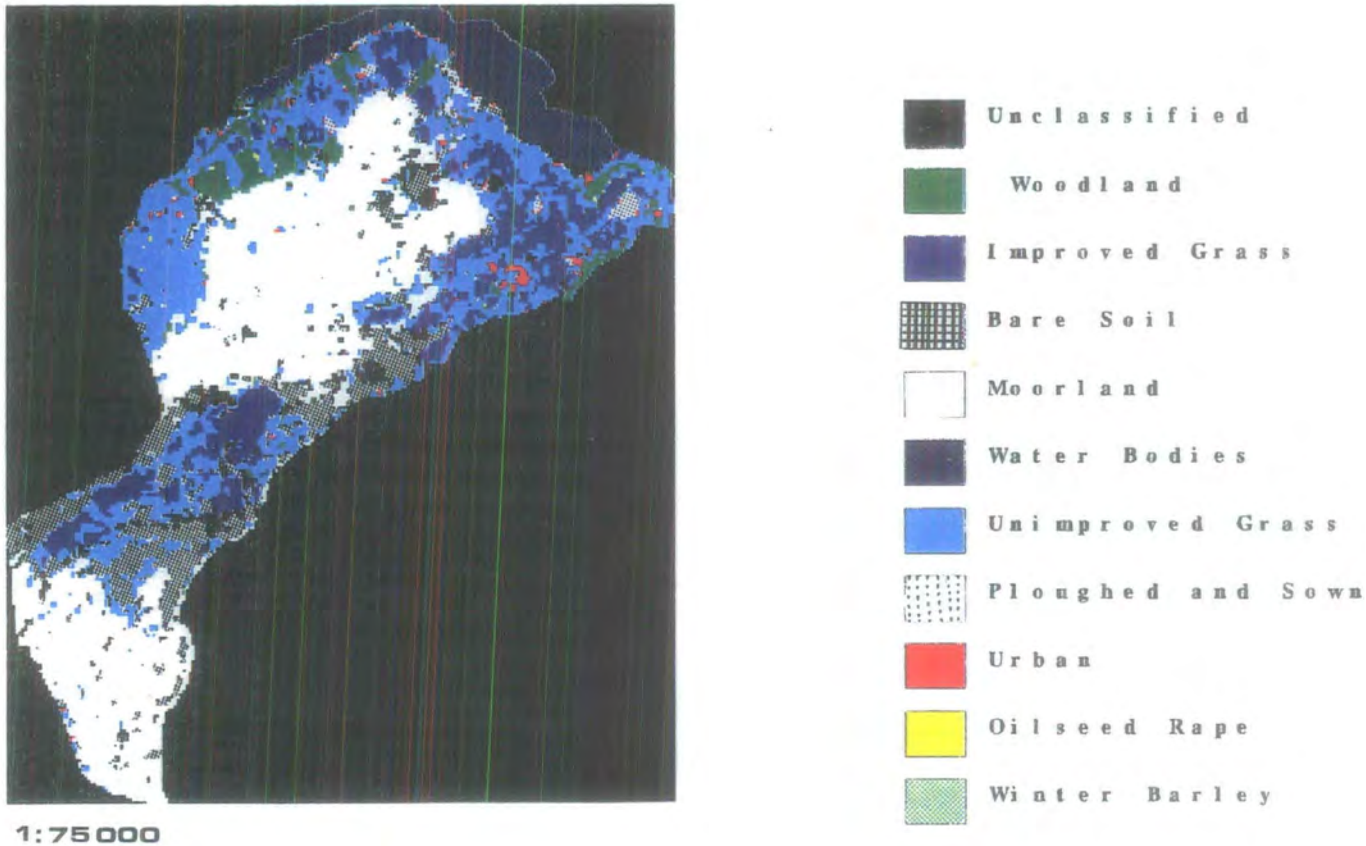


Table (6:5):- Total area estimation of the study area for the image of May 1985, (detailed classification)

NO	LAND USE	ha	%
0	UN.	307.63	5.61
1	MWL	29.2	0.53
2	Q+BS	127.48	2.32
3	IG.T	1244.99	22.71
4	S	12.18	0.22
5	WB	341.36	6.23
6	OSR	136.93	2.5
7	WW	270.96	4.94
8	IG.P	1201.53	21.91
9	P+S	201.3	3.67
10	U	69.21	1.26
11	DWL	212.32	3.87
12	CWL	81.51	1.49
13	P	49.08	0.9
14	O	25.96	0.47
15	F	7	0.13
16	UG	329.47	6.01
17	M	706.05	12.88
18	W	129.05	2.35
	TOTAL	5483.18	100

Table (6:6):- Total area estimation of the study area for the image of August 1990, (detailed classification)

NO	LAND USE	ha	%
0	UN.	445.43	8.12
1	OSR	164.91	3
2	WB	382.96	6.98
3	U	50.21	0.91
4	Q+BS	145.1	2.64
5	MWL	24.09	0.44
6	IG.T	1919.58	34.98
7	IG.P	410.05	7.47
8	S	5.18	0.09
9	P	3.43	0.06
10	S+K	30.69	0.56
11	WW	171.33	3.12
12	SW	124.84	2.27
13	DWL	148.36	2.7
14	CWL	63.21	1.15
15	F	4.97	0.09
16	SB	87.05	1.59
17	LS	40.25	0.73
18	UG	385.63	7.03
19	MLC	1.98	0.04
20	M	715.52	13.04
21	W	91.9	1.67
22	S.R	10.87	0.2
23	P+S	56.75	1.03
	TOTAL	5487.76	100

Table (6:7):- Total area estimation of the study area for the image of July 1992, (detailed classification)

NO	LAND USE	ha	%
0	UN.	442.11	8.06
1	OSR	129.63	2.36
2	WB	281.21	5.13
3	WW	447.58	8.16
4	IG.T	956.17	17.42
5	IG.P	1004.72	18.32
6	U	61.1	1.11
7	Q+BS	270.92	4.93
8	S	11.95	0.22
9	MWL	28.78	0.52
10	CWL	67.89	1.24
11	DWL	193.08	3.52
12	P+S	105.18	1.92
13	F	22.96	0.42
14	O	19.1	0.35
15	UG	549.01	10
16	MLC	2.1	0.04
17	P	1	0.02
18	SB	9.67	0.18
19	W	150.19	2.74
20	M	725.5	13.23
	TOTAL	5485.5	100

6.2.1 Generalisation of Land Use \ Land Cover Classes

Since remote sensing deals directly with environmental and land cover terms rather than land use terms, it is difficult to make a definite and direct functional analysis of the classes' areas estimated by this technique. So, detailed classification results are generalised and related to their broader functional (land use) classes.

6.2.1.1 Generalisation of Classes for the Image of May 1985

The number of land use \ land cover classes included in this the classification scheme of this image is 18. These classes are generalised to 11. The following generalisations are made:- (a) mixed, deciduous, and coniferous woodland classes are generalised to a woodland class, (b) temporary and permanent grass are generalised to an improved grass class, (c) winter barley, winter wheat, oats, ploughed land, and ploughed and sown classes are generalised to an arable class (cereals). The inclusion of the last two land cover classes in this broad class is because at this period of the year, in May, the ploughed and the ploughed and sown fields are more likely to be under spring crops cultivation.

Table (6:8):- Generalised area estimation of the six study areas for the image of May 1985, ha\ %

NO	*CLASS*	HAW.	HETT	WACK.	GREEN.	SAT.	EDMUND.
0	UN.	25.26\ 4.4	57.77\ 11.4	12.98\ 4.3	26.93\ 4	59.06\ 4.3	125.63\ 6.1
1	WL	29.2\ 5.1	18.53\ 3.7	-	78.8\ 11.6	83.73\ 6.2	112.77\ 5.5
2	Q+BS	28.48\ 4.9	-	-	-	25.67\ 1.9	73.33\ 3.6
3	IG	283.48\ 49	144.83\ 28.8	112.97\ 37.1	393.17\ 58	897.31\ 66.3	614.48\ 29.4
4	S	12.18\ 2.1	-	-	-	-	-
5	A	160.6\ 27.8	231.91\ 45.7	151.09\ 49.6	109.74\ 16.2	235.32\ 17.4	-
6	OSR	34.57\ 6	48.22\ 9.5	23.75\ 7.8	-	30.39\ 2.3	-
7	U	3.76\ 0.7	5.77\ 1.1	3.68\ 1.2	15.1\ 2.2	21.1\ 1.6	19.76\ 1
8	F	-	-	-	7\ 1	-	-
9	UG	-	-	-	47.59\ 7	-	281.88\ 13.7
10	M	-	-	-	-	-	706.05\ 34.2
11	W	-	-	-	-	-	129.05\ 6.3
TOTAL		**577.81**	**507.03**	**304.47**	**678.3**	**1352.62**	**2062.95**
		100	**100**	**100**	**100**	**100**	**100**

6.2.1.2 Generalisation of Classes for the Image of August 1990

The number of land use \ land cover classes included in the classification scheme of this image is highest of the three image dates (25 classes). The reason for this as was mentioned before is that because, in August, spring and winter crops exist with different land cover conditions exist in fields. So, for easier and more workable class area estimation analysis, the same previous generalisation process with some seasonal change considerations is applied to this image classification; (a) winter and spring cereal crops (harvested and not harvested) are included in arable (cereals) class, (b) ploughed and ploughed and sown classes are included in the improved grass broad class. The reason is, at this time of the year (August), cereal crops will not be freshly sown or ploughed. So, these fields are more likely to be sown or prepared to be sown with improved grass.

