NOTES FOR ADVISORY GROUP

THE ECOLOGICAL CONSEQUENCES OF LAND USE CHANGE

ADVISORY GROUP MEETING

MONDAY 16TH NOVEMBER 1987

DEPARTMENT OF THE ENVIRONMENT, MARSHAM STREET
LONDON

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2.11.87

1 Overview

Since the last advisory group meeting there have been three major developments in the links between the divisions of the project that will ensure that the final product integrates the various elements.

1.1 Pattern analysis

The method of pattern analysis being developed for the land cover types is equally applicable to satellite images, the relationship between units within 1km^2 can be analyzed the same way as pixels. The analysis of pattern will provide information on connectivity which in turn relates to island biogeography theory. Correlation between the measurements of pattern in satellite images and ground cover data will enable the potential links between the two sections to be assessed.

1.2 Incorporation of autecological data

The analysis of connectivity and pattern requires detailed biological data on dispersion, establishment and life form of species since their behaviour will determine the degree of isolation involved. Such structures will involve searching existing sources of ecological data but will also suggest species where further ecological details are required.

1.3 Application of the land classification to expert systems

The development of an expert system based on the land classification will enable the topics involved in the project to be incorporated into a common framework. For example possible changes in bird populations due to land use change or management of grassland could be linked to different areas of the country. Advice will be able to be produced at a variety of levels from strategic to local.

2 Remote sensing

2.1.1 Ground survey - The Selection of 1Km

The specification in the contract is that studies should be concentrated on areas of change but that also there should be measures of comparison with relatively stable areas. The sampling scheme outlined below was described at the last advisory group meeting and was based on:-

(1) The squares with the highest number of changes recorded from the ITE surveys in 1978 and 1984.

(2) The squares with the highest degree of change identified by HTS in each of the major categories and in their study.

These individual squares do not, however, contain enough locations for certain areas for the correlation with the satellite imagery. Accordingly the following procedure was devised to extend the sample number:

Square X. A central 1Km square for one of the 8 land-classes thought (by ITE) to be most likely to undergo change.

Square E. One from the ring of 16 non-contiguous squares in the 5 x 5 Km area centred on X. This would be selected at random but with some over-riding rules concerning excessive water, excessive urban content etc. 'E' squares would not belong to any pre-determined land-class (in fact the land class will not be known). The 'E' squares will therefore act as control squares, to enable comparisons to be made.

On this basis there were 48 $10Km^2$, containing a total of 96

$1Km^2$ (6 'X' squares for each of the 8 land-classes, plus 48 'E' squares).

Ordnance Survey 1:10,000 maps cover 5Km x 5Km, and therefore are sufficiently large to provide a choice of 'E' squares (although not usually all possible candidates).

The sampling scheme was then extended to an additional 25 10Km squares based on the areas that emerged as most liable to change in the HTS aereal-features survey. 1Km squares from within these areas were as 'X' squares, with 'E' squares selected at random as before. 25 new maps will be needed.

Previously obtained statistical advice stated that the number could not be reduced further and so the squares could not be apportioned to the variance or heterogeneity of the land classes. However if great variability is found then these squares can be used to increase the sample number surveyed in the second year. Such a procedure has already been adopted by Highland Region Council in their survey of woodlands and in a study of urban development on farmland. The statistics are well established for this procedure.

An alternative approach for small samples is partial replacement. In this approach each time a resurvey takes place an additional series of squares are selected which can be compared with the initial sample. This was the strategy followed in the repeat survey by ITE.

The total number of squares for this year's survey was 146.

2.1.2 Ground survey - 1987 fieldwork S Warnock

During the summer of 1987 a total of 146 1 Km squares were surveyed throughout England , Scotland and Wales for use as ground truth to test the usefulness of remote sensing in monitoring land use change. The survey was carried out over an 11 week period from 22 June to 2 September involving 230 man days of work. On average each square took approximately 5-6 hours for complete survey , including permissions and travelling.

Analysis of information recorded in 1978 and1984 by ITE and from other studies in England and Wales by Huntings (1985-86) identified a number of areas where significant land use changes had taken place. These included four land classes in the lowlands (3,10,11,26) and three in the uplands (17,20,32) together with 25 other areas identified by Huntings. One further land class (6) was also included as this was predicted to have a high probability of change.

Two 1 Km squares were surveyed in each sample area : a central 'X' square based either on one of the ITE land classes or a Huntings area ; and an 'E' square selected at random from a ring of 16 non-contiguous squares in a 5x5 Km area centred on the 'X' square. Sample squares were coded using a standard format , first with their land class number (or 'H' if a Huntings square) followed by a national square series number , with an 'X' or 'E' to distinguish between the two squares in each area (eg. 10/467 X , H/644 E).

The sample squares were split into six groups (see figure 2.1.1) with the intension that survey teams would be based at five ITE stations. In the event many of the squares , particularily in southern and eastern England were surveyed by mobile teams from Merlewood.

In all cases permissions were sought before commencing survey. This was generally done on the day of the survey and for those squares already worked a letter was also sent beforehand explaining the purpose of the work. In many cases identifying and contacting farmers/landowners proved to be almost as time consuming as the survey itself. However , apart from gaining legal access to all parts of the square and ensuring the goodwill of all concerned , much useful background information on land ownership was collected for possible future visits. In addition details on the size of the holding and tenure type were also collected , where possible , for analysis of farm structure at a later date.

The survey itself was basically a mapping exercise in which vegetation and land use were recorded on 6" (1:10000) maps. As far as possible , this information was formatted according to the list of options available (see figure 2.1.2) , but occasionally it was necessary to add other categories to the list. The minimum mapable unit (mmu) was considered to be 1/25 ha (20 x 20 m). For each square the data recording sheet together with its 6" map were formatted unto a single sheet for convenience of field recording. Once completed this was combined with the ownership data sheet/map and made into a booklet. Figures 2.1.3 and 2.1.4 show examples of field sheets from a lowland and upland square respectively.

In order to give as much information about each area of land , combinations of data codes were used to annotate each category on the map. To facilitate this form of coding , boxes were provided on each data recording form enabling a series of numeric codes to be combined and represented by a single alpha character. For instance , a particular area of grassland might be coded with a letter "A". In the boxes at the foot of the recording form "A" might be recorded as being a combination of codes 32, 75/100, 67/100, 95/100 , where: 32 = permanent grass ; 75, 67 = *Agrostis* and *Holcus* respectively , each of which cover 25-50% of the vegetation unit ; 95 = mixed species , making up the remaining cover. In other words , the use of an alpha code to represent a series of numeric codes not only saves space in marking up the map but also allows a more informative record to be made. Where more than 26 codes were needed double alpha characters were used (ie. AA, AB, etc.). This system enables classification into vegetation types to be carried out at a later date thus allowing much greater flexibility during the analysis stage.

Digitisation of the field data is presently being carried out and when complete the cover figures for the major vegetation types will be compared with previous surveys.

