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INSTITUTE OF TERRESTRIAL ECOLOGY
(NATURAL ENVIRONMENTAL RESEARCH COUNCIL)

ITE PROJECT 1130

DOE/NERC CONTRACT

PROGRESS REPORT

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THE ECOLOGICAL CONSEQUENCE OF LAND USE CHANGE.

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CONTENTS

ABBREVIATIONS

ALC	Agricultural Land Classification
ATM	Aerial Thematic Mapper
BTO	British Tust for Ornithology
CAP	Common Agricultural Policy
CAS	Centre for Agricultural Strategy
CC	Countryside Commission
DC	Development Commission
DOE	Department of the Environment
ESRC	Economic and Social Science Research Council
FWAG	Farming and Wildlife Advisory Group
GB	England, Wales and Scotland
HTS	Huntings Technical Surveys
IBM	International Buisness Machines
IALE	International Association for Landscape Ecology
ITE	Institute of Terrestrial Ecology
LDNPA	Lake District National Park Authority
LDSPB	Lake District Special Planning Board
MSC	Manpower Services Commission
NCC	Nature Conservancy Council
NNR	National Nature Reserve
NP	National Park
NRSC	National Remote Sensing Centre
NSA	National Scenic Areas
OS	Ordnance Survey
PC	Personal Computer
RAD	Rural Areas Database
SSSI	Site of Special Scientific Interest
TM	Landsat Thematic Mapper

SUMMARY

Whilst rural land in Britain has always been changing, the current situation is unstable because of technological progress in farming and the influence of CAP. Likewise, concern with the general environment has never been higher, reflected in the strength of pressure groups, and in government statements. Advisors on policy matters therefore require information on the underlying ecological parameters behind broad general statements of land use change. Advice is also required as to how these changes can be detected and converted into a form that is readily assimilated.

1. CORE PROJECT

Changes in land cover from available sources have first been defined and areas with maximum change identified for detailed study. The major ITE database on vegetation within Britain, based on the Merlewood Land Classification System, has been developed into an appropriate format. The first analyses have now been produced and will eventually enable species composition, spatial arrangement and diversity to be associated with the observed land use changes. In conjunction with the development of scenarios of future potential change, these analyses will form the basis of predictive models involving a variety of parameters eg bird populations and vegetation composition. Statistical aspects of estimating land use change have also been discussed and further work initiated on critical topics.

2. REMOTE SENSING PROJECT

The appropriate satellite images have been identified for 48 1 Km2 from 8 land classes defined in the core project, other sites will be identified from the Monitoring Landscape Change project. Initially TM images will be used but SPOT images will also be used for comparative purposes. The programme is being coordinated with NRSC to increase coverage and the comparision of techniques. Field survey of 144 sample squares throughout Britain is currently being organised and will take place between July and August. These data will provide ground truth for distinguishing relevant cover types and form the basis for the assessment of change with a repeat survey in 1988. These data will also form the basis for analysis of pattern and will enable a feasible schedule of routine monitoring to be recommended for detection of change in land cover.

3. EXPERT SYSTEMS PROJECT

A series of consultations have been held to identify suitable topics for the development of expert systems. The systems will be interrogative tools incorporating expert knowledge of ecological factors associated with land use change. Trial systems have been produced on the management of roadside verges and meadows and have been used to gain experience of the potential of the technique. The 2 main areas for development are (i) a graphics system for FWAG farm plans, which will be extended later to land use changes, and (ii) forestry involving the ecological consequences of afforestation on a variety of scales.

4. LINK PROJECT

The project is to coordinate the ITE work with that of other organizations carrying out related research. Currently ten universities, government agencies and institutions have been included in the work programme of the current year, with other links planned in due course.

FORWARD

The main emphasis in the work programme to date has been in the organization of the project, in developing the procedures to be followed and building contacts with other organizations. This is reflected in the composition of the present report which mainly describes the approaches being adopted rather than results. The main sections of the work programme are now underway with the first results available and further analysis in an advanced state. The report is structured, along the pattern of the Project Plan, around the major projects which comprise the work programme. A diagram of the relationships between the various comparable projects being undertaken in ITE is given in Figure 1.

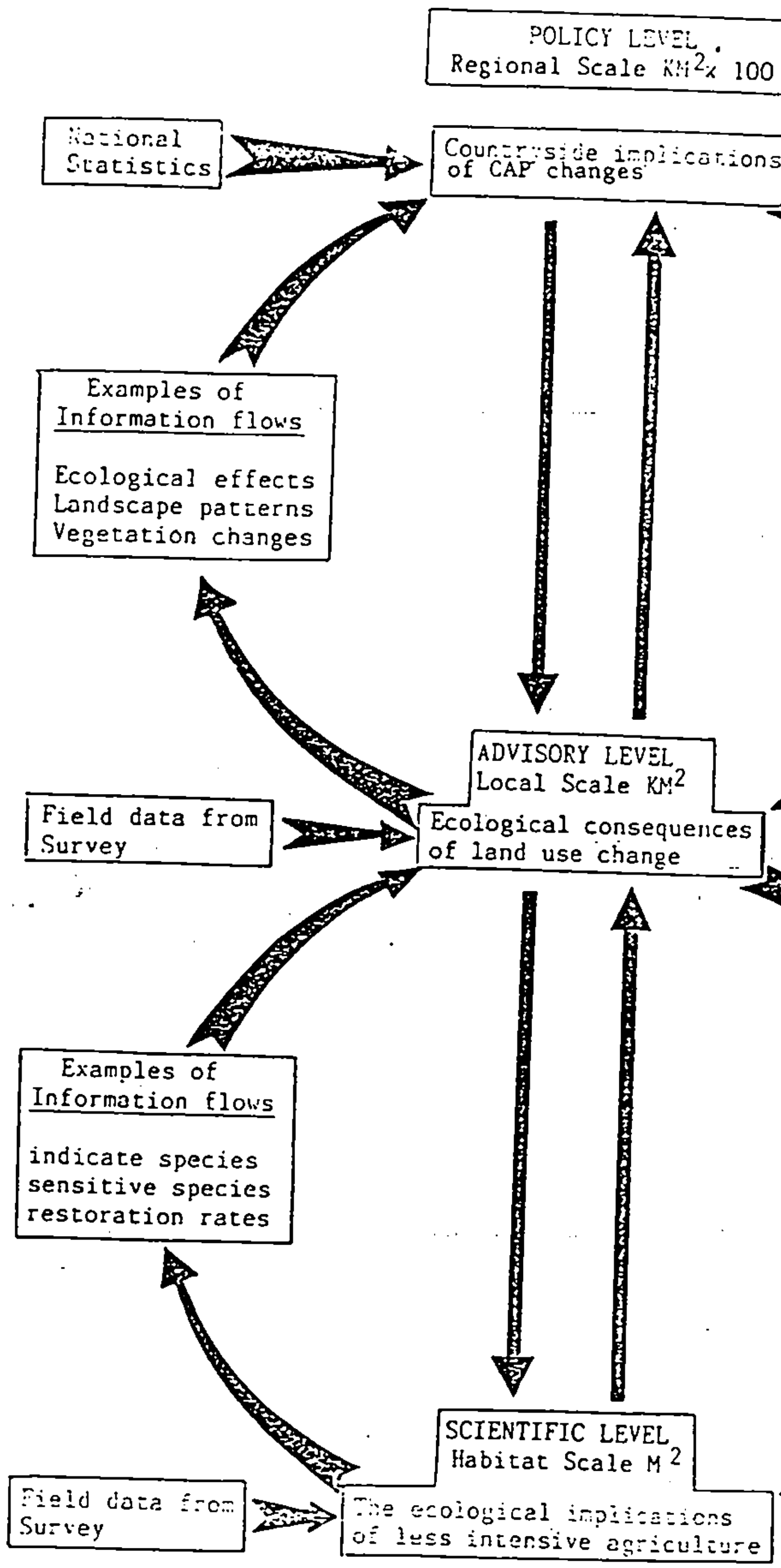

Figure 1 - Relationship between projects

1. INTRODUCTION

Currently, there is great interest in the rate and direction of land use change and consequent landscape change. Although much of the expressed concern comes from groups whose primary interest is visual, such changes are inextricably mixed with ecological factors, such as soil and wildlife species. The wide interest in the subject is reflected, not only in the media and in general publications, such as Shoard (1980) and Bowers and Cheshire (1983), but also in an extensive ecological literature, eg Ball et al. (1982) and Miles (1979).