Table (6:9):- Generalised area estimation of the six study areas for the image of August 1990, ha\ %

NO	CLASS	HAW.	HETT	WACK.	GREEN.	SAT.	EDMUND.
0	UN.	59.8\ 10.4	63.24\ 12.5	29.61\ 9.7	51.05\ 7.5	83.47\ 6.2	158.26\ 7.7
1	A	202.79\ 34.6	184.08\ 36.3	157.63\ 51.8	113.52\ 16.7	117.68\ 8.7	-
2	IG	215.18\ 37.6	141.97\ 28	77.36\ 25.4	338.4\ 49.8	984.88\ 72.7	628.58\ 30.5
3	WL	24.09\ 4.2	13.11\ 2.6	3.75\ 1.2	47.9\ 7.1	65.42\ 4.8	81.71\ 4
4	Q+BS	17.22\ 3	-	-	0.13\ 0.02	62.87\ 4.6	64.88\ 3.1
5	OSR	51.48\ 8.9	58.01\ 11.4	7.06\ 2.3	13.3\ 2	23.27\ 1.7	11.8\ 0.6
6	U	1.84\ 0.3	6.72\ 1.3	1.1\ 0.4	10.97\ 1.6	1.78\ 0.1	27.8\ 1.4
7	M	-	-	-	-	-	715.52\ 34.7
8	W	-	-	-	-	-	91.9\ 4.5
9	S	5.18\ 0.9	-	-	-	-	-
10	S+K	3.11\ 0.5	-	22.94\ 7.5	-	4.64\ 0.3	-
11	LS	-	35.33\ 7	4.92\ 1.6	-	-	-
12	UG	-	-	-	102.36\ 15.1	-	283.43\ 13.7
13	MLC	-	-	-	1.98\ 0.3	-	-
14	S.R	-	-	-	-	10.87\ 0.8	-
15	F	-	4.97\ 1	-	-	-	-
	TOTAL	577.58	507.43	304.37	679.62	1354.88	2063.88
		100	100	100	100	100	100

6.2.1.3 Generalisation of Area Estimation for the Image of July 1992

The number of land use \ land cover classes included in the classification scheme of this image is 20 classes. These classes are generalised in the same way as for the image of August 1990.

Table (6:10):- Generalised area estimation of the six study areas for the image of July 1992, ha\ %

NO	*CLASS*	HAW.	HETT	WACK.	GREEN.	SAT.	EDMUND.
0	UN.	17.16\ 3	37.78\ 7.4	19.37\ 6.4	47.47\ 7	180.16\ 13.3	140.17\ 6.8
1	A	184.49\ 31.9	259.87\ 51.2	131.9\ 43.5	83.78\ 12.4	95.2\ 7	3.3\ 0.2
2	IG	252.88\ 43.7	141.02\ 27.8	102.24\ 33.7	354.53\ 52.2	944.72\ 69.8	270.68\ 13.1
3	WL	28.78\ 5	7.46\ 1.4	4.84\ 1.6	76.47\ 11.3	80.37\ 5.9	91.58\ 4.4
4	U	7.13\ 1.2	5.79\ 1.1	5.1\ 1.7	21.04\ 3.1	1.38\ 0.1	20.66\ 1
5	UG	-	-	5.65\ 1.9	84.43\ 12.5	-	464.58\ 22.5
6	M	-	-	-	-	-	725.5\ 35.2
7	W	-	-	-	-	-	150.19\ 7.3
8	OSR	47.35\ 8.2	32.58\ 6.4	34.21\ 11.3	6.04\ 0.9	8.65\ 0.6	0.8\ 0.04
9	MLC	-	-	-	2.1\ 0.3	-	-
10	Q+BS	28.34\ 4.9	-	-	2.47\ 0.4	43.64\ 3.2	196.47\ 9.5
11	S	11.95\ 2.1	-	-	-	-	-
12	F	-	22.96\ 4.5	-	-	-	-
	TOTAL	**578.08**	**507.46**	**303.31**	**678.6**	**1354.12**	**2063.93**
		100	**100**	**100**	**100**	**100**	**100**

Table (6:11):- Total area estimation of the study area for the image of May 1985, (generalised classification), ha\ %.

NO	LAND USE	ha	%
0	UN.	307.63	5.61
1	WL	323.03	5.89
2	Q+BS	127.48	2.32
3	IG	2446.52	44.62
4	S	12.18	0.22
5	A	888.66	16.21
6	OSR	136.93	2.50
7	U	69.21	1.26
8	F	7	0.13
9	UG	329.47	6.01
10	M	706.05	12.88
11	W	129.05	2.35
TOTAL		5483.18	100

Table (6:12):- Total area estimation of the study area for the image of August 1990, (generalised classification), ha\ %.

NO	LAND USE	ha	%
0	UN.	445.43	8.12
1	A	775.7	14.14
2	IG	2386.38	43.48
3	WL	235.66	4.29
4	Q+BS	145.1	2.64
5	OSR	164.92	3
6	U	50.21	0.91
7	M	715.52	13.04
8	W	91.9	1.67
9	S	5.18	0.09
10	S+K	30.69	0.56
11	LS	40.25	0.73
12	UG	385.63	7.03
13	MLC	1.98	0.04
14	S.R	10.87	0.20
15	F	4.97	0.09
TOTAL		5487.76	100

Table (6:13):- Total area estimation of the study area for the image of July 1992, (generalised classification), ha\ %.

NO	LAND USE	ha	%
0	UN.	442.11	8.06
1	A	758.56	13.84
2	IG	2066.07	37.66
3	WL	289.75	5.28
4	U	61.1	1.11
5	UG	549.01	10
6	M	725.5	13.23
7	W	150.19	2.74
8	OSR	129.63	2.36
9	MLC	2.1	0.04
10	Q+BS	270.92	4.93
11	S	11.95	0.22
12	F	22.96	0.42
TOTAL		5485.5	100

6.3 Analysis of Area Estimation Results

The following observations were made from the image area estimation of each land use \ land cover class and their spatial distribution over the three image dates:-

(1) The total surface area of each study area image is slightly different to their actual surface area (map area). These differences can be due to (a) image geometric correction error, and (b) conversion of image units to grid units, and reference map units (polygons) to grid units. Table (6:14) shows these differences.

Table (6:14): Reference map area (ha) versus its image area of the total study area

Reference Map	Image of 1985	Image of 1990	Image of 1992
5483.86	5483.18	5487.76	5485.5

(2) The percentage of unclassified pixels varies from one study area to another, and also from one date to another, table (6:15).

Table (6:15):- Unclassified pixel percentage (%) of the six study areas

	Hawthorn	Hett	Wackerfield	Greencroft	Satley	Edmundbyers
1985	4.37	11.39	4.26	3.97	4.3	5.73
1990	10.35	12.46	9.73	7.51	6.16	7.67
1992	2.97	7.44	6.39	6.99	13.3	6.79

In general, the majority of unclassified pixels are concentrated in the urban areas and the field boundaries. However, this percentage varies according to different considerations;

(a) It can be seen from the previous table that the percentage of unclassified pixels for the area of Hett is the highest amongst the six study areas for the image of May 1985 and that of August 1990. This can be explained by the fact that this area is dominated by arable (cereal) cultivation in addition to improved grass. Barley represents 20.75% of the area of the 1985 image of Hett, while wheat accounts for 12.96% of the total area of the parish. The reason for the high percentage of unclassified pixels for this parish on the image of August 1990 is the large number of classes included in the classification scheme and the considerable representation of cereal crops in the total area of the parish (36.28%). Sometimes, the Maximum Likelihood classifier could not assign pixels of mixed land cover types with similar spectral properties to any class, especially when the resultant mixed pixel had an equal probability of being assigned to both land cover types. (b) The percentage of unclassified pixels for Satley was highest for the image of July 1992. The reason for this, in addition to the general reasons mentioned above, is that in this study area both arable cereal crops and improved grass existed in relatively small fields, and the area has considerable topographic variations.

(c) If the percentage of unclassified pixels is taken on seasonal basis, the images of July and August had the highest percentage, and the reason for this is the high frequency of land use \ land cover types that existed in fields in this season.

(3) The area percentage for the ploughed and sown class varies from one date to another. It is 3.67%, 1.03%, and 1.92% of the total study area respectively. The image of May shows the highest percentage because spring crops are freshly sown in this month.

(4) The sand area percentage in Hawthorn for the image of August 1990 is less than half that of the other two images. High sea tides are normally responsible for this phenomenon.

(5) The arable crops are concentrated in the eastern agricultural region of County Durham, represented by Hawthorn, Hett, and Wackerfield. The area percentage of this land use class for these three areas exists between 30-50%. So, there is a competition between this class and the improved grass class which have similar area percentages in this region.

(6) In the central agricultural region of County Durham represented by Greencroft and Satley, improved grass is the dominant land use type. It represents between 50-70% of the area of these two parishes. The representation of arable crops in these two areas is only between 7-17% of total area.