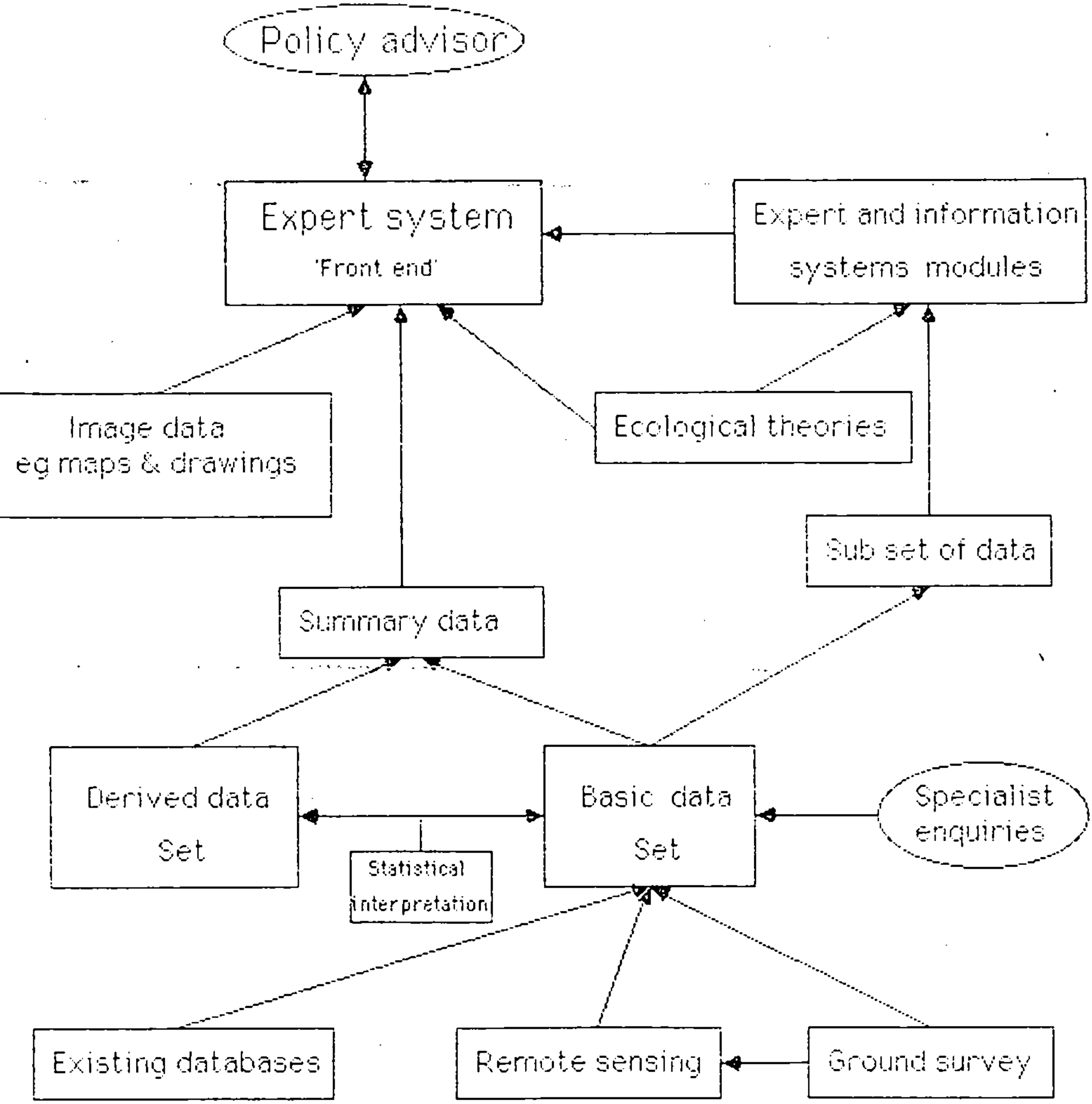


Figure 1.1 The relationships between the sections in the project.

2.2 Data preparation D F Evans & B K Wyatt

2.2.1 The land cover maps derived from the 1984 and 1987 surveys have been digitised with priority being given to the latter.

To keep the task within manageable bounds the recording scheme has merged cover types where it seems unlikely that they will be distinct radiometrically. The process is common to both ITE and NRSC, and it is hoped to achieve a common standard by using a key based on the code numbers that were used in the field survey. Such a key has been worked out jointly and is now being applied by both groups. It will inevitably be imperfect in that it cannot cater for every possible combination of species - there will always be some ambiguities - and these cases will have to be judged subjectively. Experience has shown that the main problems arise when in the divisions of lowland/agricultural grasslands are combined with *Molinia*, *Pteridium* or *Juncus effusus*. These have usually been allocated to the 'permanent grassland' class, which is may be rather heterogeneous, and may not therefore be consistent radiometrically.

The merged categories have been mapped using a standard range of coloured pencils (Rexel Derwent), and the same colours (as near as we can get) generated on the I2S. The RGB weightings used to specify these colours have been recorded and will be applied generally to classified images.

Maps are being digitised using an I2S software package called "STRINGS" and a very large digitising tablet. The resulting raster images are outline maps only, and contain no information on the identity of each cover-type. Their use for training will therefore involve constant reference to the original paper maps. On average, each map takes one hour to digitise, and if the equipment remains available, we expect to finish this phase of the operation by the end of October.

2.2.2 Having obtained the relevant TM imagery from NRSC it was intended to warp the imagery within ITE, but because of the decision to use a sin (x)/x resampling function, not available on the I2S, NRSC will now provide the warped imagery.

The poor summer weather means that the hopes of acquiring anything approaching comprehensive TM coverage in 1987 have more-or-less faded, and it will therefore be necessary to use on earlier images. As far as the uplands are concerned, any discrepancies (grassland improvement or tree-felling are the most likely) should be obvious enough to avoid being confused, but crop data may be unreliable.

Black and white aerial photographs of some sites were obtained by the NERC aircraft during the summer, and these may be useful in various ways. They will provide a check on the positioning of boundaires in semi-natural vegetation (which can be hard to map at ground level), and could help in identifying additional training areas outside the 1km boundairies. The photographs will be used to check that the areas chosen for training are reasonably homogeneous. A total of 56 1km squares were covered (36 NRSC, 20 ITE).

Where sites were not covered by NERC during this year's campaign, it will be necessary to fall back on photography from other sources (DoE is conducting a library search). Much of this will be quite old, and will therefore have to be used with caution. It could have particular value however, if the photography could be chosen to roughly match the acquisition dates for satellite imagery.

2.2.3 Each 10km square (containing 2 1km core squares) will be subsectioned out of the full scene, and retained on an account (with tape backup) specific to that square.

The subsectioned images will then be calibrated using tape header data, and radiometrically corrected for sun-angle (in that Order).

The digitised survey maps will be registered to the image and superimposed on it by contrast stretching within a ROI specified by the lines themselves. Because of the small size of a 1Km square (1Km = 40 pixels), it is intended to work with the map enlarged to 400 pixels (the "STRINGS" package is flexible in this respect), so that the lines themselves are not covering a significant proportion of the image (some parcels of land may otherwise disappear behind the lines). The TM image will need to be similarly enlarged by replication of pixels.

Each 10Km square will be classified independently of other sites, and using training data extracted from within the 1Km squares only.

2.3 Image capture and preparation M G Wooding

2.3.1 Introduction

The work programme in the period July to October 1987 has involved the following aspects:

- Identification of TM and SPOT data coverage for the 1 km sample squares in Land Classes, 3, 10 and 11.

- Extraction of 10km x 10km images centred on the 1km sample squares, from geometrically corrected TM and SPOT scenes available within the NRSC archive (Land Classes 3, 10 and 11).

- Geometric correction of selected image sub scenes, followed by the extraction of 10km x 10km (1984 imagery for Land Class 3).

- Preparation of Versatec plots at 1:50,000 scale for selected 10km x 10km TM and SPOT images.

- An investigation of land cover discrimination using TM data for Land Class 3.

2.3.2 A summary of the work carried out for land class 3

This has concentrated on the study of 1984 TM images because of the good satellite data coverage for this year and the fact that the ITE ground maps are also available. A total of 11 of the 12 sample squares have coverage on 21/10/84, 7 on 12/4/84, 3 on 14/5/84 and 2on 8/7/84. Sample squares LC3.367 and LC3.451 possess the best cover; with the very interesting combination of spring (April or May), summer (July) and Autumn (October) coverage.

early work has concentrated on a study of land cover discrimination using the October images. An image composite of the 11 1km sample squares has been produced, and the ITE ground data maps have been used to identify and draw boundaries around the largest of the land parcels on the image analysis system. Mean and standard deviation reflectance values have been extracted from the images for each land parcels (TM bands 3, 4 and 5).