The accelerating rate of change of recent years has led to the initiation of a series of strategic studies sponsored by various government agencies, with the general objective of examining future trends in land use and landscape. The following are the most significant:

i. the countryside implications of potential changes in the CAP (Harvey et al. 1986) (sponsored by DOE and the DC; carried out by CAS and ITE);

ii. monitoring of landscape change in England and Wales (sponsored by DOE and CC, carried out by HTS (1986));

iii. land use changes to the year 1990 and 2000 (sponsored by NCC, carried out by Laurence Gould);

iv. the possibilities of set-a-side policies (sponsored by ESRC, carried out by Wye College);

v. monitoring land use change in GB (currently being carried out within NCC (1986));

vi. changes in the rural environment (changes 1978-1984, carried out by ITE)

The Ecological Survey of Britain, carried out by ITE, has a central role in the current project because of its design as a system for integrated studies. It is based at Merlewood and has acquired field data at a 1 km2 scale for the whole of Britain, based on 32 environmentally determined land classes (Bunce et al. 1983). The initial survey was carried out in 1978 and comprised data on vegetation, soils, land use and several ecological parameters from 8 x 1 km2 sample units randomly derived from each of the environmental strata. These data were used to validate the classification and led to a repeat survey in 1984 to estimate changes in land use and cover (Barret al. 1986) and to refine data.

The stratified sample approach enables the co-ordination of a range of different ecological studies within a general framework which allows various correlations to be assessed. Whilst the initial data have been descriptive, it is now important to define the dynamic ecological changes which result from land use changes, whether observed from the repeat survey carried out in 1984, or predicted from other sources. The wide range of expertise in ITE and elsewhere can be used to develop co-ordinated, dynamic appraisals from static data.

ITE has also undertaken a range of fundamental ecological research related to land use. These studies indicate that the distribution of ecosystems and their constituent species is influenced both directly and indirectly by the function of the land. Thus, for example, the work on red deer, grouse and grassland herbs has, of necessity, been linked to the types of land use in the areas where the target species were studied. In the majority of these studies, however, the actual land use was incidental to the primary objectives. It has only been in relatively recent years, in response to the increased pressure on the ecological resources of the countryside, that ITE has developed work related specifically to land use, including the complexes of habitats which comprise the landscape. Such work has paralleled developments elsewhere, eg in Europe, where such interest stimulated the formation of the International Association for Landscape Ecology in 1981. Typical of such recent work are the historical studies by Sheail (1980) using traditional methods, and by Fuller (1983), using aerial photographic techniques.

At present, the principal means available to the ecologist for the detection of change is repeated ground survey. However, it has been shown, eg Stove and Robertson (1980) and HTS (1986), that remote sensing also has great potential for this purpose, and the most recent imagery, eg SPOT, has increased resolution. Moreover, the ability of the satellites to make regular passes to monitor change is likely to be of major significance in monitoring change in landcover. The degree of resolution which can be achieved in monitoring change in land cover needs to be assessed and linked with ground truth data provided by the original ITE surveys and new data acquired specifically for the current cover. changes in land cover is indicative of ecological change, and the critical requirement is to relate change in land cover to their affects on vegetation and wildlife. Thus there are 3 links in the chain;

i. detection of land cover by remote sensing
ii. validation through ground survey
iii. interpretation in terms of impact on plants and animals.

Whilst there is much work readily available on ecosystems, the study of pattern in landscape has not received the same attention. Baudry (1985) and Phipps (1984) have described some of the methods which might be employed, but the literature is still sparse. The various IALE conferences have also provided a forum for such discussions, but further research is needed in this area in order to develop predictive models.

The central theme of the project is to determine the changes that are taking place, where they are occurring and their ecological implications, through co-ordination of a variety of data sources. Many of these data have been acquired for other purposes and have not been linked together, and their combination into a unified knowledge system will provide a powerful tool for planning purposes. However, the final stage is that the information must be made available to as wide a range of users as possible. Traditionally, this dissemination has been achieved through a series of reports but such reports are often not readily converted into the form needed by advisors on policy matters. The recent development of expert systems has created a potential to present management guidelines on a variety of topics, eg the restoration of wasteland or hedgerow management, based on the co-ordinated framework on knowledge mentioned above.

In expert systems simple multi-attribute instructions are used to access relevant information with qualitative or quantitative data. Existing knowledge can be synthesized, and predictions made of logical outcomes from known situations based both on experience, ie conventional wisdom, and on hard data where these are available. Such information can be co-ordinated into a geographical framework and can the incorporate visual material, eg landscape and graphic representations. The potential of this approach is such that it forms a major section of the project, emphasising the need for a joint approach between ecologists and information analysts to produce a system that is ecologically valid and user-friendly.

The contract with DOE aims to assess the ecological consequences of current and potential changes in land use and to examine ways of presenting this information to land managers and policy makers in the readily useable form of expert systems. In developing the study a wide range of research workers and groups will be involved, as required by the DOE. This first report, covering the period 1st January - 1st May 1987 summarizes the progress on the analysis of land cover change and its ecological consequences (Section 2); the development of remote sensing (Section 3); and the development of expert systems (Section 4). The contributions made by other institutions and universities are described in Section 5.

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2. CORE PROJECT

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In order to predict the ecological consequences of land use change it is necessary to correlate land use and ecological data. The ITE land classification has been used as a basis for this study because it has both national coverage and contains sufficient ecological data. This Section deals with;

- i. selection of areas for intensive investigation,
- ii. an initial assessment of ecological diversity in relation to land cover, as a basis for interpreting change in land use,
- iii. an assessment of statistical requirements,
- iv. development of databases.

2.1 Identification of areas of change

The land classification system and hence all 32 land classes will be used as the framework on which to base the comparative studies of parameters such as diversity. However where it is not possible to cover the whole country eg in the remote sensing project, it has been necessary to identify core land classes, representative of British environments. An analysis, described below, has therefore been carried out to identify such classes where the largest number of changes have taken place, to ensure that as much variation as possible is included in the limited subsample.

The land classes were divided into 4 groups of 8, depending on the land use. The divisions form 2 upland and 2 lowland groups. The original aim was to select 2 classes from each division. Since the changes in land use are likely to differ between upland and lowland, different selection criteria were used for each.

For the lowland groups, the total number of changes in land cover and linear features 1978 - 1984 were recorded. The land classes which showed maximum change in each group were:

Group	Land class exhibiting most changes in Linear features	Land class exhibiting most changes in Land cover
(1) Lowland, predominantly cereals	3	11
(2) Lowland, predominantly grassland	10	26

In the upland groups, it was more difficult to determine criteria as there were few changes. Accordingly, it was decided to use improvement of rough grazing as the criterion for selection in the first instance, but, even so, only 3 classes were identified:

(3) Marginal upland	17 and 20.
(4) Upland moorland	32.

There is no guarantee that any area which has changed a lot in the past will continue to change in the future. This aspect will be covered in the second phase of the HTS study, but ideally should also be covered by selecting areas with a high potential for change. However it was only possible to use 3 classes and as there were many more changes in the lowland than the uplands, land class 6 was selected because the Reading model predicts that it has a high probability of change.

The distribution of the 8 sample squares in each selected land class is shown in Figure 2. These squares are the core areas for analysis, particularly for remote sensing. The classes give a wide range of regions and types of cover and are also likely to include some features which will not change, eg cereal land in class 3.

The subcontract with HTS (Phase I) (Section 5) will identify further areas where the degree of change is high for further analysis by remote sensing. Discussions have also been held with Jonathan Budd (NCC) to incorporate similar data from Scotland in due course.

The base data on land cover in the 8 core classes where change is maximal can be extended by use of data on land cover in the remaing 24 classes.