(7) In the western region represented by Edmundbyers, the image class area estimation over the three dates shows that moorland, unimproved grass, and improved grass are the dominant land use \ land cover types. Moorland and unimproved grass represent about 50% of this area. There is hardly any arable cropping in the area.

(8) The woodland land cover type is concentrated in the central region, and the lower area of the Pennines in the western region. More than 85% of this class area exists there. The existence of this land cover type is strongly correlated with dales and slopes.

(9) Quarrying is concentrated in the coastal region and the lower edges of the Pennines in the western region, where the geology in predominantly limestone (see ch. 1).

(10) Oilseed rape is cultivated mainly in the eastern agricultural region, and some areas in the central region.

(11) Water bodies (in the form of reservoirs) existed only in the western region (Derwent Reservoir). The level of water in this reservoir fluctuates according to annual precipitation, evaporation rates and human use.

6.4 Land Use Change Detection Between 1985-1992 Based on Image Classification Area Estimation

The advantage of a multi-temporal image study is that it allows the detection of land use \ land cover change over a certain time period. The types of change can range from short-term phenomena such as snow cover, to long-term phenomena such as desertification (Lillesand & Kiefer, 1987). One fundamental aim of this study was to investigate the ability of remote sensing to detect land use change in the study area accurately, in comparison with other survey methods. The choice of these two image dates for land use \ land cover change detection rather than the image of 1990, is because firstly, they have similar solar elevation, and secondly, the time period between them is greater. Also the image of 1992 allows for the examination of the response of farmers to the EU set aside policy.

Table (6:16):- Land use change of the six study areas between 1985-1992 images (%)

NO	CLASS	HAW.	HETT	WACK.	GREEN.	SAT.	EDMUND.
0	UN.	- 1.4	- 3.95	2.13	3.02	9	0.7
1	A	4.1	5.48	- 6.13	- 3.83	- 10.37	0.16
2	IG	- 5.4	- 0.78	- 3.4	- 5.72	3.46	- 16.67
3	WL	- 0.1	- 2.22	1.59	- 0.3	- 0.25	- 1.03
4	U	0.58	0	0.47	0.88	- 1.45	0.04
5	UG	-	-	1.86	5.43	-	8.84
6	M	-	-	-	-	-	0.93
7	W	-	-	-	-	-	1.02
8	OSR	2.2	- 3.1	3.48	0.89	- 1.61	0.04
9	MLC	-	-	-	0.31	-	-
10	Q+BS	- 0.03	-	-	0.36	1.32	5.97
11	S	- 0.04	-	-	-	-	-
12	F	-	4.51	-	1.03	-	-

Table (6:17): Total land use change of the major land use \ land cover classes between 1985 and 1992 images

NO	LAND USE	ha	%
1	WL	- 33.28	- 0.61
2	IG	- 380.45	- 6.94
3	A	- 130.1	- 2.37
4	OSR	- 7.3	- 0.13
5	UG	219.54	4
6	M	19.45	0.04
7	W	21.14	0.39

From the tables 6.16 and 6.17, the following observations are made:-

(1) The land use \ land cover changes show that at the parish level, there is no specific regional agricultural change trend for the arable and the improved grass land use classes. It can be seen that the area of both these land use types in Hawthorn and Wackerfield has decreased. Oilseed rape areas in these two parishes have increased, which may represent farmers substitution of set aside to be used for industrial use.

(2) In Hett, the area of arable crops has increased, while both the improved grass and oilseed rape areas have decreased. However, this can be explained by the agricultural rotation in the County and does not reflect a real trend of agricultural change in the region.

(3) In Greencroft, there is a change from improved grass to unimproved grass (-5.72%, + 5.43%). This surprising trend of land use change can be explained by the positive response of farmers towards ***the EC set aside policy.*** Actually, the areas assigned to unimproved grass are set aside areas, but because these areas are left without management, their texture is rougher. So, the spectral properties of these areas have changed and become similar to unimproved grass. Because remote sensing deals with the morphology of land cover rather than its functionality, the automatic maximum likelihood classifier assigned these area to the unimproved grass class. On other hand, the area of arable crops has decreased.

(4) In Satley, there is a change from arable crops to improved grass, and the area of quarries has increased.

(5) In Edmundbyers, there is a change from improved grass to unimproved grass, due to the set aside policy. The water level in the Derwent Reservoir is not constant; annual precipitation, evaporation rate and human use of the water are the factors responsible for this water level fluctuation.

(6) The woodland area has decreased in all study areas except in Wackerfield where a small area of grass has been afforested with coniferous trees after 1985.

(7) The general land use change between the image of 1985 and that of 1992 shows that the EC set aside policy is followed by farmers in the central and the western agricultural

regions of the County. So, a certain amount of arable and grass crops are left unmanaged.

To verify the response of farmers towards the government policy of encouraging grass cultivation rather than arable cropping, a study of land use change was carried out in the study area between the area estimation results for the image of 1985 and that of 1994 (is based on field mapping survey done by the author). To facilitate this study, the classification of the field survey, which has been resampled to the classification of 1931, is resampled again to the generalised image classification; (a) moor and heathland class is split into its original components; moorland and unimproved grass, and (b) oilseed rape is separated from the arable class.

Table (6:18):- Land use and land use change of major classes between 1985 (image) and 1994 (field map), %

NO.	CLASS	1985	1994	CHANGE
1	**Arable Crops**	**16.21**	**13.28**	**- 2.93**
2	**Improved Grass**	**44.62**	**41.11**	**- 3.51**
3	**Unimproved Grass**	**6.01**	**10.27**	**4.26**
4	**Moorland**	**12.88**	**19.29**	**6.41**
5	**Water**	**2.35**	**3.03**	**0.68**
6	**Oilseed Rape**	**2.5**	**1.84**	**- 0.66**
7	**Woodland**	**5.89**	**6.32**	**0.42**

If land use change results which are based on the image-image area estimation method are compared with these based on an image-field map area estimation method (table 6.18), it can be seen that:-

(1) land use change based only on the image-image area estimation method shows that the moorland area is almost constant between 1985 and 1992, while that based on the image-field map area estimation methods shows that a substantial increase of this class area occurred between 1985 and 1994. The reason for this is that the two methods behave differently in land use \ land cover terms. Remote sensing methods record the

area occurred between 1985 and 1994. The reason for this is that the two methods behave differently in land use \ land cover terms. Remote sensing methods record the instant environmental conditions of the ground, while a field-map method records the functionality of these conditions. The moorland cover is not as pure as maps describe, so remote sensing also records these impurities to other land cover types, and consequently reduces its functional area. These area differences between the two methods do not indicate a real change but an inability of the field-map survey method to provide an exact environmental description of the ground.

(2) Both area estimation results for the two methods show that the area of arable and improved grass has decreased whilst the area of unimproved grass has increased. In addition to the difference between remote sensing and field survey in terms of what they record, there is likely to be an area overestimation of the area of unimproved grass over the image of 1992 due to the set aside policy as previously mentioned.

(3) Both methods show that the area of oilseed rape has not considerably changed since 1985.

(4) The image area estimation change shows a slight decrease in the woodland area, while the image-map area estimation change shows an increase in the area of this class (ref. point 1).

(5) As discussed previously, the change in water area is due to external conditions.

(6) Despite differences in area estimation between the field mapping and remote sensing methods, it can be seen that there is good agreement between the results of these two methods. This emphasises the capability of remote sensing techniques for land use \ land cover mapping.

6.5 Reflection of Land Use Results of the Study Area to Major Land Use \ Land Cover in the Whole County Durham

It was discussed in the first chapter of this research that the six study areas are selected regionally, assuming the systematic general distribution of land use patterns in the County according to its main agricultural regions. To verify this, a comparison between the class area estimation done by the government (MAFF) over the whole of County Durham in June 1992 and results of the image class area estimation done by the author was made. Table (6:19) shows this comparison.

Table (6:19): Land use area estimation of major crops of the whole County (MAFF data) in 1992 versus that of the study area, ha\ %

No	Crop Type	Image Data	MAFF Data	Accuracy %
1	Wheat	447.58\ 8.16	21,039\ 8.7	93.8
2	Barley	290.88\ 5.31	13,425\ 5.5	96.5
3	Oilseed Rape	129.63\ 2.36	7,041\ 2.9	81.4
4	Improved Grass	2,066.07\ 37.66	107,112\ 44.3	85

It can be seen from the previous table that the study area represents the major agricultural crops of the whole county very well (81.4-96.5%).

6.6 Conclusion

A comparison of the results of area estimation done by the remote sensing technique with those done by the field mapping method emphasises the ability of the former technique to give accurate results for most land use \ land cover types. However, it was affected by the following conditions; first, the woodland class was underestimated in the areas of low density such as Edmundbyers and Hett. Second, unimproved grass was overestimated because of the EC set aside policy, and this land cover type also existed within woodland areas of low density. Third, the urban class area estimation is not reliable due to its poor classification accuracy. Fourth, the area estimation of improved grass and arable crops compared very well with that of field mapping. Finally, the area estimation of water and oilseed rape classes is the most accurate, with the highest classification accuracy results.