This excercise showed the ITE field maps to be a valuable as a source of ground data for the most commonly occurring land cover types, such as grassland and the main crop types, but many of the less common cover types were found to be poorly represented. For instance, only 1 small area of broadleaf woodland occurs in any of the 11 sample squares, and there were no areas of coniferous woodland. This indicates that additional ground data are required both for investigating the potential for land cover discrimination and for using as training data for subsequent classification studies.

Simple graphs showing the usefulness of different bands for the separation of the different land cover types will be available at the progress meeting.

A study of land cover discrimination using the available multi-temporal images has been started, using the 10km square centred on LC3.451 and the available May, July and October imagery. Approximately 10 land parcels of the most important land cover types have been identified using the ITE field map and general experience of land cover in this part of East Anglia. Again mean and standard deviation reflectance values have been measured for these land parcels, and graphs have been prepared to investigate the usefulness of different dates for land cover discrimination.

2.3.3 Methodological aspects

One of the main justifications for the use of satellite remote sensing for monitoring changes in land cover is to enable the study area, or the sample size, to be increased. Within the framework of the ITE sampling scheme this essentially means increasing the number of sample squares included within a survey. The remote sensing work is being concentrated on the 10km areas centred on the 1km sample squares. Following land cover classification for these 10km areas it will be possible to produce area measurements separately for each of the 100 km squares. To increase the sample size for particular Land Classes it will be necessary for the Land Classes of each of the 100 squares to be known.

From the early work it is clear that remote sensing is going to be of limited value for discriminating between grassland categories. It is unrealistic to expect categories such as permanant grassland, leys and unimproved grassland to be able to be classified even when good multi-temporal data are available.

2.3.4 Future work

The next stage of the study will concentrate on the following aspects:

- The development and testing of different image classification techniques (As an extension of the work on land cover discrimination and concentrated on Land Class 3).

- Experimentation with change detection techniques using pairs of images obtained in different years (2 suitable pairs with a 3 year interval have been indentified for this work).

- The development of image analysis software to enable classified areas to be obtained separately for the 100 1km squares within a 10km area.

2.4 NRSC Progress Survey: The upland land classes

G H Griffiths & N Jewell

2.4.1 Ground Data Collection

Three days were spent in the field with ITE Merlewood staff to learn about field recording techniques. Subsequently Steve Warnock visited NRSC to discuss the coding and colouring of the field data maps to facilitate comparison with the TM satellite imagery. A final ground data map coding and colouring scheme has now been agreed (Table 1) and the 1984/87 maps for the six class 20 squares (X/E) and the Huntings' squares have now been received

2.4.2 Extraction of Image Squares

A number of TM scenes have now been corrected (section 2) enabling image data for squares within these scenes to be extracted by National Grid coordinates. This has been completed for five of the 10km x 10km class 20 squares and the images plotted on a Versatec colour plotter.

2.4.3 Digitising Ground Data Maps

Following coding of the ground data maps, the information was digitised on a Calcomp digitising table and overlain onto the image data for the Croglin (723) and Dent squares (673) (X/E). Unfortunately as a result of the small size of each square (1km) and the large number of fields/parcels within each square, the maps had to be digitised at 10x enlargement and superimposed onto the imagery enlarged by the same amount (400x400 pixels). By superimposing the digitised ground data onto the imagery, reflectance values (DN) for selected cover types and training statistics can be extracted from the image data. In fact training statistics were derived from the Dent and Croglin 1Km squares and applied to the 10km Croglin square. The classified image data for the Croglin X/E squares were subsequently transform of function, f (x). This enables the degree to which the transform preserves the spectral quality of the original data to be determined by presenting the distribution of amplitude against frequency for a given interpolation process. If this distribution has a small amplitude for higher frequencies smoothing will occur and the image will appear blurred. In fact the ideal interpolation function is a block of constant value in the range +1, -1 in which a weight of unity is given to the sample to be transferred and zero weights the other samples. Such a function enables the image to be resampled without any attenuation of high frequency information and consequent blurring of the image.

2.4.6 Nearest Neighbour

In this method the transformed pixel is assigned the intensity value of its nearest neighbour in the original scene. this interpolation is equivalent to convolving with a block of constant height in the range - 1/2, + 1/2. This is the only interpolation function that does not alter the DN values of the original data but it has very poor geometric properties; pixels can be offset in the resampled image by up to 0.7 pixels. The result is a resampled image with good spectral characteristics but a disjointed appearance.

2.4.7 Linear Interpolation

The linear interpolation function, which is equivalent to convolving with a triangular function, uses a proximity-weighted average of four input values to compute the output intensity. Although linear interpolation (bilinear in two dimensions) has much better geometric properties than the nearest neighbour function, its spectral properties are less good. The advantage of the nearest neighbour function is that the range of the function from -1/2 to + 1/2 is a convolution kernel with a dimension of one; interpolation between adjacent sample points is not required as the resampling simply involves a shift of the original intensity values to a new location defined by the output matrix. In bilinear interpolation the frequency distribution of cubic convolution can be used to resample the image to a specified map projection such as Universal Transverse*/0 Mercator (UTM) or Space Oblique Mercator (SOM).

Earthnet TM data obtained by the NRSC for the national archive are 'system' corrected to Level 5 using a high order polynomial. The image data are corrected for:

i) non-linear mirror velocity profile
ii) earth rotation
iii) panoramic distortion and earth curvature

Although the image data are also resampled to a SOM projection, the remaining sources of non-systematic error are not corrected for in the processing procedure. This is because the attitude and orbital position of Landsat which varies appreciably across a full scene, are not known precisely as a function of time. Thus it is necessary to use GCP's to generate an accurate transformation model in order to extract precise areas from the imagery using national grid coordinates and to make accurate measurements of areas.

The resampling procedures available, including nearest neighbour, bilinear interpolation, cubic convolution etc., shift the original samples or interpolate between them to estimate sample values on the output matrix defined by the GCP's

The accuracy with which the interpolator is capable of recovering the original function (i.e. spectral characteristics of the original data) depends upon several factors, including the nature of the original data, how it was sampled and on the nature of the interpolation function. The problem of designing the best interpolation function for Landsat data is similar to fashioning a digital filter having specific properties; the interpolation process is a convolution of the sampled data with a continuous function.

A useful tool for examining these factors and explaining the sampling and reconstruction process is the generalised Fourier desnity-sliced in colour and the area of each classified cover type calculated. A preliminary qualititative comparison of the classified 1Km squares with the digitised ground data showed a reasonably good correspondence between the distribution and extent of the classified cover types and the ground data.

This methodology would enable classified land cover information to be extracted from additional land class 20 squares in order to reduce the sampling error for this class and to increase the accuracy of the national estimates. However, considerable difficulties were encountered in finding sufficient training areas for some cover types and this will also be a problem in the quantitative measurement of classification accuracy.

2.4.4. Image analysis

The NRSC have agreed to undertake geometric correction of the TM imagery required for the project. A list of the scenes to be corrected is given in Table 2.

2.4.5 Resampling Techniques

The principal distortions in the imagery are caused by systematic, predictable errors and by non-systematic, largely unpredictable errors.

i) systematic errors: different sampling rates in the along and cross track direction; non-linear mirror velocity profile; earth curvature and rotation and panoramic distortion.

ii) non-systematic errors; mostly variations in satellite attitude-roll, pitch, yaw and satellite orbital position.