2.2 Analysis of diversity

It is generally perceived that one of the major changes taking place in the countryside is a decline in diversity due to modification of land cover. Such diversity in landscape can be caused by the loss of prominent elements, such as trees, but ecological diversity is particularly difficult to assess. It is first therefore necessary to restrict the range of parameters to be covered and initially vegetation has been selected for analysis as data are readily available and many other species are dependant on it. Subsequently, it is hoped to extend the analysis to bird and insect populations. Even within this restricted area there has been much controversy so that diversity was one of the major topics in the statistics workshop (Section 2.5). It was concluded that in addition to changes in numbers of species the most effective measure of the diversity of vegetation within landscape was the number of vegetation types.

During the 1978 ITE land classification survey the species composition of the vegetation was recorded in 200 m2 quadrats (5 random quadrats in each of 8 squares in each of the 32 land classes). The data from 1280 quadrats have been analysed (TWINSPAN) and 75 vegetation types identified. From this analysis the number of vegetation types and associated land use has been defined for each of the land classes. The results (Table 2) show the strength of the lowland to upland gradient and the necessity for considering diversity at given points on that continuum. At those points arbitrarily determined by the land classes, valid comparisons of diversity may be made as the background environment is held relatively constant. The heterogeneity is measured by the occurrence of the TWINSPAN classes and shows the continuum that is present. Whilst adjacent types may be similar and are arbitrary points, overall the differences are highly significant. The Table also provides an indication of the way in which the average composition of a land class will be used as a base against which diversity can be compared. Changes in individual vegetation types can therefore be modelled either theoretically or according to recorded data, and their ecological influence assessed. For example, land class 17 has a spectrum of:

CR	PG	UG	M	B	OT
6	6	5	1	0	0

For key to vegetation types refer to Table 2 on page 12.

If drainage or improvement were to take place on the limited proportion of unimproved semi-natural vegetation, then that decline would be reflected in the loss of the semi-natural vegetation types affected. Further, in due course the class can be broken down into the individual 1 km squares and their contribution to the spectrum assessed. In some cases, the variation may be spread evenly throughout the squares; whereas in other cases all the residual variation may be concentrated in a single site. Such a situation is likely to exist in the lowlands, where a single farm holding may have remained unimproved, as an island in a sea of surrounding improved land. Such a situation would emphasise the fragility of a given habitat/vegetation type.

2.3 Initial interpretation

Table 2 reflects conventional wisdom - the most variable landscapes are those with mixtures of upland and lowland. Thus the pure lowland classes (3,11,12) and upland classes (23, 30, 18) respectively, have fewer vegetation types represented than the marginal classes 13, 15 and 16.

This Table is included as an example of the way in which the land classes will be used to assess the ecological consequences of change, rather than direct land use changes. Currently, analysis is proceeding along similar lines for the linear features, as described in the data processing section. The initial TWINSPAN results have recently been produced as the first output of the project, and will provide the basis for the assessment of the contribution of linear features to heterogenity within the landscape. In addition to the vegetation types themselves, groups of species will be identified by a clustering procedure. These groups will be used to break down the variability further, and will be more comparable to groups of birds which occupy similar habitats. These groups will be used as a further measure of variability within the landscape, in order to provide a basis for modelling change. An important area of study will be to see whether the variability within the different habitats is parallel or divergent.

This analysis shows that the principal divisions in all these habitats are similar at a high environmental level, as upland types are identified at the first stage in each case. Such divisions are in parallel with those present within the broader spectrum of vegetation. In the hedgerows and streams the surrounding land use determines the vegetation classes. On the other hand roadside vegetation is dominated by management practice. Preliminary interpretation of these analyses shows that the various habitat elements in the landscape need to be treated separately. The results will be used to build up a picture of the patterns of variation within the landscape.

2.4 Pattern within squares

A variety of other measurements of pattern and networks will also be carried out to provide an integrated assessment of the degree of organization within the sample squares. This information may then be used as a baseline on which the observed changes from ITE data, HTS data and, subsequently NCC data can be superimposed. The ability of satellite imagery to assess pattern (Section 3) will be an important contribution to the later stages of the project.

2.5 Statistical considerations of measurements of change.

Standard errors have been calculated for the estimates of area of land under different features. The major land cover types have relatively small error terms eg barley 1 856 Kha ± 9.4 %, grass leys 3 718 Kha ± 7.7 %. Less extensive aerial measurements have wider limits, which can be reduced by increasing the sample size eg oilseed rape 183 Kha ± 23.6 % herb rich grassland 41 Kha ± 29.4 %. The type of distribution is very important, for example broadleaved woodland tends to be dispersed and in small blocks whereas conifer plantations are extensive and clumped. Thus the estimates for the former are 612 Kha ± 14.6 % and for the latter 1 510 Kha ± 21.1 %.

These terms include all sources of error from the inefficiencies of the land classification on a sampling frame, field observer error and computing error to the inherent spatial variability between sampling points. If more accurate estimates are required for a particular parameter, then the available data can be used to define the increase in sample number that is required to achieve the specified accuracy.

2.5.1 Partial replacement. The variability in the population requires assessment in order to determine the size of the further sample. Trial studies are being designed for different parameters of change in order to determine the size of the partial replacement sample.

2.5.2 There are plans to repeat the monitoring of landscape change surveys. A sampling procedure will be devised to incorporate the HTS and ITE samples to improve the efficiency of the new sample. Hybrid methods of ground survey, remote sensing and aerial photography will be involved.

2.5.3 The DOE are primarily concerned with national, regional, ad hoc or policy area patterns. Explicit statements of precision are required involving an assessment of what is achievable within the specified financial limits. A flexible method for aggregating/extracting data for policy as well as administrative areas is required with recommendations as to how local data sets can be incorporated into national figures. Whilst recommendations will be produced, these are likely to be based on logic using known statistical principles rather than using new techniques.

2.5.4 A specific problem concerns the situation where many of the observations were recorded as zeros. The statistical implications of such data sets are currently being examined.

2.5.5 The covariance between sampling dates had a bearing on the errors attached to the of estimates of change which had not been incorporated so far. An appropriate analytical technique was, therefore, required and will be developed.

2.6 Database preparation

The comprehensive database resulting from the ITE surveys in 1978 and 1984 consists of data sets on environmental characteristics, land cover, species composition of vegetation quadrats and species composition of linear features. At the outset of the Project, the various data sets were in very different stages of preparation and one of the main initial requirements has been to process relevant data for which previously inadequate documentation had been available.

A separate summary has been supplied to DOE of the data sets and their current state of preparation, including those already completed.

Many of these data sets are to be lodged with Rural Area Database (RAD). Some data sets have already been transferred satisfactorily. Further re-structuring of data will be carried out at RAD to increase compatability with other data sets.

Most of the involvement of Merlewood staff has been in checking and editing existing data sets. These activities will be completed in May as the first stage of the present project.

Table 1. Principal characteristics of the 32 land classes

1.	Undulating country, varied agriculture, mainly grassland.
2.	Open, gentle slopes, often lowland, varied agriculture.
* 3.	Flat arable land, mainly cereals, little native vegetation.
4.	Flat, intensive agriculture, otherwise mainly built-up.
5.	Lowland, somewhat enclosed land, varied agriculture and vegetation.
* 6.	Gently rolling enclosed country, mainly fertile pastures.
7.	Coastal with variable morphology and vegetation.
8.	Coastal, often estuarine, mainly pasture, otherwise built-up.
9.	Fairly flat, open intensive agriculture, often built-up.
*10.	Flat plains with intensive agriculture, often arable/grass mixtures.
*11.	Rich alluvial plains, mainly open with arable or pasture.
12.	Very fertile coastal plains with very productive crops.
13.	Somewhat variable land forms, mainly flat, heterogenous land use.
14.	Level coastal plains with arable, otherwise often urbanised.
15.	Valley bottoms with mixed agriculture, predominantly pastural.
16.	Undulating lowlands, variable agriculture and native vegetation.
*17.	Rounded intermediate slopes, mainly improvable permanent pasture.
18.	Rounded hils, some steep slopes, varied moorlands.
19.	Smooth hils, mainly heather moors, often afforested.
*20.	Midvalley slopes, wide range of vegetation types.
21.	Upper valley slopes, mainly covered with bogs.
22.	Margins of high mountains, moorlands, often afforested.
23.	High mountain summits, with well drained moorlands.
24.	Upper, steep, mountain slopes, usually bog covered.
25.	Lowlands with variable land use, mainly arable.
*26.	Fertile lowlands with intensive agriculture.
27.	Fertile lowland margins with mixed agriculture.
28.	Varied lowland margins with heterogeneous land use.
29.	Sheltered coasts with varied land use, often crofting.
30.	Open coasts with loww hills dominated by bogs.
31.	Cold exposed coasts with variable land use and crofting.
*32.	Bleak undulating surfaces mainly covered with bogs.