The change in land cover types such as woodland and unimproved grass can be better detected between two image classifications rather than between the image and map classifications. On other hand, it would be possible to detect agricultural land use

CHAPTER SEVEN

Chapter 7: Conclusion

The major aim of this study was to verify and investigate the capability of satellite remote sensing to produce accurate land use maps and to detect land use change using multi-temporal images. The objectives of the study can be summarised as follows:-

- To investigate the capability of satellite remote sensing to produce accurate land use maps of the study area.
- To investigate land use change in the study area over different dates by field mapping and satellite remote sensing techniques.
- To investigate the efficiency of remote sensing for detecting farmers' response towards the EC set aside policy.
- To evaluate the accuracy of remote sensing area estimation results in comparison with other sources of data.
- To incorporate remote sensing data in a Geographical Information System.

The results of this study, linked with these aims, can be discussed through the following main points:-

(1) Land use mapping by field survey method.

(2) Land use \ land cover image classification.

(3) Dates of images

(4) Integration of data in GIS.

(5) Land use change.

(6) Applicability of research results on the whole County Durham.

To achieve the aims of the study, the following data sets were used:-

(a) Ordnance Survey maps of the study area dated 1988 of different scales; 1:10,000, 1:25,000, 1:50,000, and 1:100,000.

(b) Large scale land use maps of the study area prepared by the author through the field survey mapping method.

(c) Area estimation for the major land use \ land cover types in the study area was undertaken using the Dudley Stamp's Survey map dated 1931.

(d) Satellite data obtained by the Thematic Mapper sensor onboard Landsat-5. The images were acquired on 31 May 1985, 1 August 1990, and 10 July 1992.

7. 1 Land Use Mapping by Field Survey

Large scale Ordnance Survey maps were used for this purpose. Each field in each study area was visited and labelled with its actual land use \ land cover type at the time of the survey (February, 1994). The field data obtained were integrated in the Geographical Information System ARC \ INFO. Hence, a data base for the study area is built, and then combined with the satellite images over the three dates. Field data represented the core on which the research was based. The classification scheme was detailed (see ch. 2) and represented the actual status of the fields at that time. This method of land use mapping is laborious and time consuming.

7.2 Land Use \ Land Cover Image Classification

Land cover in each study area over the three image dates was classified using the Maximum Likelihood classifier. The study produced between 18-25 land use \ land cover classes with more than 80% accuracy. The classification accuracy based on class number was affected substantially by the poor accuracy of the urban class; however class generalisation improved the classification accuracy. Multi-temporal image classification improved the classification accuracy by offering the opportunity to compare the spectral properties of agricultural crops in different seasons.

7.3 Image Acquisition Dates

The dates of image acquisition represented the main stages of crop growth (May, July, and August). The image of August was ideal for the discrimination of improved grass from cereal crops. The images of May and July were ideal for the discrimination of oilseed rape because this crop was in the flowering stage. Nevertheless, the classification accuracy obtained using Landsat-TM data reflected the accuracy of maps produced by the remote sensing technique for land use mapping.

7.4 Integration of Fields Maps and Images in GIS

The field maps and images of the study area were integrated in ARC \ INFO. The purpose of this integration was to geometrically correct these images, assess classification accuracy, estimate crop area, and produce land use maps from the classified images. Geometric correction of images was done after classification to avoid the effect of image data resampling on classification. The classification accuracy assessment was done using the grid-by-grid overlay method. This method was appropriate for the relatively small study areas.

7.5 Land Use Change

The area estimation and land use change detection results provided by the satellite remote sensing technique were efficient for most land cover types. It was possible to detect the set aside fields. These fields were assigned as the unimproved grass class, so they could be separated from this class by using reference and contextual data of these fields, allowing evaluation of the response of farmers towards the EC set aside policy. Comparing the area estimation of image classification for agricultural crops with the field and the MAFF data proved the ability of remote sensing to verify the farmer's statistical reports accurately. On the other hand, remote sensing in this study area (rural environment) could not detect land use change of the urban class. So, the class area estimation results done by remote sensing were not reliable. The land use change in the County between the Dudley Stamp's land use map of 1931 and both the field and image survey was significant. This change is mainly due to the construction of water reservoirs and the change from a common agricultural system to a private one. MAFF statistics showed a real shift from intensive to extensive farming in the County. All area estimation results by the field survey, the image survey, and the MAFF survey showed that the area of cereal crops has not changed considerably since 1981, see table (1:4).

7.6 Applicability of Research Results on County Durham

A comparison was made between the percentage of the major agricultural crops in the study area for the image of 1992, with that for the whole County using (MAFF data) in the same year, to verify the applicability of the research results on the whole county. The results of this comparison indicated that the selected study areas reflected overall changes in the agricultural status of the county as a whole by a percentage of 81-96%, figure (6:19).

7.7 Recommendations

(a) The results of this research showed that the agricultural land use in the County is to a great extent controlled by its physical characteristics (topography, soil and climate). This can benefit the application of remote sensing techniques to mapping the land use of the County in the following ways:-

(i) Relationships between different agricultural land use types and the physical elements of the County can be investigated. These could be subsequently used to improve image classification accuracy, especially in multi-temporal studies where training data may be unavailable.

(ii) Digital data for land use, soil, climate, topography and geology are necessary to achieve first, a better classification accuracy, especially for the urban class, and second, to assess the accuracy of image classification using a grid-by-grid overlay method rather than an independent test data method.

(b) It has been seen that the accuracy of results is affected by the different stages of data processing such as map errors, image errors and data conversion from one format to another. These errors could be recorded and integrated in the GIS and results "adjusted" according to these errors.

(c) The suitability of image acquisition dates for land use mapping varies from one land use to another. The image of May was not the best to discriminate cereal crops from improved grass; on the other hand it and the image for July were ideal for the discrimination of oilseed rape. The images of July and August were ideal for discriminating between different cereal crops and between these crops and improved grass. Thus the differences between the image acquisition dates in terms of their suitability for mapping different land use types benefitted the study by giving the opportunity to compare the ambiguous land use in some fields with those which are clearer and consequently improve the classification accuracy. The best two images as a whole in this study were the images of July and August.

(d) The study showed that the best wavebands for image classification varied from one region to another; in the eastern agicultural region represented by Hett and Hawthorn the best wavebands were bands 2, 3, 4, and 5, while in the corridor agricultural region the best bands were band 4, 5, and 7 (detailed illustration is included in section 4.4.2).

The results obtained from this study emphasise the ability of remote sensing techniques to produce accurate maps and crop area estimations for the whole of County Durham, especially when used as a multi-temporal study.

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APPENDICES

Appendex A: Land Use of the Study Area in 1931

Table (1) : Land use classification of Hawthorn for the year 1931

No	Land use class	ha	%
1	Arable Land	326.58	56.57
2	Woodland	38.15	6.6
3	Improved Grass	103.73	19.79
4	Moor and Heathland	28.8	4.99
5	built-up Areas	5.30	0.92
6	Roads and Railways	18.37	3.17
7	Quarries	38.67	6.7
8	Water Bodies	-	
9	Sand	17.46	3.1
	Total Area	**577.24**	**100**

FIGURE (1) : LAND USE OF HAWTHORN FOR THE YEAR 1931

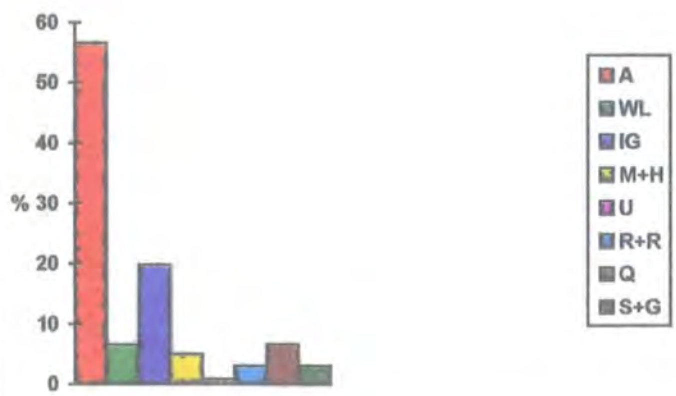


Table (2): Land use classification of Hett for the year 1931

No	Land use class	ha	%
1	Arable Land	129.6	25.65
2	Woodland	11.8	2.35
3	Improved Grass	302.41	59.85
4	Moor and Heathland	36.8	7.28
5	built-up Areas	4.53	0.89
6	Roads and Railways	20.17	3.99
7	Quarries	-	-
8	Water Bodies	-	-
9	Sand	-	-
	Total Area	**505.31**	**100**