Without ground control points (GCP's) a simple affine transformation (i.e. simple rotation or translation) can be performed from the orbital parameters of the satellite to give a first-order correction for systematic errors. By expanding the number of terms in the transformation a polynomial such as unsuitable for applications involving set of registered multi-date imagery. In particular, one of the important aspects of the project to analyse change between multi-date imagery would not be possible due to the problems of co-registering imagery containing spatial errors of almost +/- one pixel.

2.4.9 Examination of Imagery

A small study was undertaken to examine the geometric and spectral differences between an area of TM imagery (Downham Market; ITE Class 3) corrected with a nearest neighbour and modified sinx/x interpolation function.

The image resampled with the nearest neighbour function had a blocky, disjointed appearance with straight lines displaying considerable offset along their length. It was concluded that such an image would be unsuitable for interpretation using visual techniques. The sinx/x resampling produced a smoother image more suited to visual interpretation.

A spectral profield was recorded across the same transect of both images. The sinx/x profile displayed slightly higher peaks and troughs compared with the nearest neighbour image, indicating the slight modification to the spectral values discussed in section 2.4.8. By subtracting the two spectral profiles the spectral differences between the two functions were enhanced and confirmed the slight tendency of the sinx/x interpolator towards an edge enhancing effect.

2.4.10 Proposals for Further Work

i) Examination of radiometric correction of image data to eliminate sensor calibration, look angle and sun angle as possible sources of error in the classification procedure.

ii) Measurement and analysis of reflectance values for various land cover units within sample areas using multi-date imagery, to determine the spectral separability of land classes at different dates and for different band combinations. A the function is much more important because true interpolation between sample points is involved for a function with a range of -1 to +1. In fact the Fourier transform of the linear function shows that it is far from the ideal block shape required, with amplitudes of less than unity at x equals zero. The result is that higher frequencies are attenuated, giving an image with a smoothed appearance.

2.4.8 Modified Cubic Convolution (sinx/x)

The idealised interpolation function is unity at x equals zero and zero all other integer values of x to ensure that the interpolator does not modify the spectral values of the original data. However, this idealised function decays to zero very slowly which means that sample points at distances greater than n, where n is the function range, are given unwanted weights in the interpolation process. This problem can be alleviated by truncating the function at 8 or 16 points, but at the truncation points the transform is non-zero and this discontinuity tends to introduce image degradation due to uneven attenuation.

Although this interpolation function is costly in terms of computer time, its combination of good geometric and spectral characteristics makes it ideal for the geometric correction of imagery to the UK National Grid. The modified sinx/x function is employed at the NRSC for these reasons. A technique for the automatic registration of a set of pre-defined GCP's with the same sample points on the image to be corrected is used at the NRSC in order to reduce inaccuracies introduced by mismatching of GCP's.

With these considerations in mind and in view of the fact that the original data has already been resampled to a SOM projection, the good geometric properties of the modified sinx\x function outweigh the disadvantages of a slight spectral modification of the original data. Although the nearest neighbour function is computationally fast and does not modify the spectral values of the original data, the poor geometric qualities of imagery resampled with this function, make it radiometric correction of the image data will probably preced this reflectance sampling exercise to enable comparisons to be made between the different seasons of imagery and land cover types within different ITE land classes.

iii) Classification of 10km squares using computer-assisted and visual interpretation techniques for different land cover types and comparing the merits of each technique. In particular attention will be focussed on a methodology to increase the number of classified squares to provide a larger sample size for more accurate estimates of national change in land cover. The problem of classifying larger areas from TM imagery is addressed in a review of the Huntings' Monitoring Landscape Change Project (GHG).

iv) Detection of change between images of different dates and between imagery and ground data maps.

3 Core

3.1 The current state of methods for assessing connectivity in landscapes.

3.1.1 Introduction

At the Merlewood seminar on "Island biogeogrphy" it was agreed that although the application of the theory to landscapes aws sound there was little hard data to support its validity. The papers summarized below show that this has been corrected by current work proceeding in Europe and showed that a wide range of relevant studies have been undertaken. The situation is such that there are a number of studies providing hard data on the importance of corridors and suggesting various methods of measuring connectivity and pattern. The papers were presented at the IALE seminar in Munster, summaries of those relevant to the present project are presented below.

3.1.2.1 Milne[1] compared the actual disposition of landscape features in a raster format, against a random array as a measure of the degree of orgnaization. A modification of this would be to divide the 1Km^2 into 1 or 1/2 ha blocks and examine the probability of any one location within that square being of the same or different types to its neighbour. The method suggested below was based on his method.

3.1.2.2 Janssens and Gulinck[2] used the same approach for remote sensing, emplying a brightness index for assessment of connectivity in adjacent pixels. In this case the term connectivity was used in a statistical rather than a hypothetical biological sense. A type of linking was used to identify pixels that had much in common in order to divide up the map into units. This paper suggested a way of linking the remote sensing and ecological measures of pattern, that has a great potential in providing a unifying system for the two sections of the project.

3.1.2.4 Forman[4] gave some useful shapes for edges which could be recorded from the field data - concave, convex, straight, inverse corner, outer corner, way and peninsula. It is necessary to refer to his book for more detail as he presented no hard data.

The length of ecotones was also emphasized by several speakers, as were hexagonal shapes.

3.1.2.5 Turner[5] presented an analysis of shape and described a simulation package which could be applied to the HTS data involving possibilities of transfer between adjacent cells within a matrix of 1 ha units. These could be described as :-

(1) Random

(2) Four neighbour influence ie the immediate cells.

(3) Eight neighbour influence ie a wider area.

An initial run on early data was compared with later patterns was carried out to show the influence of neighbouring cells, showing the decline of pattern within the landscape as agricultural intensification continued. The same procedure could be used over a short or long term basis in the present project, and would be tied in with the pattern analysis as well as remote sensing.

our data for 1984. The following main scales are involved:

1. Species scale - within a peninsula or corridor.

2. Hedgerow - scale

3. Adjacent land use elements - nearby patches

4. Land scale - distance to nearest patch.

5. Biogeographical.

3.1.3 CONCLUSION

The meeting was of great value in that it brought up to date the evidence of the importance of connectivity in the landscape. There is now an abundance of hard data, both observational and experimental, to show the importance of corridors. Whilst a range of elements have been shown to be important it remains a problem as to how to integrate them in an overall measure. Rather it is more likely that, as with vegetation, a range of measures for plant species, birds, small mammals and insects may be produced. It will be useful to visit Burel/Baudry (Rouen), Verkehr (Holland) and Gulinck (Belgium), when the results of some of the analyses described below are available, a particular area of importance is the way in which different biota can be grouped together in terms of their biology and dispersability. Overdue emphasis has been placed upon plants in this respect and it will be necessary to draw upon the experience of the above people in order to identify as wide a range as possible of different groups affected by land use change.

1. Milne, B.T. (Albuquerque, USA), R.H. Gardener (Oak Ridge, USA), M.G. Turner (Athens, USA) & R.V. O'Neill (Oak Ridge, USA)
Neutral models of connectedness in rural landscapes

2. Janssens, P. & H. Gulinck (Leuven, B)
Connectivity, proximity and contiguity in the landscape:- interpretation of remote sensing data

3. Opdam, P. (Leersum, NL)
Populations in fragmented landscapes: a review

4. Forman, R.T.T. (Cambridge, USA)
Patch shape: a key ecological controller in the landscape

5. Turner, M.G. (Athens, USA)
Analysis and simulation of changing land use patterns in Georgia, USA

6. Richling, A. (Warszawa, P)
Conception of the meso-scaled map of land use

7. Verkaar, H.J. (Delft, NL)
The possible role of road verges and river dykes as corridors for the exchange of plant species between natural habitats

8. Sharpe, D.M., Y. Zhao, R. Guntenspergen, F. Stearns & C. Dunn (Carbondale, USA)
Isolation of remnant forest patches in an upper midwest agricultural landscape and their role in inter-patch seed dispersal.