* = classes in which land use change has been or is likely to be most rapid. These classes will form the core for the initial remote sensing studies.

Table 2. Assessment of diversity of vegetation within the land classes. The table shows the number of vegetation types in each class. A total of 75 vegetation types were derived from TWINSPAN analysis of 5 random 200 m2 quadrats in each of 8 km2 from the 32 classes. The classes are ordered on an lowland to upland gradient

LAND CLASS	CR	OT	PG	UG	M	B	TOTAL
* 3	10	-	4	-	-	-	14
12	12	-	-	-	-	-	12
* 11	10	-	4	-	-	-	14
25	12	3	3	-	-	-	18
2	14	2	6	2	-	-	24
4	9	4	2	-	-	-	15
9	11	2	4	1	-	-	18
14	12	4	3	-	-	-	19
* 26	9	5	4	3	-	1	21
* 10	6	5	4	2	1	1	19
1	14	-	5	-	1	-	20
15	10	-	7	1	-	-	23
* 6	15	4	4	1	-	-	25
27	10	5	3	2	-	-	20
5	12	-	7	4	-	-	23
16	12	5	3	2	1	2	25
13	12	5	5	1	1	1	25
8	13	4	5	1	-	-	23
7	12	-	5	3	1	1	22
* 17	6	-	6	5	1	-	18
18	7	-	4	5	1	2	19
* 20	8	-	3	6	2	-	19
19	6	2	2	7	3	1	22
31	6	-	4	5	2	5	22
22	2	4	2	6	4	3	21
* 32	4	1	-	3	2	5	15
29	3	1	2	4	1	6	17
21	1	-	1	5	4	5	16
24	-	1	-	3	3	7	14
23	-	3	-	3	6	4	13
30	-	1	-	3	3	5	12
18	3	2	2	6	3	3	19

CR = Crop types (including leys)

OT = Other types

PG = Permanent grass types

UG = Upland grassland types

M = Moorland types

B = Bog types

* = classes in which land use change has been or is likely to be most rapid. These classes will form the core for the initial remote sensing studies.

Table 3 Table showing examples of current land use estimates

	Area studied	Land use estimated	At what date	Area range (m ha)	Main estimate (m ha)
Wye College	United Kingdom	Area available for other uses	2000 with sensitivity tests	1-6	3-4
Laurence Gould	England, Scotland & Wales.	Surplus to needs	1990 & 2000		1.1
Reading	England & Wales	Low gross margin area equivalent of the reduction in intensity required.	5 years of various scenarios	0.2-2.2	1.3 (price) 1.9 (quota)
North	Britain	Farmland requirement and surplus	2015	5.40-5.72	5.5
Agri-culture EDC	UK	Land displaced from tillage.	Mid 1990s	0-1	0.7

Source : Bell, M. 1987. The future use of agricultural land in the United Kingdom. presented to The Agricultural Economics Society Conference.

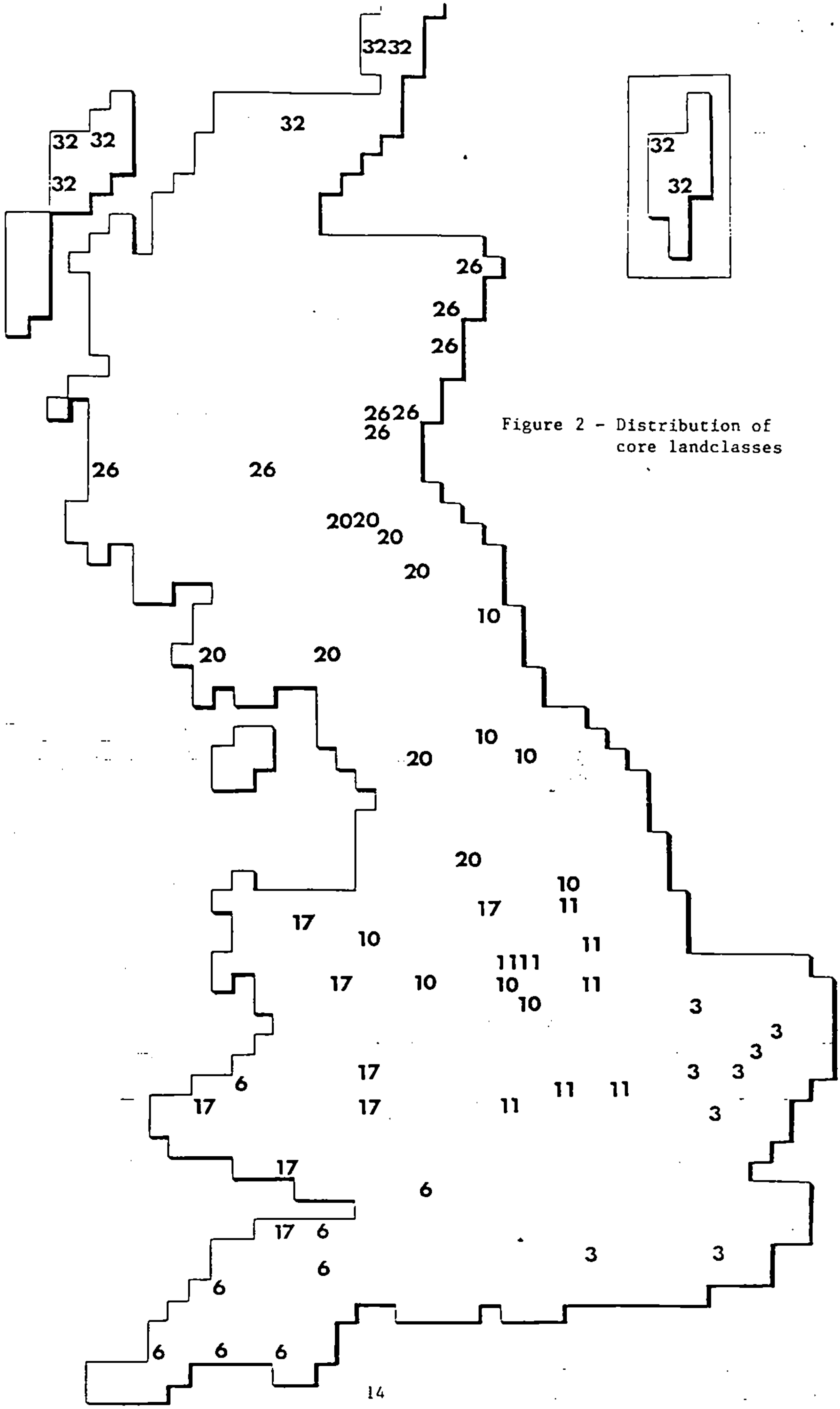

Figure 2 - Distribution of core landclasses

3. REMOTE SENSING

D.F. Evans and B.K. Wyatt

The basic requirement in remote sensing is to improve methods by which land cover features can be characterized and, through repeated observation, detect changes in features. Earlier studies by HTS and others have identified some of the problems and potential. The present work is designed to apply current knowledge to the specific features which are of ecological interest over a range of conditions. The aim is not only to detect change in a particular feature, both qualitative and quantative eg the length and state of a hedgerow. It is also to detect change in the pattern of land cover ie the spatial relationship between features, because these relationships have an important influence on vegetation and wildlife.