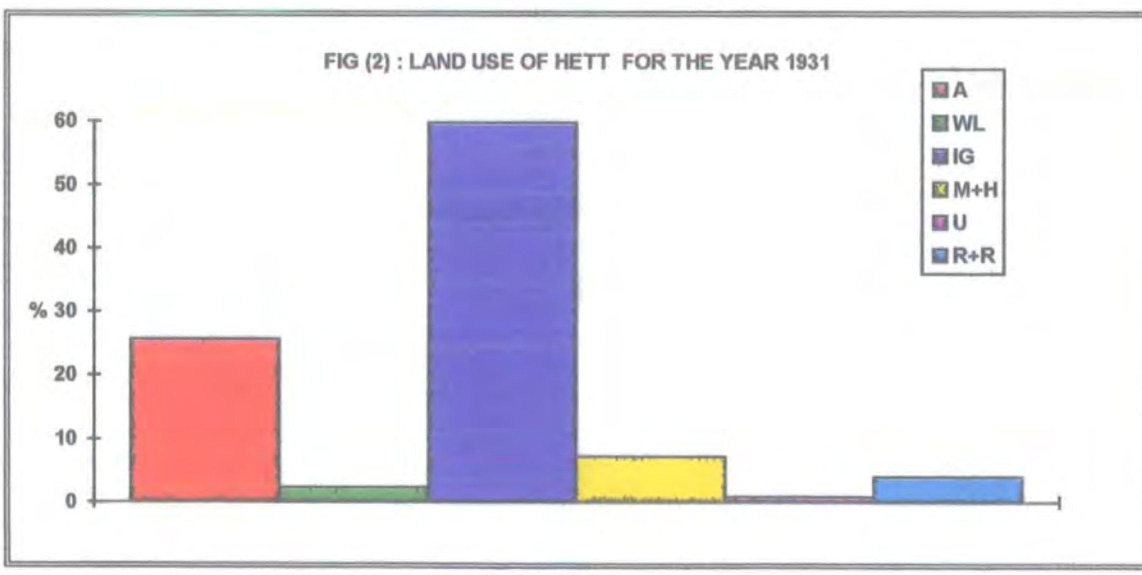


Table (3): Land use classification of Wackerfield for the year 1931

No	Land use class	ha	%
1	Arable Land	91.2	30.03
2	Woodland	4.62	1.50
3	Improved Grass	192.89	63.52
4	Moor and Heathland	-	-
5	built-up Areas	2.09	0.7
6	Roads	12.85	4.23
7	Quarries	-	-
8	Sand	-	-
9	Water Bodies	-	-
	Total Area	**303.65**	**100**

FIG (3) : LAND USE OF WACKERFIELD FOR THE YEAR 1931

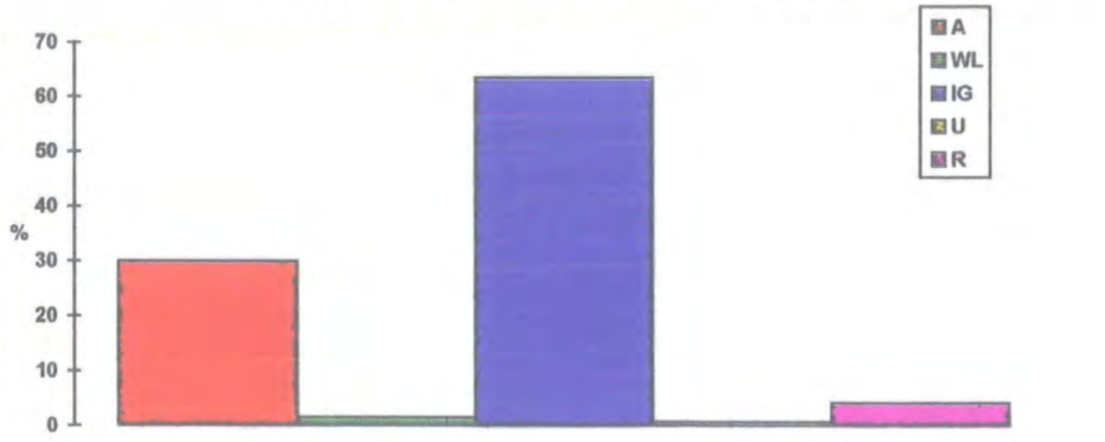


Table (4): Land use classification of Greencroft for the year 1931

No	Land use class	ha	%
1	Arable Land	78.4	11.55
2	Woodland	75.2	11.08
3	Improved Grass	437.99	64.6
4	Moor and heathland	68.6	10.10
5	built-up Areas	2.32	0.34
6	Roads	16.37	2.41
7	Quarries	-	-
8	Water Bodies	-	-
9	Sand	-	-
	Total Area	**678.88**	**100**

FIG (4) : LAND USE OF GREENCROFT FOR THE YEAR 1931

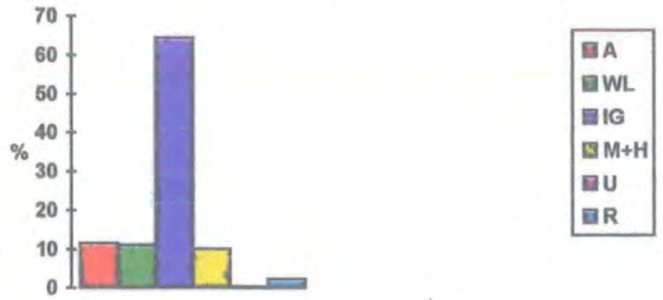


Table (5) : Land use classification of Satley

for the year 1931

No	Land use class	ha	%
1	Arable Land	131.68	9.72
2	Woodland	102.77	7.59
3	Improved Grass	845.69	62.59
4	Moor and Heathland	213.57	15.76
5	built-up Areas	9.53	0.70
6	Roads	33.75	2.49
7	Quarries	17.73	1.31
8	Water Bodies	-	-
9	Sand	-	-
	Total Area	**1354.72**	**100**

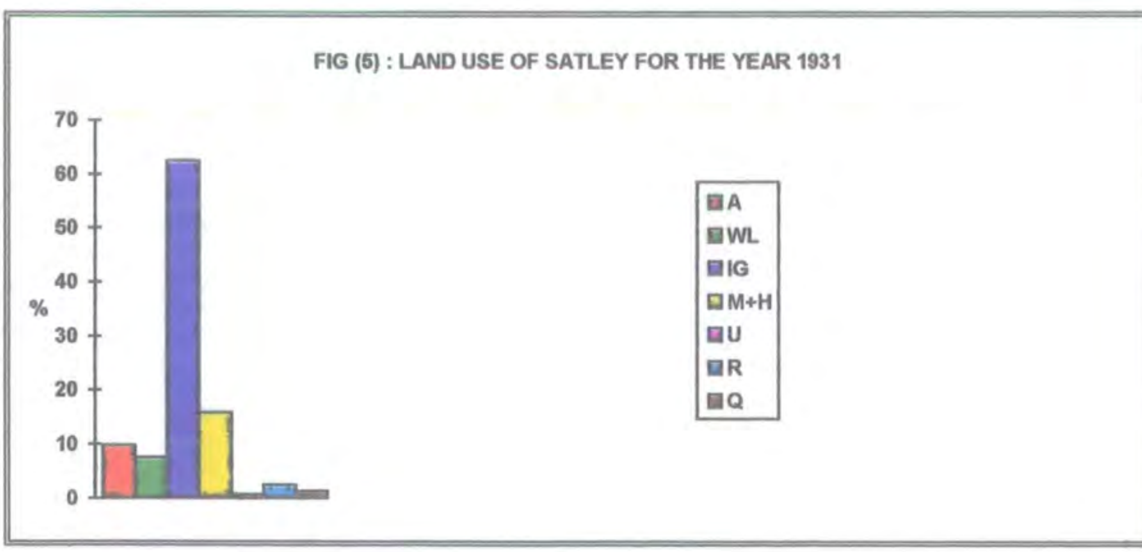
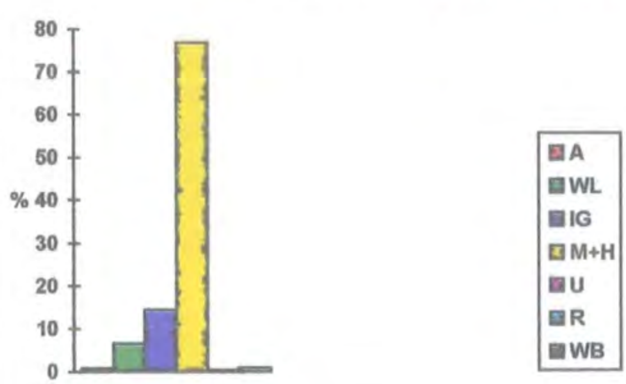


Table (6) : Land use of Edmundbyers for the year 1931

No	Land use class	ha	%
1	Arable Land	14.45	0.7
2	Woodland	134.37	6.5
3	Improved Grass	299.23	14.5
4	Moor and Heathland	1588.35	76.92
5	built-up Areas	7.84	0.38
6	Roads	20.02	0.97
7	Quarries	-	-
8	Water Bodies	0.65	0.03
9	Sand	-	-
	Total Area	**2064.06**	**100**

FIG (6) : LAND USE OF EDMUNDBYERS FOR THE YEAR 1931



Appendex B: Land Use of the Study Area in 1994

Table (1):- Land use classification of Hawthorn for the year 1994

No	Land use class	ha	%
1	Arable Land	121.65	21.1
2	Improved Grass	281.64	48.8
3	Oilseed Rape	19.99	3.5
4	Stubble Land	1.96	0.3
5	Mixed Forest Land	38.16	6.6
6	Deciduous Forest Land	0.58	0.1
7	Unimproved Grass	2.29	0.4
8	Ploughed and Sown Land	14.15	2.4
9	Ploughed Land	3.67	0.6
10	Bare Soil and Quarries	38.77	6.7
11	Sand and Gravel	17.64	3.1
12	Roads and Railways	27.09	4.7
13	Built-up Areas	9.65	1.7
	Total Area	**577.24**	**100**