9. Harms, W.B. & J. Knaapen (Wageningen, NL)
Landscape planning and ecological infrastructure: the Randstad study

10. Burel, F. (Brux, F)
Biological patterns and structural relations in the landscape.

3.2 Proposed method of pattern analysis

3.2.1 Introduction

Following the meeting at Munster a provisional method was identified. The 1Km^2 are divided into a 1 ha grid and a boundary of the marginal units (i.e. 36 ha) marked up leaving 64 ha blocks which are always surrounded by 8 hectares (see figure 3.2). The land cover types were then recorded in the central square and the different types present in the surrounding squares recorded. These data therefore represent a measure of 2 factors:-

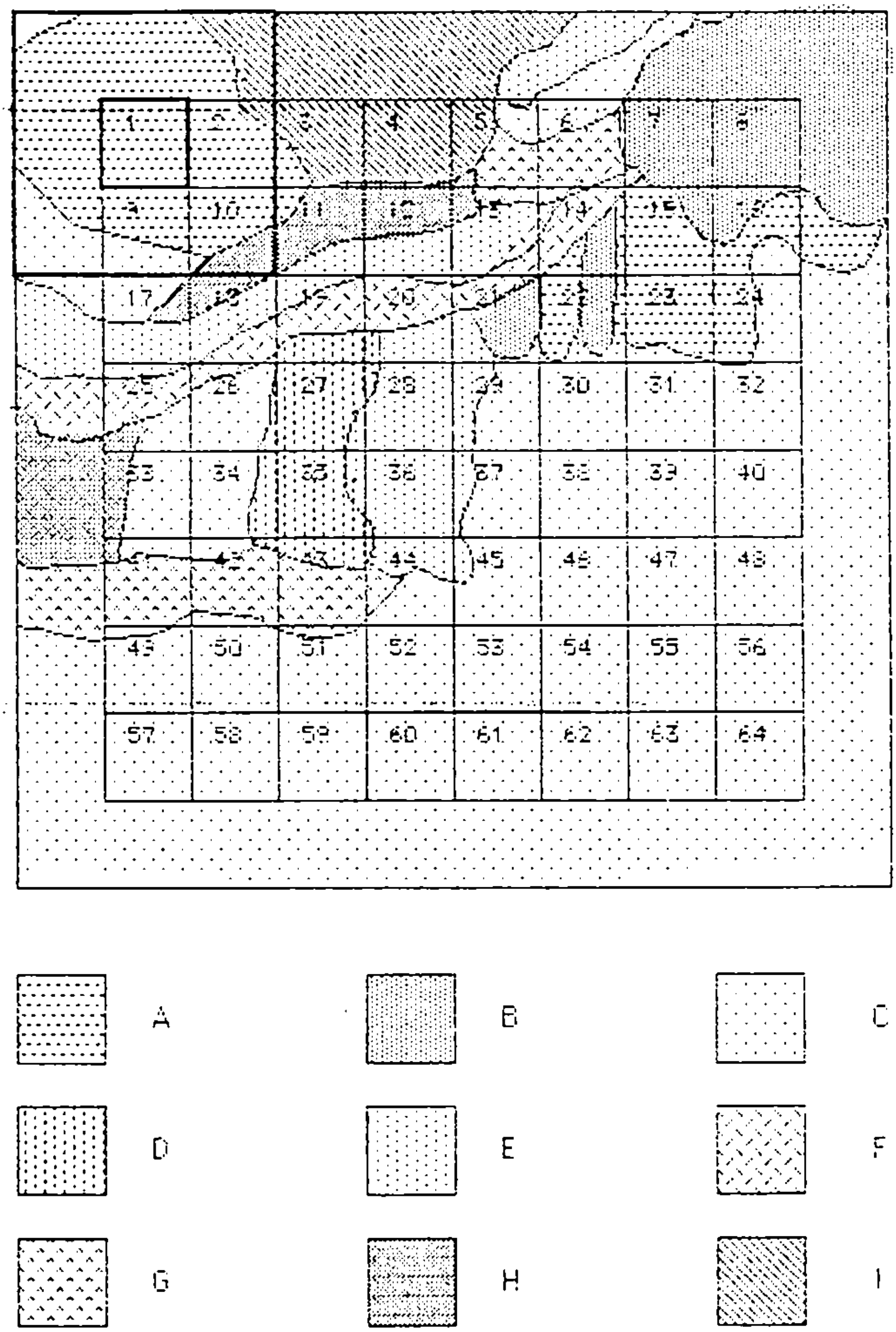
(1) The frequency accurrence of different land cover types around the central squares gives an overall measure of the degree of pattern present.

(2) The patterns associated with different specific land cover types reflect their ecology and can be used as a basis for further study.

These data can also be processed in due course for spatial pattern as the digital outlines are held on the computer. At the current time the preliminary analysis has been done by hand in order to demonstrate the approach and present some preliminary results but the method is designed to be carried out on the computer. It is also important to note that a comparable approach could be used to analyse the satellite images using the pixels - as reported by Janssens & Gulinck in the previous section. Correlation analyses could then be carried out for the measurement of pattern on the ground data and on the satellite image. If the correlation is sufficiently good the latter could then be used to predict ecological pattern.

3.2.2 The method is also applicable to the changes in pattern our time, with extant data being used either on the I.T.E. survey or HTS.

Figure 3.2.1 A simplified example of pattern analysis



The grid indicates the squares which are scored. The number of squares containing a similar land use surrounding each centre square are counted and the total for each type calculated.

Land Class 10 Lowland grassland

Square	471X	443X	467X	521X
Perm. Pasture	3	83	62	120
Ley	4		18	73
Woodland	28	27	16	3
Scrub				
Shrub				1
Horiculture/urban	16	13	6	61
Herb rich neutral	4	6		
Upland				
Bog				
Marsh				
Unmanaged	3			1
Other vegetation	3			
Grass moor				
Burned vegetation				
Non calc flush				
Arable	145	8	104	
Physiography		63		
Ruderal/ephemeral		2		
TOTAL	206	202	206	259

Mean 218

3.2.2

There are other more sophisticated ways of examining the data related to spatial variation. In statistics there is an increasing trend away from convoluted methods of significance testing, towards more descriptive explanations of variation. Advances in areas such as fractal geometry have illustrated how scale affects spatial pattern, revealing the importance of taking into consideration the way increasing scale reduces variation. It has suggested, for example, that there are disproportionately more small insects observed on plants than we would expect, because our perception of the space available to them is made at a different scale.

Having taken scale effects into account, spatial variation due to edge effects, aggregative effects or spatial heterogeneity may provide valuable insights into ecological processes. For example, patterns of variation in crops or vegetation may be important in determining agricultural influences on the environment. Similarly environmental patchiness is known to affect population dynamics eg pest populations are strongly influenced by the spatial structure of their host.

A completely uniform square in the present example will be 22 x 8 ie 176

* The closer the score is to **176** the more uniform the square.

Further examples of the two land classes are currently being analysed and will be presented at the Advisory Group meeting. The method will need to be refined further particularly in relation to the relative frequency of the types present within a particular square.

3.2.2.3 In addition there has been considerable recent work looking at the various scales of pattern. In the above example 1 ha units were used but an examination of the variance using different size units has been used to see if the pattern changes at different levels. The structure of the present data lend themselves to this analysis and it will also be investigated.

The scale is important also for the various animals in the landscale. For example foxes can more easily traverse the square whereas some small beetles will be restricted in their potential movement. The size and spatial distribution of the patches will therefore need to be considered in conjunction with the individual ecologies of the species.