3.1 Work sharing with NRSC

Current work of relevance to the present questions is being done by NRSC under contract with DOE. We have agreed with NRSC that, because our contracts overlap, we should avoid duplication of effort by splitting the work regionally. Of the 8 land classes selected for special study, we shall each deal with 4, assigned on the basis partly of accessibility from our respective research stations, and partly on the distribution of study areas used in other research. ITE will be dealing with class 6 (S Wales and Devon), class 17 (mainly N Wales), and classes 26 & 32 (Scotland). For compatibility, we shall need to agree on certain points:

i. which imagery to use. TM will be used initially for the reasons given in the next section, but SPOT imagery will become increasingly useful as its coverage builds-up.

ii. Preferred months for image acquisition (July/August?).

iii. Which land-cover features to consider.

iv. What preliminary processing will be needed. Geometric correction to match the National Grid is essential, and for detection of change some form of radiometric calibration is desirable.

v. What processing methods should be used. These will be agreed and applied consistently to all images.

vi. How will results from the two separate contracts be brought together at the reporting stage.

3.2 Choice of imagery

Ideally, the imagery should have a spatial resolution sufficient to distinguish features at the scale of the ground mapping - resolving, for example, small fields, roads, buildings and large trees. SPOT imagery will be used in the later stages of the project, but its coverage is still very incomplete (see section 5), and the relatively small scenes (65 x 65 km as compared to 170 x 170 km for TM). TM coverage, by comparison, is much more complete and, because it has been operational for longer, there is more scope for comparing multi-date images.

From May 1987, the NRSC full-scene charges are £1800 for TM, and £1050 for SPOT. In terms of aerial coverage therefore, the SPOT:TM cost ratio is about 4:1. TM also has better spectral coverage (7 bands instead of 3), and is available as quarter scenes.

Also favouring TM is the fact that many early scenes (between April and October 1984) were bought by Huntings for their 'Monitoring landscape change' contract, and will be available to us.

As the number of cloud-free scenes builds up, SPOT imagery will become a more viable alternative to TM. It could be particularly valuable for the detecting detailed changes such as hedge removal, or the loss of large trees. For this sort of application, the spatial resolution of the image is a more important attribute than its spectral resolution, and, because Panchromatic and Multispectral images are similarly priced, Panchromatic cover (with 10 m resolution) would be preferred. Winter images, with low sun-angles, would be especially useful because of the longer shadows.

ATM imagery is also possible, but, although it can give much higher resolution than either SPOT or TM, it has a serious drawback in that it is subject to scale variation due to changes in aircraft attitude, and produces images that are almost impossible to register precisely. It would, therefore, be difficult to make machine comparisons of 2 ATM images of the same area.

Our preference in terms of acquisition dates would be for 1984 - the year of the most recent ITE ground survey. Strictly speaking, we can only characterize ground features from the imagery when we are certain of their identity on the ground. Use of imagery from other years could produce mis-identification as, for example, when crops change as part of a normal rotation.

Although the cover provided by 1984 TM imagery is incomplete, and other dates will sometimes have to be used, the consequences may not be as serious as one might expect, because (i) the areas for which cloud-free cover of the right date is lacking are mostly non-arable, and (ii) spectral differences between crop species will often be clear enough to avoid any risk of confusion.

3.3 Detecting change - a general approach

It is likely that some changes may be uncommon and difficult to detect in the timescale of the project. Others such as the change from cereals to grass or vice versa should be sufficiently common to enable useful comparisions to be made. Although there are squares with TM coverage for more than one year, some are represented by only one acceptably cloud-free scene (in Scotland especially). The potential for testing methods of detecting change by applying them to actual changes is therefore fairly limited at present.

Resources will be available for some additional ground survey in 1987, and could be used in part to check on features where there are apparent discrepancies between the TM imagery and 1984 ground data. The latter are available as digital maps, and machine comparisons with post-1984 images will be possible, if maps and images can be accurately registered.

The detection of such discrepancies will depend on changes being generally uncommon enough for us to be able to characterize classes of ground cover, even when some examples are being mis-identified. In practice, it should be possible to avoid many such cases by rejecting areas that look abnormal, either on a colour composite or principal components image.

If possible, we would like to have all 48 study squares re-surveyed this year, so that when (and if) new images are acquired we shall have the means of checking post-1984 changes in the imagery against known changes on the ground. Even when there is no 1984 TM coverage, new imagery (TM or SPOT) accompanied by survey data will provide a baseline for the detection of future land-use changes.

An important requirement for detection of changes in crop plantings is that the images from different years should relate to about the same part of the growing season. Only then will it be possible to recognize genuine changes in land use against a background of seasonal effects. Natural vegetation will also be subject to seasonal changes, and will be affected by the weather.

The range of spectrally distinct types will be much smaller than the cover types recorded in the field - many crop species (different cereals, for example) will be difficult to distinguish reliably, even when the dates match. In practice, we would expect to make only minor extensions to the 12 category scheme adopted by HTS:

1 Broadleaved high forest
2 Coniferous high forest
3 Heather moorland/heathland
4 Grass moorland
5 Bracken
6 Cultivated land
7 Improved pasture
8 Open water
9 Bare rock
10 Sand/shingle
11 Developed land
12 Despoiled land and quarries

Although these will be the categories used for comparison with HTS, the field data for the ground truth will be recorded in a disaggregated format. A variety of simpler classifications can therefore be derived for different purposes eg the CC National Park categories.

With the 30 m resolution of TM imagery (corresponding to 1100 pixels in a 1 km square), it will be possible to recognize the various land cover types only for relatively large mapping units (large fields, woodland, open water or expanses of fairly uniform natural vegetation).

3.4 Processing - detailed proposals

Image processing and analysis will be done on the International Imaging Systems (I2S) equipment in Bangor. As a preliminary, the full TM scenes (containing the study squares) will be geometrically matched to the National Grid, using a standard I2S 'warping' function.

3.5 The 2 mainprocessing routes

3.5.1 Direct comparisons

i. If images are seasonally compatible, and the changes are not too widespread, it will be possible to match their overall radiometric characteristics, and then highlight points of difference, either by subtracting one image from the other or by ratioing. The nature of the changes would then need to be determined either by reference to the classified images (option 4.2), or by site visits.

ii. Changes in linear features (field boundaries and roads) will be difficult, if not impossible, to detect with 30m resolution, although edge enhancement techniques may help. Very narrow boundaries, such as wire fences, will show up only when there is contrasting land use across the boundary.

   Automatic detection of changes in linear features would only be possible if the images were perfectly registered. As such precision is virtually unattainable, we shall generally have to rely on visual interpretation. It may be possible, however, to automate the measurement of areas (fields, urban development, etc), and lengths (boundaries, roads, etc).

iii. Detection of tree losses will probably be possible only using SPOT Panchromatic imagery. Winter scenes, with low sun-angles, would be particularly valuable.

3.5.2 Comparisons based on classification

Standard image processing techniques will be used to define the various cover classes statistically, to determine the separability of the classes, and to classify scenes with appropriate confidence limits.

3.6 Principal stages

3.6.1 Transfer of land-cover maps, first as vector images on to the SYSCAN Geographic Information System in Bangor, and then, after raster conversion, on to the I2S.

3.6.2 Defining the various cover types by extracting radiance statistics from a number of 'training areas' selected to cover the variability inherent in each. The areas available within each class will be displayed by overlaying masks derived from the rasterized maps.

3.6.3 Using a divergence measure to determine the statistical separability of the classes defined in 3.6.2. Where necessary, classes may be merged.

3.6.4 Applying the statistics in a 'maximum likelihood' classification of all the sample areas.

3.6.5 Detecting changes between multi-date images by looking for differences between class maps (as and when suitable multi-date imagery is available).

3.7 Work to date

3.7.1. A search of the SPOT computer browse catalogue at Toulouse showed that UK coverage is available for most of southern Britain, but lacking for most of Scotland. As 2 of the 4 land classes under ITE's purview are almost entirely Scottish (26 & 32), SPOT imagery is not appropriate for the initial stages of the project.