FIG (1) : LAND USE OF HAWTHORN FOR THE YEAR 1994

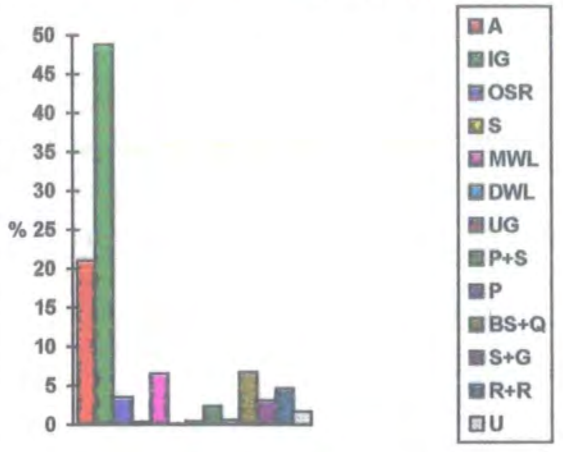


Table (2): Land use classification of Hett for the year 1994

No	Land use class	ha	%
1	Arable Land	127.00	25.13
2	Improved Grass	163.99	32.4
3	Oilseed Rape	44.47	8.8
4	Stubble	56.32	11.1
5	Mixed Woodland	1.01	0.2
6	Deciduous Woodland	10.23	2.0
7	Coniferous Woodland	0.64	0.1
8	Unimproved Grass	8.0	1.6
9	Water Bodies	0.53	0.1
10	Ploughed and Sown Land	22.67	4.5
11	Ploughed Land	33.42	6.6
12	Bare Soil	13.13	2.6
13	Roads and Railways	20.17	3.9
14	Built-up Areas	6.19	1.22
	Total Area	**505.31**	**100**

FIG (2) :LAND USE OF HETT FOR THE YEAR 1994

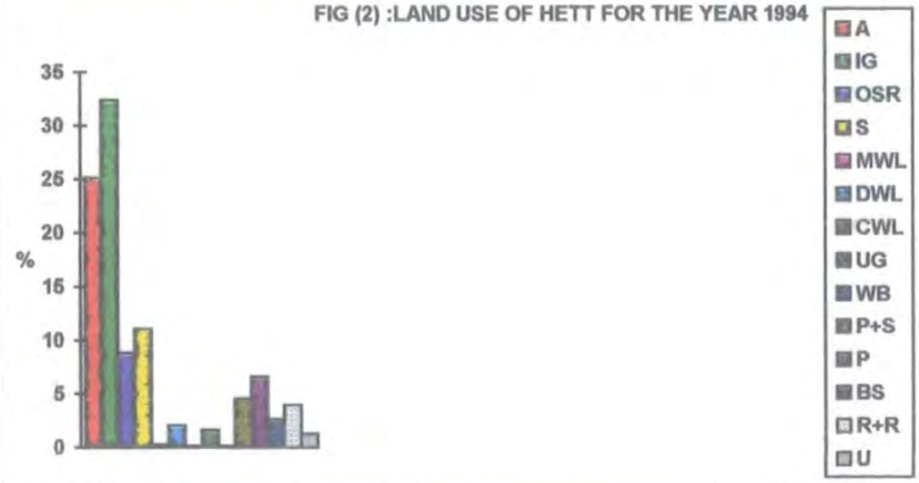


Table (3): Land use classification of Wackerfield for the year 1994

No	Land use class	ha	%
1	Arable Land	56.18	18.5
2	Improved Grass	99.16	32.8
3	Oilseed Rape	28.15	9.3
4	Kale	3.36	1.1
5	Stubble	59.0	19.4
6	Deciduous Woodland	0.61	0.2
7	Coniferous Woodland	4.02	1.3
8	Unimproved Grass	4.07	1.3
9	Ploughed and Sown Land	34.15	11.2
10	Roads	12.86	4.2
11	Built-up Areas	2.09	0.7
	Total Area	**303.65**	**100**

FIG (3) : LAND USE OF WACKERFIELD FOR THE YEAR 1994

Table (4): land use classification of Greencroft for the year 1994

No	Land use class	ha	%
1	Arable Land	59.65	8.8
2	Improved Grass	500.2	73.7
3	Mixed Woodland	1.47	0.2
4	Deciduous Woodland	54.26	8.0
5	Coniferous Woodland	1.19	0.2
6	Unimproved Grass	14.56	2.2
7	Improved Grass + Deciduous Wood L.	1.57	0.2
8	Unimproved Grass + Deciduous Wood L.	12.19	1.8
9	Unimproved Grass + Coniferous Wood L	3.30	0.5
10	Water Bodies	0.62	0.1
11	Ploughed Land	4.93	0.7
12	Bare Soil	0.98	0.1
13	Roads	16.37	2.4
14	Built-up Areas	8.13	1.2
	Total Area	**678.88**	**100**

FIG (4) : LAND USE OF GREENCROFT FOR THE YEAR 1994

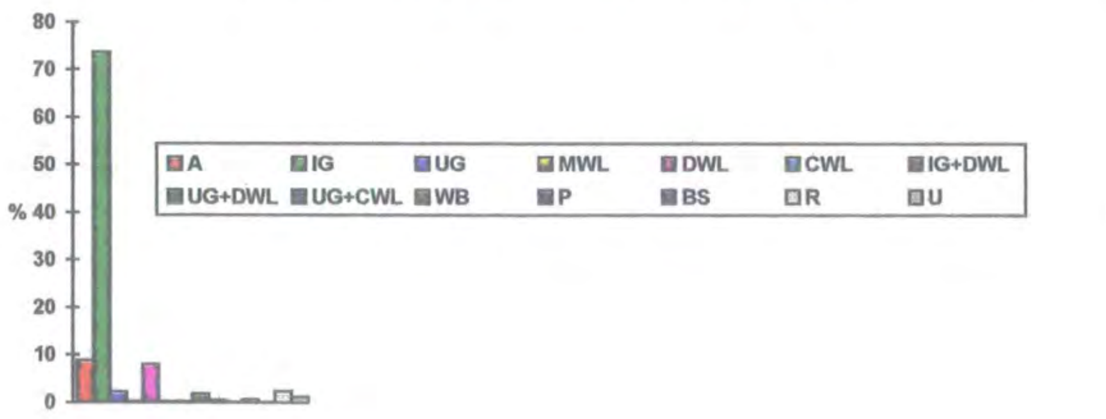


Table (5): Land use of Satley for the year 1994

No	Land Use Class	ha	%
1	Arable Land	41.88	3.09
2	Improved Grass	1027.14	75.82
3	Oilseed Rape	8.37	0.6
4	Stubble	21.94	1.62
5	Mixed Woodland	5.17	0.38
6	Deciduous woodland	43.67	3.23
7	Coniferous woodland	41.73	3.08
8	Unimproved Grass	31.03	2.30
9	Ploughed and Sown Land	44.60	3.29
10	Ploughed Land	27.32	2.00
11	Bare Soil and Quarries	17.74	1.31
12	Roads	33.75	2.49
13	Built-up Areas	10.37	0.76
	Total Area	**1354.72**	**100**

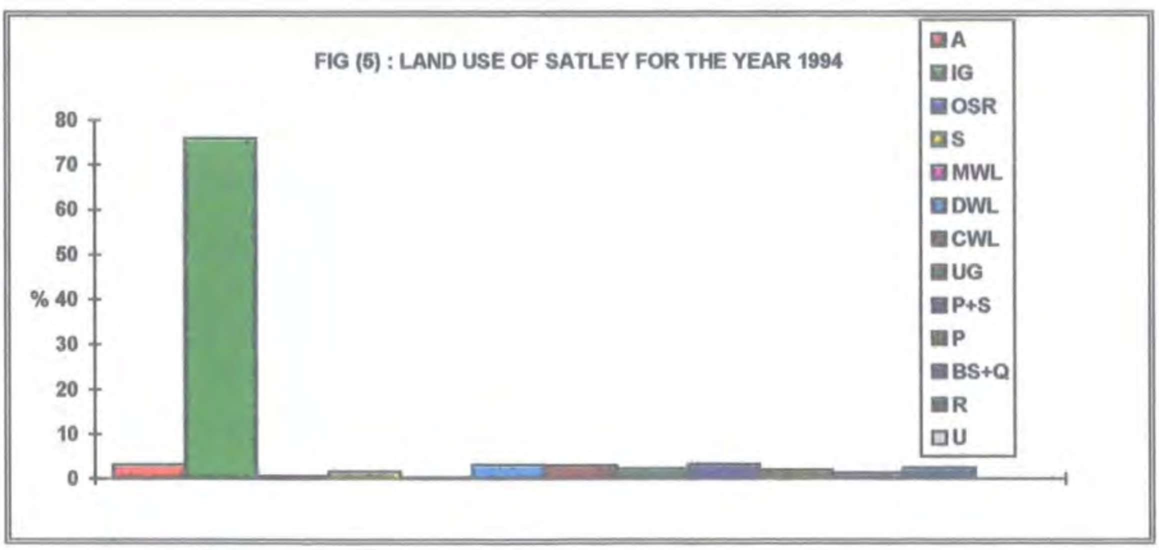


Table (6) : Land use classification of Edmundbyers for the year 1994

No	Land use class	ha	%
1	Improved Grass	182.47	8.8
2	Mixed Woodland	60.38	2.9
3	Deciduous Woodland	30.36	1.5
4	Coniferous Woodland	34.56	1.7
5	Unimproved Grass	501.73	24.3
6	Moor land	1057.77	51.3
7	Water Bodies	165.92	8.0
8	Roads	20.0	1.0
9	Built-up areas	10.87	0.53
	Total Area	**2064.06**	**100**