3.3 Species analysis

3.3.1 The analysis of the species data has not proceeded far since the last meeting for 2 reasons:-

(1) The main effort has been concerned with the carrying out of the field survey for the remote sensing program.

(2) Once the data have been set up on ORACLE their manipulation will be much easier, and so the data from the analyses have been prepared and will be analysed shortly. Over the next few months the emphasis will be on this section.

It is intended to produce keys to the vegetation in the squares as well as streamsides, roadsides and hedges. These keys will be available in both printed form as well as being incorporated into the expert system. This will fit in with the land class description and provide a standard basis for comparison of vegetation within different habitats. They will also provide a link between the expert systems project and the land classes to tie in advice, eg for herb rich meadows.

The vegetation data contains 45 types largely concerned with grasslands that are fitted into a general flora primarily associated with management and nutrient levels. These are therefore ideal for linking management prescriptions to modifications in current vegetation. The main breakdown in the classification is given below, plus an example of a section the key and type description. The type description will be used as the basis for describing the ecology of the land classes.

In conjunction with the analysis of pattern and the Sheffield unit data, these species analysis will enable, hypotheses of the control of species by land use change to be set up for testing in the 1988 field season.

Preliminary breakdown of vegetation types

- 1 - 36 High nutrient grasslands
  - 1 - 23 High nutrient leys
  - 24 - 36 High nutrient perm. pasture
- 37 - 45 High nutrient arable
- 46 - 60 Low nutrient moorland
  - 46 - 53 Low nutrient wet peat
  - 54 - 60 Low nutrient organic top
- 61 - 75 Low nutrient grassland
  - 61 - 68 Low nutrient grassland
  - 69 - 75 Low nutrient woodland

Vegetation type 63

Description

Traditionally termed acid upland grassland, this type occurs on a variety of soils presumably because heavy grazing has modified the vegetation to give a grassy sward which, if left ungrazed, would probably diverge according to the soil type. (Nardo-Galion or Carici-binervosum in B-B classification)

Preferential cover species

Agrostis tenuis
Anthoxanthum odoratum
Deschampsia cespitosa
Deschampsia flexuosa

High cover species

Agrostis tenuis
Nardus stricta
Deschampsia cespitosum

Total number of species recorded

151

Average number of species per 200 m2

26

Constant species

Holcus lanatus
Galium saxatile
Agrostis tenuis
Luzula multiflora

Preferential species

Agrostis tenuis
Deschampsia flexuosa
Luzula multiflora
Nardus stricta
Potentilla erecta

pH 4.58 (3.7-6.1)

LOI 27.1% (3-92)

Brown earth	27%
Gleyed brown earth	5%
Gley	41%
Brown podzol	6%
Peaty podzol	6%
Brown ranker	6%
Ranker	6%
Podzol	6%
Calcaereous soil	6%

3.4 The UCPE Autecological Database

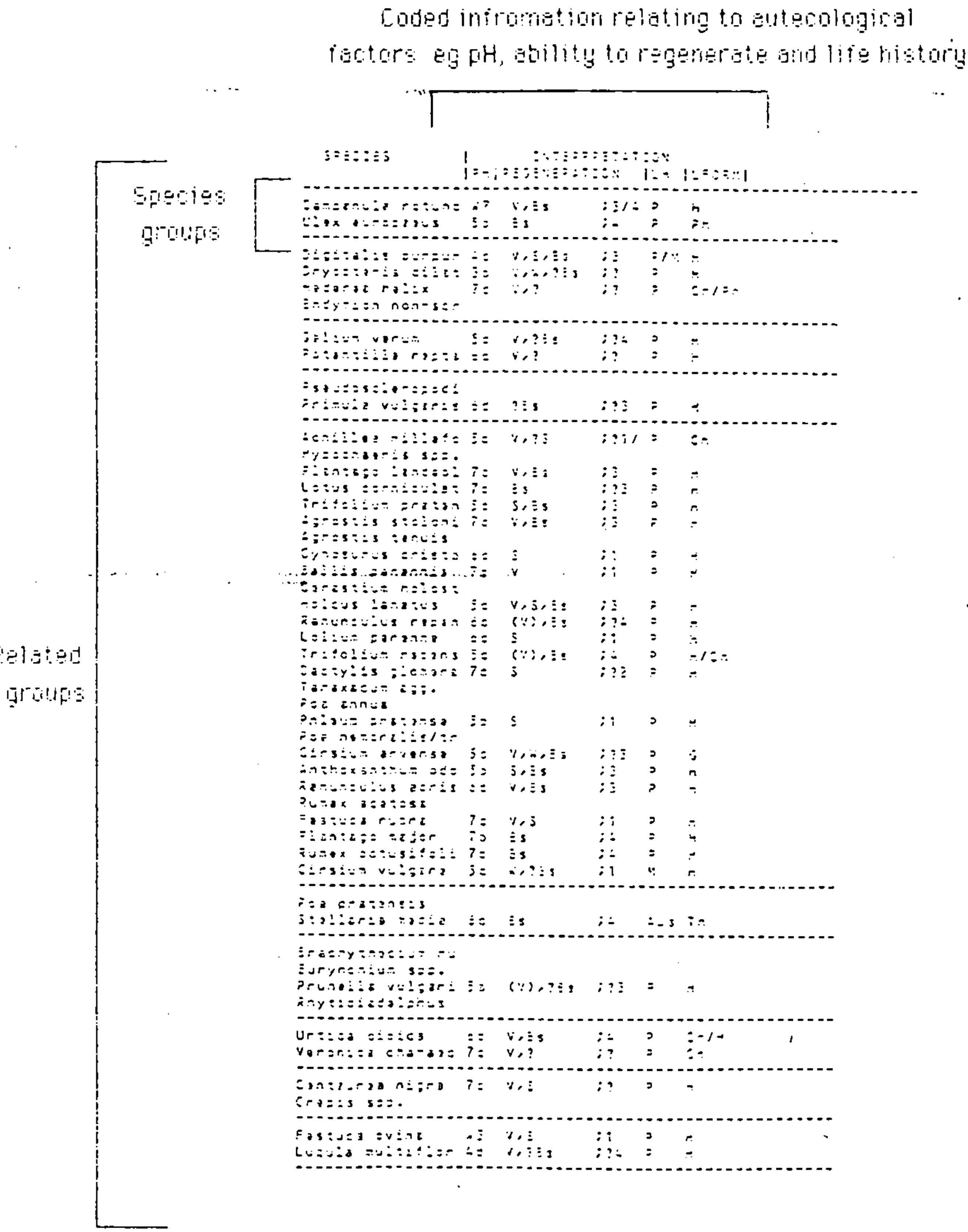
N R Jenkins

The Unit of Comparitive Plant Ecology (UCPE), based at Sheffield University, has been undertaking broad-based comparative, and systematic, studies on plant physiology since 1961. Recently the Unit has been developing a plant autecological database based on studies of some 500 species. In collaboration with the Land Use Survey Team at ITE, Merlewood, an assessment is being made of the value and ways in which such a database could be utilised in more applied environmental research activities.

The database is being initially used on an ITE project on farm extensification, as an aid to identifying the ecological processes and impacts behind changes in agricultural practices. The attached Figures 3.4.1 and 3.4.2 illustrate how the autecological information can be cross-referenced to species information such that ecological and physical processes can be related to vegetation and environmental classifications. In collaboration with other information relating classifications to agricultural and management practices, this will provide a powerful analysis of environmental data to illustrate the underlying dynamics, processes and impacts.

An example of the information available from the UCPE autecological database is given in the second attached Figure. At this stage the information is in the form of a provisional listing rather than a fully interactive database. However, this should provide enough information to assess how useful the database may be in association with the classifications, surveys and models being developed by the Land Use Survey Team.