3.7.2 A similar search of the TM archives at NRSC (Farnborough) and at NERC (Swindon) acheived more encouraging results. There are TM scenes to give at least partial cover of all 4 land classes, although some are less than ideal. Acquisition dates are variable from one scene to another, and many are from outside the preferred (July - August) window. Although images are only bought into the archive if they are reasonably cloud-free, there is still localised cloud-cover on many scenes. The TM scenes selected for the first year of the project are:

PATH	ROW	QUADRANTS	DATE	AREA
203	24	1,2,3 & 4	26/04/84	GLOUCS
203	25	1 & 3	26/04/84	DEVON
203	25	1	02/07/85	DEVON
204	20	1 & 3	13/10/85	ABERDEEN
204	21	1 & 3	14/09/86	EDINBURGH
204	25	1 & 2	11/09/85	CORNWALL
206	18	2 & 4	24/06/86	SHETLAND
206	21	2	04/07/84	ARRAN
206	21	2	17/03/85	ARRAN
207	19	4	09/06/84	CAPE WRATH
207	21	4	18/08/86	ISLAY
208	19	4	22/06/86	LEWIS
204	23	1,3 & 4	22/07/84	N WALES
204	23	1,2 & 3	13/10/85	N WALES
204	24	1,2,3 & 4	22/07/84	POWYS

The squares in the land classes allocated to ITE (including those surveyed for the first time in 1984) are covered as follows:

Class 6	9 squares
Class 17	10 squares
Class 26	12 squares
Class 32	9 squares

A search will be carried out of these squares to assess the coverage of various topics. Those with inadequate coverage for training areas will be identified and further squares located nearby for ground truth records. In addition the HTS sample strips with the highest degree of change (cf subcontract with HTS in Section 5) will also be included.

3.8 NRSC liason

ITE have sent to NRSC the grid references of the 4 land classes. NRSC have identified and geometrically corrected appropriate images for land class 3 and located the 1 Km2 sample squares. ITE then forwarded data on land cover for 1984. NRSC is currently digitizing the parcels of land for the appropriate categories as a basis for comparison with the imagery. Slightly different procedures will be followed compared with ITE Bangor enabling comparisons to be drawn but the categories and sites covered will be complimentary.

4. EXPERT SYSTEMS

P.J. Bacon, P. Hammond, M.O. Hill and D.K. Lindley

4.1 Introduction

The original concept was to use the modern development of expert systems to convey readily assimilatable ecological information to advisors and land managers, as experience on other projects had shown that availability of such knowledge was a critical factor. The initial approach has been time consuming in that it has proved that the necessary logical framework takes time but when achieved it appears as an obvious solution. The initial stages have inevitably not had a major ecological input but the next stages of the project will be incorporating appropriate ecological information. Whilst the initial delevelopments have not specifically involved land use change as such the next stages planned over the coming year will enable the analytical studies of the core project to be translated into the expert system package.

A formal definition of an expert system produced by the British Computer Society's specialist group on the subject reads as follows.

"As expert system is regarded as the embodiment within a computer of a knowledge-based component, from an expert skill, in such a form that the system can offer intelligent advice or take an intelligent decision about a processing function. A desirable additional characteristic, which many would consider fundamental is the capacity of the system, on demand, to justify its own line of reasoning in a manner directly intelligible to the enquirer. The style adopted to attain these characteristics is rule-based programming."

Forsyth (1984) suggests that a list of distinctive features may also be a useful supplement to the formal definition:

i. An expert system is limited to a specific domain of expertise.
ii. It can reason with uncertain data.
iii. It can explain its train of reasoning in a comprehensible way.
iv. Facts and inference mechanism are clearly separated.
v. It is designed to grow incrementally.
vi. It is typically rule-based.
vii. It delivers advice as its output.

4.1.1 Components of an expert system

Forsyth (1984) also describes the 4 essential components of a fully fledged expert system:

i. The knowledge base.
ii. The inference engine.
iii. The knowledge - acquisition module.
iv. The explanatory interface.

A knowledge base contains facts (or assertions) and rules. Facts are short-term information that can change rapidly. Rules are the longer-term information about how to generate new facts or hypotheses from what is presently known.

Ecological knowledge is a scarce, expensive and widely scattered resource. Much of the information is fragmented and is stored in many journals and databases; also, much of the knowledge is stored in the heads of human experts. Knowledge acquisition has to take place through a painstaking study of the literature and by one-to-one consultations with experts. The results of the consultations produce a codified version of what the expert knows. The fourth main component of a true expert system is an explanatory interface with the user. Much care should be exercised over this interface. As Forsyth (1984) points out, a reasoning method that cannot be explained to a person is unsatisfactory, even if it performs better than a human expert.

An increasing number of applications of expert systems are now appearing in the scientific literature. Davies and Nanninga (1985) suggest that they are routinely employed in medicine, organic chemistry, mineral exploration and computer configuring. However, only one paper is quoted as discussing the possibilities of expert systems for land management (Starfield & Blelock 1983).

Davies and Nanninga (1985) point out that, to realize their potential for land planning and management, existing expert system designs will require modifications, perhaps most importantly in the ability to treat spatially varying problems. At the core of this requirement is the need to subdivide the management area into spatial units, within each of which the information can be assumed to be spatially homogeneous.

4.2. Design and software

The Imperial College Logic Programming Group is acting as consultant on software and design, their contribution has concentrated on the following:

i. helping to identify suitable application areas;

ii. meeting potential users and discussing problems with which they would like help, matching the problems with the available ecological expertise and feasible software tools;

iii. designing example systems that are seen to be essential components of any knowledge-based systems that might be built within the timescale of the project;

iv. implementing software tools in PROLOG, using existing APES modules wherever possible to demonstrate what is feasible and hopefully to attract the interest and participation of potential collaborators and users.

The selection of the most appropriate application areas is crucial to the success of the expert and knowledge-based systems contribution. Application areas which are of interest to ITE have formed an initial list of possibilities to which potential collaborators and users have been asked to respond, as well as suggesting topics of their own. In order to sustain interest in the construction of a knowledge based system, any application area chosen must have something interesting or useful (preferably both) to offer to all parties involved - the users, the domain experts/ITE and the computer scientists.

Any application domains that arise because they involve the evaluation of planning applications should be acceptable both in terms of reasonably frequent occurrence (so as to generate a good source of examples for identifying relevant ecological expertise and for testing), and in their usefulness to the user.

4.3 User requirement discussions

A range of different users have been consulted in order to ensure that the trial systems are as widely relevant as possible. The user requirements and current facilities are summarized below.

4.3.1 M. Taylor
Conservation Branch, CC, Cheltenham

The CC need to assess the likely impact of small changes which if allowed to proliferate may produce an undesirable effect. A system that could assess the impact of such changes on the public's use of any changed area including their appreciation of the changed view/landscape would be of considerable value in controlling development.

4.3.2 P. Taylor
Conservation Officer, LDNPA

At present information on areas where constraints operate is held on maps, and mechanical checks on whether these affect a particular application are done on the basis of National Grid co-ordinates of the site for proposed change held on their own computerized system.

4.3.3 W. Murray
Computer Manager, LDNPA

The LDSPB has a computerized planning application package, and associated database. However the system currently has no 'intelligence'; it is up to the user to envisage which constraints may apply, and to ask the system to make the appropriate searches.

The system consists of a series of files, which hold locations of planning constraints (such as previous planning applications). When processing new applications or enquiries the user can automatically get a list of the previous applications and/or constraints that apply within a specified rectangle around the present co-ordinate(s). The system also allows LDSPB managers to request summaries of grants and planning.

4.3.4 I. Bonner
NCC North-West Regional Office

The NCC has a standard approach when considering planning applications. A manual system of cross-referenced files and maps are used to classify the habitats on a site and an impact matrix of the potential damaging operations is calculated. While computerizing the system per se would not be of great benefit, it would find it useful to have access to other larger and related databases. However, NCC considered that a computerized system would be useful as an information source.

4.3.5 D. Challen
Cheshire County Council

Cheshire County Council has a computerized system based on digitized outlines from maps. Although some of the data are of uneven quality and incomplete they have information on:

i. Urban areas.
ii. Grade 1 and 2 ALC.
iii. NNRs, SSSIs and NPs.
iv. Green belt.
v. An MSC habitat survey - 15 graduates for a field season covering c. 2500 km2.