FIG (6) : LAND USE OF EDMUNDBYERS FOR THE YEAR 1994

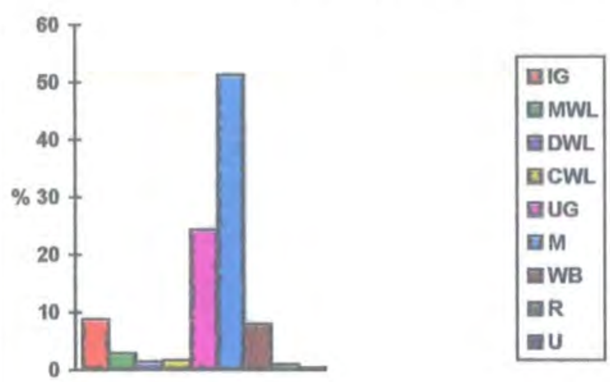


Table (7): Generalised land use classification of

Hawthorn- 1994

No	Land use class	ha	%
1	Arable Land	161.42	27.9
2	Woodland	38.74	6.7
3	Improved Grass	281.65	48.8
4	Moor and Heathland	2.29	0.4
5	Built-up areas	9.65	1.7
6	Roads and Railways	27.09	4.7
7	Quarries	38.67	6.7
8	Water Bodies	-	-
9	Sand and Gravel	17.46	3.1
	Total Area	577.24	100

FIG (7) : ENERALISED LAND USE OF HAWTHORN IN 1994

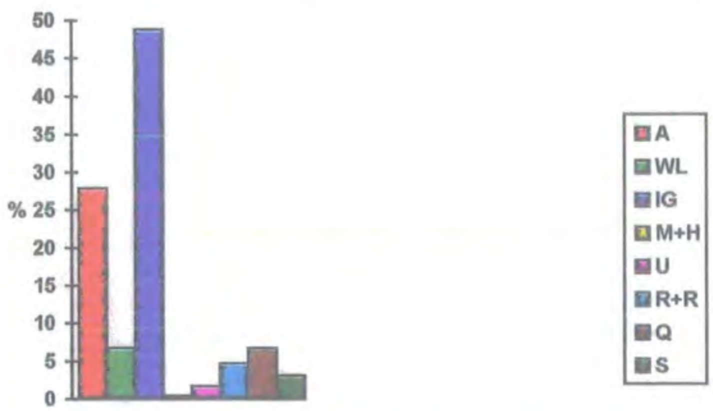


Table (8) : Generalised land use classification of Hett- 1994

No	Land use class	ha	%
1	Arable Land	295.02	58.38
2	Woodland	11.89	2.35
3	Improved Grass	163.99	32.45
4	Moor and Heathland	8.0	1.60
5	built-up Areas	6.19	1.22
6	Roads and Railways	20.17	3.99
7	Quarries	-	-
8	Water Bodies	0.05	0.01
9	Sand	-	-
	Total Area	**505.31**	**100**

FIG (8) : GENERALISED LAND USE OF HETT IN 1994

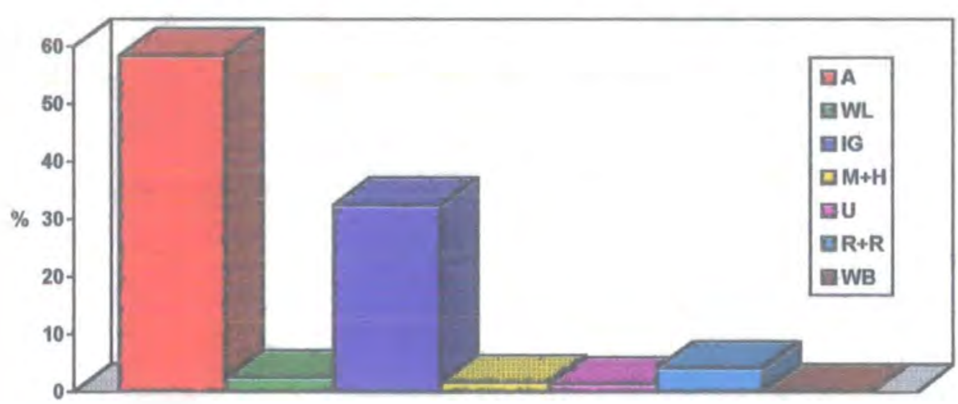


Table (9): Generalised land use classification of Wackerfield - 1994

No	Land use class	ha	%
1	Arable Land	180.85	59.50
2	Woodland	4.62	1.50
3	Improved Grass	99.16	32.8
4	Moor and Heathland	4.07	1.3
5	Built-up Areas	2.09	0.7
6	Roads	12.86	4.2
7	Quarries	-	-
8	Water Bodies	-	-
9	Sand and Gravel	-	-
	Total Area	**303.65**	**100**

FIG (9) : GENERALISED LAND USE OF WACKERFIELD IN 1994

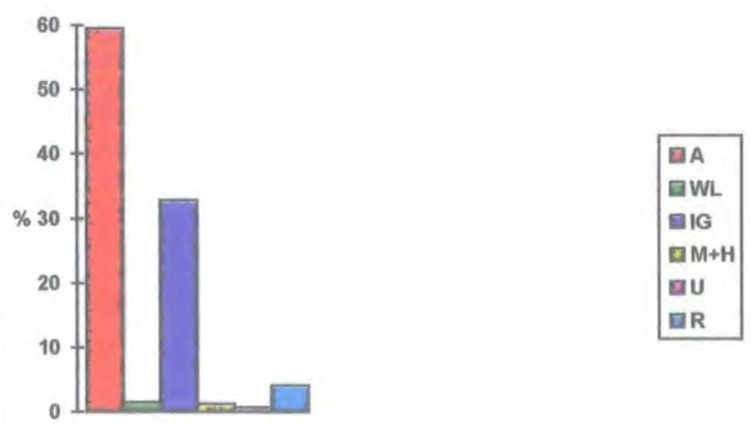


Table (10): Generalised land use classification of Greencroft - 1994

No	Land use class	ha	%
1	Arable Land	65.57	9.66
2	Woodland	65.46	9.64
3	Improved Grass	500.20	73.68
4	Moor and Heathland	23.09	3.40
5	Built-up Areas	8.13	1.2
6	Roads	16.37	2.4
7	Quarries	-	-
8	Water Bodies	0.06	0.01
9	Sand	-	-
	Total Area	**678.88**	**100**

FIG (10) : GENERALISED LAND USE OF GREENCROFT IN 1994

Table (11) : Generalised land use classification of Satley - 1994

No	Land use class	ha	%
1	Arable Land	144.10	10.64
2	Woodland	90.58	6.69
3	Improved Grass	1027.14	75.82
4	Moor and Heathland	31.03	2.30
5	Built-up Areas	10.37	0.76
6	Roads	33.75	2.49
7	Quarries	17.74	1.31
8	Water Bodies	-	-
9	Sand and Gravel	-	-
	Total Area	**1354.72**	**100**

FIG (11) : GENERALISED LAND USE OF SATLEY IN 1994

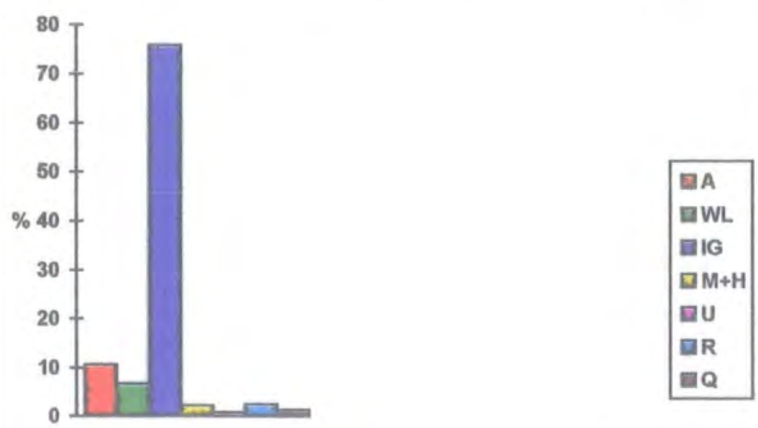
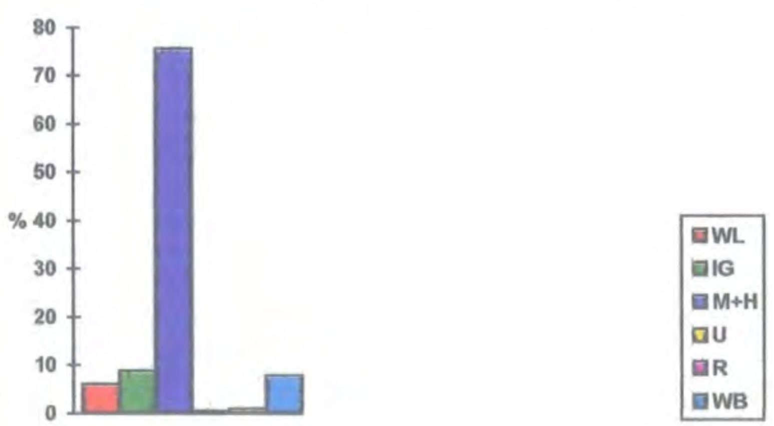