Figure 3.4.1 An example of data from the UCPE database



SPECIES	PH	REGENERATION	[illegible]	LIFORM	
Campanula rotund	4?	V,Es	?3/4	P	H
Ulex europaeus	5c	Es	?-	P	Ph
Digitalis purpur	4c	V,S,Es	?3	?/M	H
Dryopteris dilat	5c	V,W,?Es	??	P	H
Hedera helix	7c	V,?	??	P	Ch/Ph
Endymion nonscr					
Galium verum	5c	V,?Es	?4	P	H
Potentilla recta	6c	V,?	??	P	H
Pseudoscleropodi					
Primula vulgaris	6c	?Es	?3	P	H
Achillea millefo	5c	V,?S	?1/	P	Ch
Hypochaeris spp.					
Plantago lanceol	7c	V,Es	?3	P	H
Lotus corniculat	7c	Es	?3	P	H
Trifolium praten	5c	S,Es	?3	P	H
Agrostis stoloni	7c	V,Es	?3	P	H
Agrostis tenuis					
Cynosurus crista	6c	S	?1	P	H
Bellis perennis	7c	V	?1	P	H
Cerastium holost					
Holcus lanatus	5c	V,S,Es	?3	P	H
Ranunculus repen	6c	(V),Es	?4	P	H
Lolium perenne	6c	S	?1	P	H
Trifolium repens	5c	(V),Es	?4	P	H/Ch
Dactylis glomera	7c	S	?2	P	H
Taraxacum agg.					
Poa annua					
Phleum pratense	5c	S	?1	P	H
Poa nemoralis/tr					
Cirsium arvense	5c	V,W,Es	?3	P	G
Anthoxanthum odo	5c	S,Es	?3	P	H
Ranunculus acris	6c	V,Es	?3	P	H
Rumex acetosa					
Festuca rubra	7c	V,S	?1	P	H
Plantago major	7c	Es	?4	P	H
Rumex obtusifoli	7c	Es	?4	P	H
Cirsium vulgare	5c	W,?Es	?1	M	H
Poa pratensis					
Stellaria media	6c	Es	?4	A,S	Th
Brachythecium ru					
Eurynchium spp.					
Prunella vulgari	5c	(V),?Es	?3	P	H
Rhytidiadelphus					
Urtica dioica	6c	V,Es	?4	P	Ch/H
Veronica chamaed	7c	V,?	??	P	Ch
Centaurea nigra	7c	V,S	??	P	H
Crepis spp.					
Festuca ovina	4c	V,S	?1	P	H
Luzula multiflor	4c	V,?Es	?4	P	H

Figure 3.4.2 List of species charecteristics available from the UCPE database

Ecological attributes

1 Habitat range
  a) Abundance in seven primary habitats
  b) Commonest terminal habitat
2 Soil pH
3 Floristic diversity
4 Distribution in northern Europe
5 Present status

Attributes of the established phase

6 Life history
7 Established strategy
8 Life-form
9 Canopy structure
10 Canopy height
11 Lateral spread
12 Mycorrhizas
13 Leaf phenology
14 Flowering time and duration
15 Polyploidy

Attributes of the regenerative phase

16 Regenerative strategy
17 Agency of dispersal
18 Dispersule and germinule form
19 Dispersule weight
20 Dispersule shape
21 Germination requirements
22 Family

3.5 Oracle database

3.5.1 Database systems

Database systems are computer management systems for maipulating and storing information. ORACLE is a database system which will work on mainframe, mini and micro computers. The system stores data in files called TABLES, each table being structured and divided into fields called COLUMNS. The database is relational in that data can be automatically cross-referenced through several tables using common fields. ORACLE is a powerfull tool which can sort, summarize and display information in a variety of ways.

There are several important parts to the ORACLE system

1. SQLplus.
2. SQLforms
3. SQLgraph
4. SQLcalc
5. pro*SQL-fortran, C, Cobol, basic
6. SQLreport.

The system can also interact with SAS and GRAFIX directly for graphical output.

3.5.2 The Advantages of Oracle

1. Ease of manipulation.

A database has a regular, uniform structure and simple language (closer to English than normal programming languages). The system will also operate in a fully interactive manner ie you type a question in at a terminal and the response is immediate.

For more complicated queries searches can be combined in routines which can be repeated with different selection criteria.

2. Validation of data.

Since it is easy to mainpulate the data it is possible to perform complex checks on the data before it is loaded into to database (eg does the series no. exist? are the grid references true references? is there already data for this square and how does it compare?). A number of errors have been removed from the data already loaded.

3. Security.

The system has a structured set of passwords which can be applied to all the data, part of the data or even part of a table so that restricted access can be allowed to people and they cannot accidentally corrupt the data.

4. Interaction with software packages.

Data can be exported directly to packages such as SAS, GRAFIX and GENSTAT so that it can be presented and analysed more conveniently.

5. Compatability with other databases.

Several other groups are using ORACLE as a database language. At Merlewood the radionuclide group are entering their data (surveyed using the LUST system) other groups (eg acid rain) are likely to follow. Other institutes (eg Edinburgh) already have ORACLE linked to a powerful GIS (we have already imported drift data from them).

6. Efficiency.

Since ORACLE maintains its own indeces data can be accessed quickly and disk space is used efficiently.

7. Standard responses.

For responses to common queries, standard screen displays for interogation can easily be generated and there is even a report generator which will produce a document including standard text blocks along with selected tables and graphs.