The system can be used to identify and measure areas with combinations of characters. Also individual sites can be identified and zones of influence projected from them. The main objective was to use the database to limit damage due by development to the ecology of the county, but it is also used as a baseline on which to advise on policy.

4.3.6 Summary

The discussions produced the following points.

1. There is a range of different databases already in use by the organizations.

ii. Many of the questions asked are site specific and require some ecological inferences.

iii. Other policy oriented questions are more widely applicable and require the assessment of the ecological consequences over a range of land types eg the potential affects of afforestation.

iv. Most organizations have computer systems on which expert systems could be operated.

v. Even when data are already stored on computers, questions still require the human consideration and interpretation before advice can be obtained. This an ideal application for expert systems.

vi. Economic assessment is important in many cases - this is outside the present remit.

4.4 Knowledge base

Databases within ITE and elsewhere are being identified and their potential application assessed. The national survey data are central to the study but other comprehensive databases eg Biological Records Centre and BTO will be important as well as data related to specific habitats. Expert knowledge of ecologists has not been used at this stage but will be once more specific requirements are known.

4.5 Trial systems

A number of simple trial systems have been developed to demonstrate and test different aspects of expert systems and generate skills in PROLOG rule based programming. Although the systems developed so far are only "toy" systems they involve the tools and techniques required to write marketable systems. The software has been developed and has been tested on three makes of micro-computer (IBM PC, Apple Mackintosh and Amstrad PC). The portability of the systems (ie the ability to operate on different makes of machine) is especially important if users wish to use computers they already own. The systems constructed so far are;

i. Animal — an example of the use of rule based programming to identify an animal.

ii. Meadows — provides information on cultivation techniques and seed gathering. Demonstrates screen handling and the storage of text.

iii. Verges — advises on the optimal time to cut and treat verges. Demonstrates the inclusion of mathematical models and graphical output.

Discussions with potential users has produced a short list of topics, the most promising is a system for FWAG. The system would involve accepting information from maps through a digitizing block and producing advisory reports possibly containing maps and overlays. It is also capable of being extended to incorporate information from the core project in due course.

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5. LINK PROJECT
R.G.H. Bunce

Up to the current time, the programme of the Link Project has concentrated on informal small workshops and visits to various groups, in order to establish contacts and set up the work programme. A summary of the workshops and visits is given below, followed by summaries of the subcontracts let to date. These provide a useful overview of the direction followed. Once results come through from the project, wider workshops are planned, and the list is likely to be available in autumn 1987. The broad outline has been to establish details of the various other research programmes, eg the Wye Set-a-side project and to devise ways of integrating these with the present study. The main problem has been the different scales and degree of detail involved, but in all cases so far, as shown below, a satisfactory method of incorporation has been found.

5.1 Summary of Informal Workshops

5.1.1 NRSC/ITE-(Held at Farnborough)

Joint programme of work has been agreed, timetable drawn up, and future co-oporation planned on the duration of the project to share experience and expertise.

5.1.2 CAS/ITE (Held at Reading)

Discussion of future co-oporation has taken place bearing in mind joint participation in the proposed project on countryside implications of possible changes in the CAP. Topics have been identified that are particularly relevant to the present project and incorporated in a subcontract.

5.1.3 Imperial College/ITE

A number of joint workshops have been held within and outside ITE and with other institutions related to expert systems. A subcontract has been let to Imperial College.

5.1.4 Bangor University/ITE (Held at Merlewood)

There have been discussions about a joint programme on the identification of agro-forestry as an alternative land use, comparable to the CAS study of recreation/attentive crops.

5.1.5 Wye College/ITE

A joint workshop was held at Wye and future co-operation discussed. As a result of this meeting, the subcontract for the detailed soils mapping of the squares was set up in order to provide the requisite information by the autumn to Wye for their analysis of Set-a-side.

5.1.6 HTS/ITE (Held At Borehamwood)

An initial meeting was attended at Borehamwood followed by a further intensive workshop to determine a co-operative programme. The subcontract summarised below was the product of these meetings.

5.1.7 BTO/ITE (Held at Tring)

An initial visit was made to Tring at which a joint programme of work was set out, defined by the subcontract. A further workshop will be held shortly.

5.1.8 Soil Survey of England and Wales/ ITE (Held at Rothamsted)

An initial visit was made to Rothamsted to define the work programme for the subcontract. Further contact will be necessary, as will development of the contacts with the Scottish Soil Survey.

5.1.9 N.C.C./ITE (Held at Harsham Street)

An initial meeting was held to inform NCC of progress and to discuss co-operation. Subsequent meetings have led to a decision as to future joint work on the National Countryside Mapping Scheme.

5.1.10 Internal ITE and Nottingham University (Held at Merlewood)

A statistics workshop was held at Merlewood to discuss various aspects of the statistical problems associated with regional and natural estimates of land use change.

5.2 Summaries of subcontracts

5.2.1 Specification of sub-contract with the Centre for Agricultural Strategy

Objectives

i. An assessment of both existing and potential recreation and tourist activity on the 256 ITE sample 1 km2 squares. The assessment will include an examination of the ecological consequences of such activities.

ii. An assessment of the potential for the most likely and significant new/alternative crops on the 256 ITE sample 1 km2 squares (forestry is not included). The assessment will include an examination of the ecological consequences of such crops, brief details of their economic and job-creating potential, and an indication of the likely areas they will take up in both the short-, medium- and long-term horizons.

iii. A categorization of some social and economic characteristics of farmers and their farm businesses on the 256 ITE sample 1 km2 squares. This work will draw on data collected by CAS using the ITE system as a sampling frame, supplemented, where necessary, from other CAS databases.

5.2.2 Specification of subcontract with the Soil Survey of England and Wales validation and appraisal of soil and agroclimatic information for ITE 1 km sample squares

Objective

The main aim is to classify the dominant soil type of the sample squares, preferably to Soil Series level, where necessary in Soil Association terms. This classification will facilitate use of the SSLRC Land Information System (LandIS) to assess land use potential for grass, crops or forestry; to examine environmental hazards and possibilities; and to evaluate land use trends. The study will also allow the ITE samples and the national soil maps (England, Wales and Scotland) to be compared in a systematic manner.

5.2.3 Specification of subcontract with the British Trust for Ornithology

Objective

The main objective of the subcontract will be to provide estimates of breeding bird densities of species selected as representative of the range likely to be affected most by land use change. This work is seen as an identification of appropriate methodologies for future studies, both under the present contract and for other potential projects.

5.2.4 Specification of subcontract with the Department of Geography, University of Edinburgh

Objective

To provide in machine-readable form information for a variety of topics, specified below, for the 5800 squares which ITE have assigned to land classes in Great Britain.

5.2.5 Specification for a subcontract with Huntings Technical Surveys for the application of the results of the MLC Project into the ITE Project 1130

Objective

To increase the size of the database on landscape and land use change by incorporating the MLC data into a land class basis. The MLC covered 707 sample strips for areal features. In their subcontract to HTS, ITE classified 3 squares in each of the 700 strips, ie 1680 squares. The first phase of the work programme described below is to interrogate the MLC data base as a means of identifying further areas of high change for survey of ground truth for the remote sensing programme. The second phase involves more detailed interpretation in order to increase the accuracy of the prediction of change.

5.2.6 Subcontract with Nigel Greenwood for Statistical Advice

Objective

To provide advice on statistical aspects of the HTS study of landscape change.

Further analysis is required of the data held by HTS (or the data archive) to enable it to be used in the general analysis of landscape change in England and Wales, including the identification of a procedure to allow for land classes which overlap Scotland. Advice is also required as to which data should be incorporated and the method of extraction from the digital information (land use) or the overlays (linear features).

5.2.7 Specification for a subcontract with Imperial College for advice on Expert Systems

Objective

To develop 2 small prototype expert systems using APES (Augmental PROLOG for Expert Systems) and LPA PROLOG to run on an IBM PC or suitable clone.