Table (12): Generalised land use classification of Edmundbyers - 1994

No	Land use class	ha	%
1	Arable Land	-	-
2	Woodland	125.3	6.07
3	Improved Grass	182.47	8.8
4	Moor and Heath land	1559.56	75.56
5	Built-up areas	10.87	0.53
6	Roads	20.0	0.97
7	Quarries	-	-
8	Water Bodies	165.92	8.0
9	Sand and Gravel	-	-
	Total Area	**2064.06**	**100**

FIG (12) : GENERALISED LAND USE OF EDMUNDBYERS IN 1994



Appendex C: Land Use Change of the Study Area Between 1931-1994

Table (1) : Land use change of Hawthorn

No	Land use class	Land use change ha	Land use change %
1	Arable Land	– 165.16	– 28.67
2	Woodland	+ 0.59	+ 0.1
3	Improved Grass	+177.92	+ 29.01
4	Moor and Heathland	– 16.08	– 4.59
5	Built-up Areas	+ 4.35	+ 0.78
6	Roads and Railways	+ 8.72	+ 1.53
7	Quarries	0	0
8	Sand and Gravel	0	0

FIG (1) : LAND USE CHANGE OF THE TOTAL AREA OF HAWTHORN BETWEEN THE YEARS 1931 - 1994

Table (2): Land use change of Hett

No	Land use class	Land use change (ha)	Land use change %
1	Arable Land	165.42	32.73
2	Woodland	0	0
3	Improved Grass	- 138.42	- 27.4
4	Moor and Heathland	- 28.8	- 5.67
5	Built-up Areas	1.66	0.33
6	Roads and Railways	0	0
7	Water Bodies	0.05	0.01

FIG (2) : LAND USE CHANGE OF THE TOTAL HETT AREA BETWEEN 1931- 1994

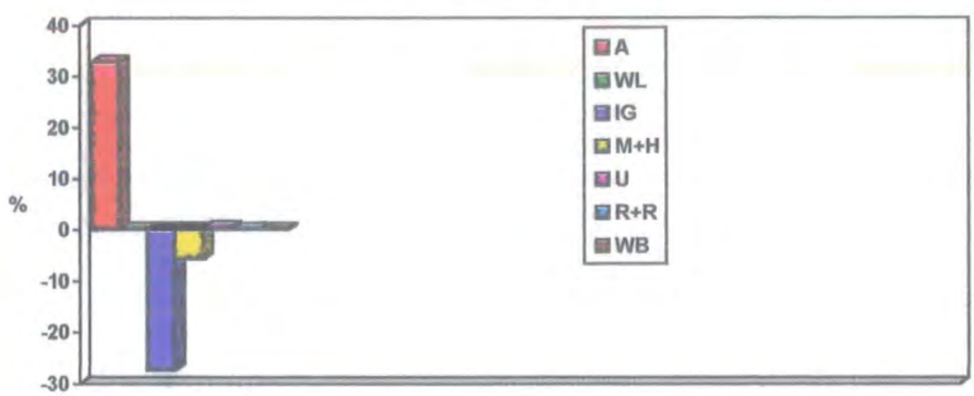


Table (3): Land use change of Wackerfield

No	Land use class	Land use change (ha)	Land use change %
1	Arable Land	89.65	29.52
2	Woodland	0	0
3	Improved Grass	- 93.73	- 30.86
4	Moor and Heathland	4.07	1.34
5	Built-up Areas	0	0
6	Roads	0	0

FIG (3) : LAND USE CHANGE OF THE TOTAL WACKERFIELD AREA BETWEEN 1931 - 1994

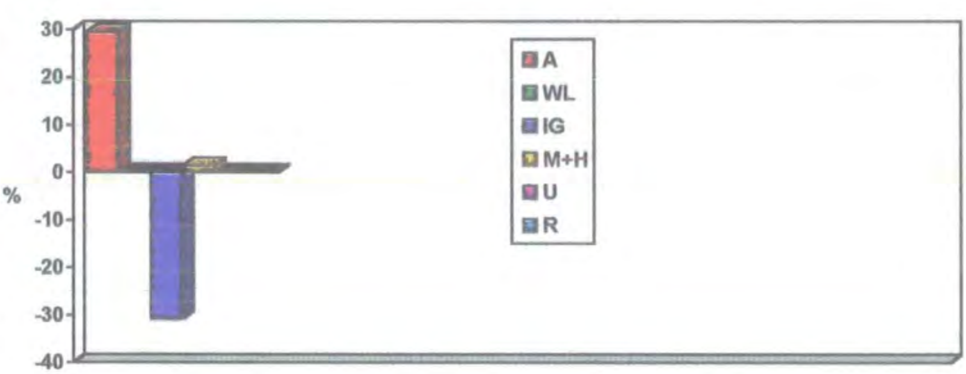


Table (4): Land use change of Greencroft

No	Land use class	Land use change (ha)	Land use change %
1	Arable Land	- 12.83	- 1.89
2	Woodland	- 9.75	- 1.44
3	Improved Grass	62.21	9.16
4	Moor and Heathland	- 45.51	- 6.7
5	Built-up Areas	5.81	0.86
6	Roads	0	0
7	Water Bodies	0.06	0.01

FIG (4) : LAND USE CHANGE OF THE TOTAL GREENCROFT AREA BETWEEN 1931 - 1994

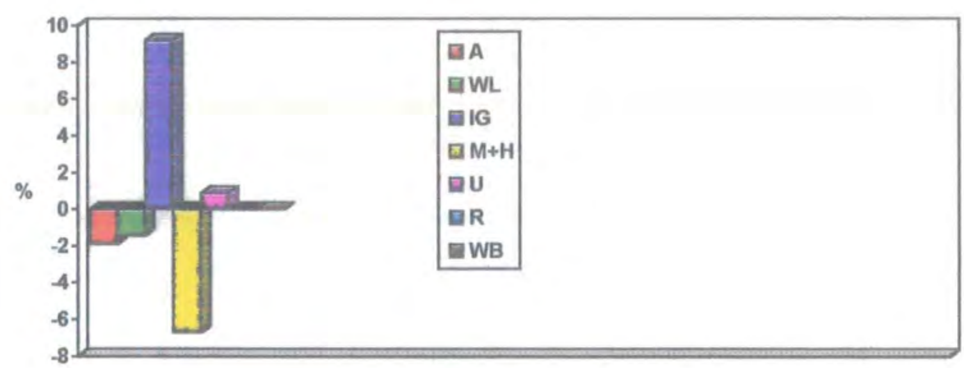


Table (5): Land use change of Satley

No	Land use class	Land use change (ha)	Land use change %
1	Arable Land	12.42	0.92
2	Woodland	- 12.19	0.9
3	Improved Grass	181.45	13.4
4	Moor and Heathland	- 182.54	- 13.46
5	Built-up Areas	0.83	0.06
6	Roads	0	0
7	Quarries	0	0

FIG (5) : LAND USE CHANGE OF THE TOTAL SATLEY AREA BETWEEN 1931 - 1994

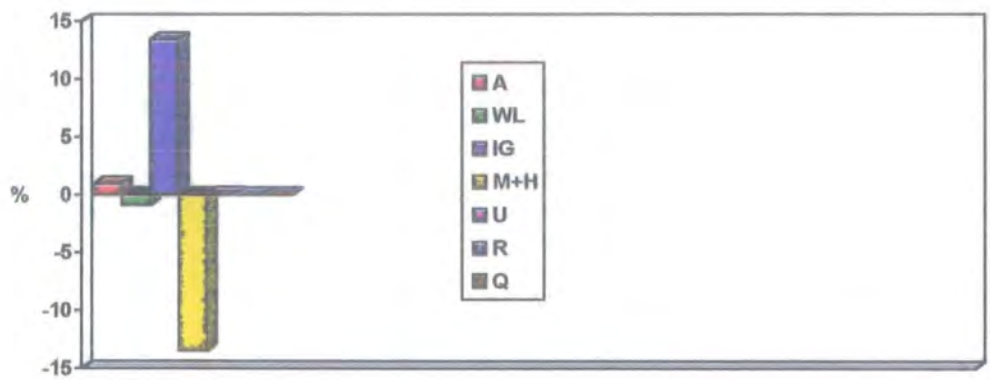


Table (6) : Land use change of Edmundbyers

No	Land use class	Land use change (ha)	Land use change %
1	Arable Land	- 14.45	- 0.7
2	Woodland	- 8.86	- 0.43
3	Improved Grass	- 116.82	- 5.66
4	Moor and Heathland	- 28.17	- 1.35
5	Built-up Areas	3.03	0.15
6	Roads	0	0
7	Water Bodies	165.27	7.97

FIG (6) : LAND USE CHANGE OF THE TOTAL EDMUNDBYERS AREA BETWEEN 1931 - 1994