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TIMETABLE AND SUMMARY OF ACTIVITIES

The numbering refers to the order of the activities from the left of the attached network, the activities are given in the order of their commencement.

C = Core R = Remote Sensing E = Expert Systems

1 C/R/E **Project Planning**

Initial discussions with DoE and preparation of the contract document.

2 C/R/E **Project Planning/Liaison**

Development and preparation of the work programme, involving preparation of Project Plan, network diagram and coordination with ITE management.

3 C **Set-up Core Team**

Discussions within the staff involved in the analysis of the core data from the 1978/84 survey and indentification of priorities and methods of computer analysis.

4 E **Set-up ES Group**

Discussions with staff of ITE and Imperial College to identify appropriate officers for the project.

5 R **Set-up RS Group**

Discussions with staff of ITE and NRSC to identify appropriate officers for the project.

6 C **Analysis of Vegetation Data**

The completion of the correction of data from vegetation plots and linear (stream, hedges and roadside) plots.

7 C **Updating Data**

The process of updating the pracels of land from 1978 and 1984.

8 C **Measurement of Change 1978/84**

Processing of the limited list of categories for which change was assessed and its incorporation into the work programme.

9 C **Development of Ecological Theories**

The range of ecological theories proposed in the Project Plan will need to be further developed and formulated eg. the contribution of streamside species to diversity.

10 R **Summary of Extant Projects**

A listing of the major projects in remote sensing that are applicable to the assessment of ecological change.

11 E **Investigation of Programming Languages**

The identification of appropriate languages for the expert systems programme.

12 E **Contact with Experts**

A major part of this programme is to be in regular contact with appropriate experts in a variety of fields to ensure that adequate experience is included.

13 E **Development with Experts**

Continuing contact will be necessary to ensure that the programme continues to develop on course.

14 C **Coordination witg Other Studies of change**

The expert systems development will need to be tied into both land use and ecological topics that are most likely to change.

15 **Acquisition of Hardware and Software**

Purchase of appropriate microcomputers for the expert systems programme.

16 E **Identification of Test Topics**

Consultation with planners to identify topics that are appropriate to the project, important in a wide range of application and useful to demonstrate applications.

17 C/R **Selection of Core Areas**

The use of the ITE change data for 1978/84 to identify 8 land classes with the highest number of changes in areal and linear features, as a basis for selecting sites for image analysis.

18R **Determination of Land Cover Categories**

The identification of the target types which will be used by both the Bangor and Farnborough teams.

19 C **Set-up Subcontracts**

Identification of key areas of work for subcontracts, negotiation of contracts and initiation of work programme.

20 C **Initial Subcontract Analysis**

The first stage of inclusion of the initial results of the subcontracts into the core programme.

21 C **Updating Data**

The continuing process of converting the complete data set in 1984 levels.

22 C **Updating Data**

The continuing process of converting the complete data base to 1984 levels.

23 C **Measurement of Change 1978/84**

Completion of the change estimates for all topics covered.

24 E/R/C **Reporting**

The production of an initial brief report stating the progress reached in the project.

25 E **Development of Software**

The continued development of appropriate programmes.

26 E **Development of Sample Systems**

The first stage is to develop several straightforward procedures for users.

27 R **Links with Other Change Studies**

These need to be built into the remote sensing project and linked to the selection of systems for change studies.

28 R **Acquisition of Imagery**

Purchase of appropriate TM and SPOT scenes

29 C **Incorporation of Designated Sites**

Incorporation of site information for NNR's, SSSI's, LFA's, RDA's and National Parks as a basis for including them as constraints in the predictive model.

30 C **Coordination with the Reading Model**

The results from the initial runs of the Reading model will be used to identify areas where change is most likely.

31 C Development of Pattern Analysis Concepts

The extensive literature will be searched and appropriate experts consulted in order to develop appropriate analytical methods.

32 E/C Development of Trial Faunal and Vegetation Systems

The identification of limited topics eg. sparrowhawks and hedgerows, for which trial systems can be developed.

33 C Analysis of the Major Sites of Change from the MLC

identification of a limited number of sites to be coverd by, satellite imagery to ensure maximal cover of change.

34 E/C Development of Trial Faunal and Vegetation System

The initial trials will give guidelines as to the most promising systems for further development.

35 E Development of Rule Procedures

The procedures for extracting rules from expert ecologists will need to be developed progressively through the project.

36 C Final Subcontract Analysis

The incorporation of the final results of the subcontracts into the model for predictive purposes.

37 R Supplementary Field Survey

The inclusion of additional squares with field data to increase the number of test sites for training areas on the images.

38 R Image Analysis

The enhancement of images using 12S and other systems.

39 R Correlation with Ground Truth

An assessment of the confusion matrices between the satellite image classification and the ground truth data.

40 C Coordination with Other Data or Change

The inclusion of data from other studies e.g. NCC and the Set-a-side project, for areas of change or likely change.

41 C Testing Ecological Theories

The various theories and hypotheses set up will need to be tested both against extant and new data, to assess their relevance.

42 C **Synthesis of Reading Results with ITE Model**

The updated version of the Reading model will be used to identify the rural changes that are likely, in order to improve the predictive capacity of the model.

43 C **Analysis of Pattern and Connectivity**

Development of appropriate statistical techniques for the analysis of the changes due to loss of hedgerows, woodlands and trees in the landscape, through an assessment of the altering patterns.

44 C **Coordination with Pattern Analysis**

The outputs from the analysis will need to be coordinated with the remainder of the programme and adjusted to the correct form.

45 C **Forestry Model**

The outputs from the forestry model will need to be incorporated into the upland land classes to define potential impacts.

46 C **Final Incorporation of the MLC Data**

Incorporation into the predictive model of a representative sample of MLC sites to increase the ability to identify change.]

47 E **Acquisition of Hardware and Software**

Purchase of appropriate equipment for the second phase of the Expert Systems programme.

48 C **Links with Other Data Sites**

Combining the forestry model outputs with other relevant information from 1 km2 on the 6000 grid.

49 C **Correlation**

Correlation analysis of relevant data sets.

50 E/R/C **Reporting**

The production of a report presenting a range of results from the first complete year's work.

51 R **Further Field Survey**

Additional detailed ecological information will be needed.

52 C **Inclusion of Scocio-Economic Factors and Designated Sites**

Data from the surveys of M Bell and R B Tranter together with the information for designated sites will be incorporated as constraints in the model.

53 C **Integration and Synthesis**

The wide range of topics covered in the early stages will need to ge incorporated into an overall model including the full range of parameters and studies involved.

54 C **Testing and Further Development of Ecological Hypotheses**

The initial studies will identify areas where further study is most likely to be rewarded and these will be followed up.

55 C/E **Cooperation with Expert Systems Group**

Continual feedback will be necessary to ensure that the ecological information is fed into the Expert System and that the results are comprehensible.

56 R **Supplementary Field Survey**

Further field survey will be required in 1988 in order to assess changes since the previous year for connection with new images.

57 R **Image Analysis**

The analysis of satellite imagery by I2S or other system.

58 E **Development of Software**

Continued development of appropriate programmes.

59 R **Measurement of Pattern**

The use of the mosaics in the satellite scence pixels in order to determine texture and pattern in landscape.

60 R **Measurement of Change**

The ability of the satellite imagery to assess change will constitute this activity.

61 C **Updating Existing Predictive Models**

A manual will need to be prepared to explain the use of the Expert systems developed to future users, this must be readily useable and understood.

63 C Integration and Synthesis

The progressive coordination of the various data streams will lead to a fully comprehensive model being developed.

64 E/C Development of Final Demonstration Systems

The production of a demonstration system incorporating the full range of topics covered over the range of the project.

65 E/R/C Reporting

The presentation of a report presenting a summary of the results from the second year's work.

66 R Extension Outside Core Areas

The strategy adopted will enable the potential of the extension of the test areas for ground truth to be assessed.

67 R Development and Recommendations for Sampling Strategies

The experience gained in the programmme of work will enable recommendations to be made for the ability of Remote Sensing to detect change either using an internally structure sampling frame or combined with external data.

68 E/R/C Reporting

The presentation of a series of reports and an executive summary reporting the complete project.