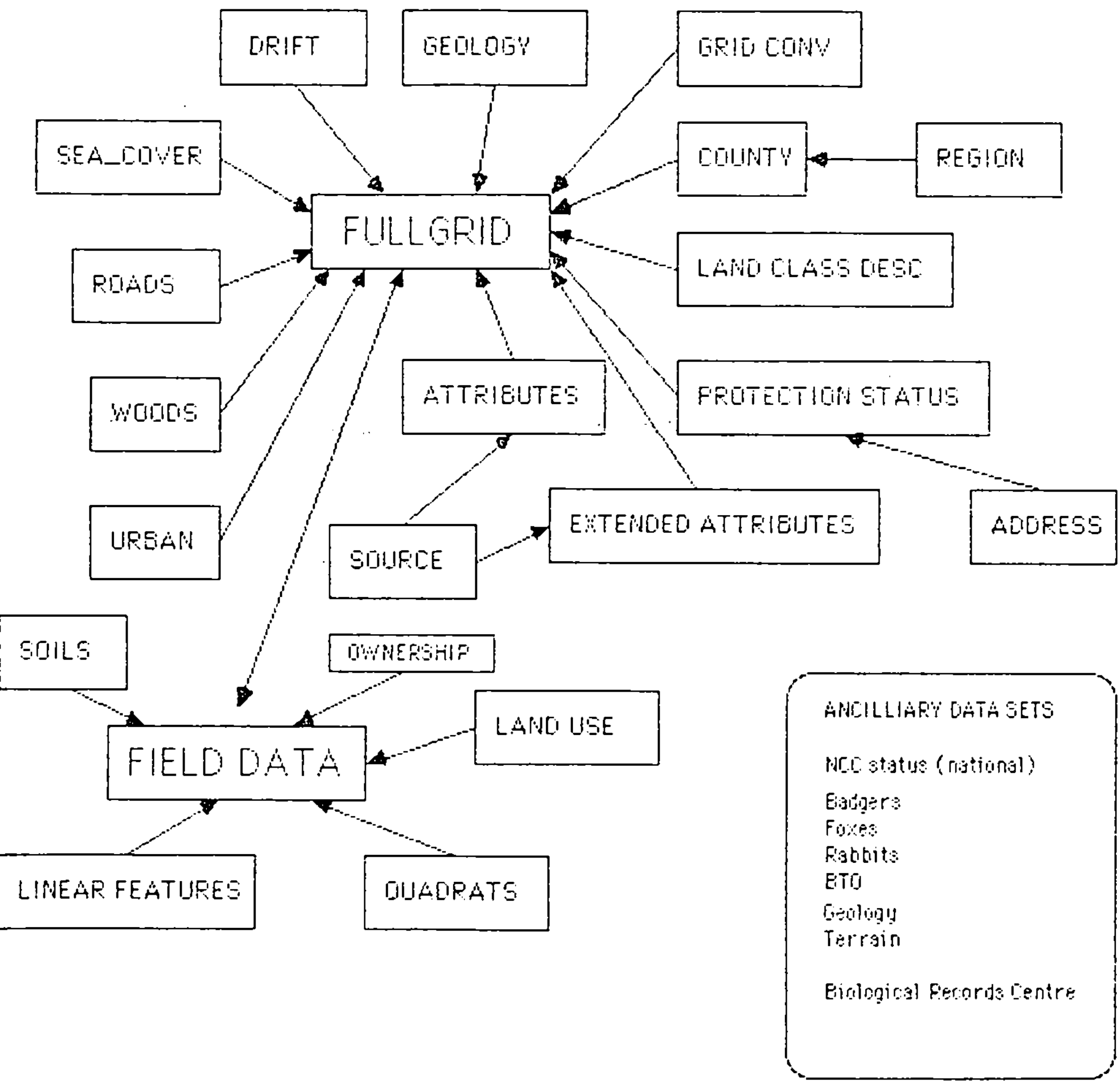
3.5.3 The LUST database

The LUST data is being entered into the database. It is intended that all members of the LUST team will have access to the data. It will also be possible to allow non-team members restricted access to selected parts of the data. At present Philip Bacon and David Howard are the only people who can enter or alter the data in the key data tables. By the use of passwords, accidental alteration of the data can be prevented and the integrity of data maintained. Figure 3.5 gives an indication of the structure of the database with the ancilliary files.

A help system for people who are unsure of the ORACLE/LUST database is in preparation and the ouput of a prototype is available for comment. The data already entered is being used to support other areas of the project and respond to specialist requests.

The database can be interogated in a variety of ways but is being structured so that apart from Ordnance Survey grid references the ITE Merlewood Land Class is the key element which links all the datasets.

Figure 3.5 A diagramatic representation of the ORACLE/LUST database indicating the ancilliary data files



4 Expert systems

4.1 General

4.1.1 The land classification as a basis for an expert system

A typical user envisaged for the system described below is a senior planner within a county council who requires rapid information on the ecological consequences of land use changes in a given area. It was decided that a useful approach to integrate the various outputs from the different sections was the land classification as it had been necessary use many of the studies on the sample squares. Currently 6140 squares have been classified in Britain as a whole and these have been referenced and entered into a computer file on the Macintosh microcomputer - they are also held on Merlewoods microVAX computer. A suite of programmes has been written which locates the the nearest 3 squares to any $1km^2$ for which a grid reference is provided. The environmental characteristics of the type may then be compared with the features of the square under consideration. In due course it is hoped to have a simple system of classifying every square without needing all 76 attributes currently required. A further development will be to incorporate all the squares already classified in the HTS, HRC and local studies. Currently the data is held by individual $1km^2$ but an option will be provided to draw round any area required.

The latest system will be presented to the advisory group for comment.

4.1.2 Having classified the squares the next stage is to present the information pertinant to that land class in order to provide a picture of the ecology of the land and the consequences of changes taking place.

The information currently available is :-

1. Topography
2. Land use
3. Natural species cover
4. A pictoral representation

information planned is :-

5. Land use change
6. Pattern
7. Vegetation types and heterogeneity
8. Potential changes in bird populations
9. Conservation areas
10. Availability of habitat information
11. Potential set-a-side

The system will be menu driven, with each section presenting tabular information followed by an interpretation.

4.2 Linking expert systems with an ecological database.

P Hammond

4.2.1 Introduction

For a database to be used by people who are not expert in the use of computers requires a method of access which is both easy to use and intelligent. As part of this project it is envisaged that a policy advisor may wish to interogate the extensive ecological database being constructed by ITE. The ITE Merlewood land classification provides a useful summary and method of leading an ecological novice into the database. In order to produce a 'friendly' system it is desirable to exploit the use of graphics (eg maps and pictures), mice and icons (ie avoiding typing in streams of unintelligable words). Ideally the system would also be intelligent, that is capable of interpreting coded rules (embodying ecological theorems) which translate the data to produce hopefully useful summaries and guidelines.

Imperial College has expertise in creating such expert systems using languages such as PROLOG. A dialect of PROLOG called MacPROLOG is capable of maipulating graphical information and can be controlled through the use of icons.

4.2.2 Programme

The work can be broken into three parts :-

1. Scanning maps and images to produce a visual database (containing for example maps at different scales, boundaries of counties, nature reserves etc and pictures which are representative of land classes managed in different ways). This can then be used as a guide for the policy advisor and allow rapid assilimation of large blocks of information.

2. Transfer of data from ITE to Imperial College, to produce a summary database so that relevant information can

be presented without needing to access a larger distant database.

3. A control system to link the different databases which will decide where the relevant information is stored and how best to present it. This is the intelligent /knowledge based front end of the system. The front end may also impliment other systems (expert systems, information systems or models).

4.2.3 Progress

A rudimentary system using icons and graphics will be demonstrated at the meeting. It will allow the user to select a $1km^2$ for which information is held and display information about it. With recent hardware acquisitions and the link between the Merlewood microVAX and Imperial Colleges Macintosh microcomputer having been proved it is hoped that more information can be included.

4.3 Expert systems topic modules

The main product to date is a small system called MEAD, designed to advise on the establisment of wildflower meadows. MEAD is written in Microprolog and runs on any IBM-compatible microcomputer. At present, the program self-contained and cannot communicate with outside databases. All the information it requires must be available on the disks and memory of the microcomputer.

The user of MEAD is envisaged as a person with minimal knowledge of ecology or ecological principles. The program explains what needs to be done, and to a certain extent why it needs to be done, but attempts to avoid using technical terms.

The underlying ecology that goes into MEAD is still rather limited, consisting of information about what types of seed mixture and plant are suitable for particular soils, and of the ecological basis of certain management prescriptions. Much of this information is available in the better seedsmen's catalogues, though not necessarily in a convenient form.

MEAD is an example of a sub-system applicable in particular ecological situations. It will be linked to the main suite of programmes by the identification of land classes. It is intended that routines such as MEAD will be offered as options to a user when information in the system (such as land class) suggests it would be appropriate.

Consultations to date have been with a FWAG advisor (Warwickshire), and with the staff of ITE.

5.1 Sub-contract report from the Centre for Agricultural Strategy (CAS)

5.1.1 Objectives and method

(i) There are two objectives to this aspect of the research:-

(a) an assessment of the amount and kind of recreation taking place on the I.T.E. squares;

(b) a forecast of the likely future levels of recreational activity on these squares with a commentary on the ecological implications.

(ii) These objectives are being met by:-

(a) studying the survey sheets and records held by I.T.E.

(b) a physical site survey of a sample of the squares.

(iii) In addition, the forecasting of future recreational activity will entail:-

(a) an appraisal of the characteristics of each square under such headings as landscape, access, amount of settlement and farming practice;

(b) identification and analysis of the demand for recreation as expressed through the size of the population living within 10 miles and 40 miles of each square. This information will be obtained through the services of CACI, a specialist firm in this field, and will give, for the first time, the I.T.E. squares a contextual dimension.

5.1.2 Progress

(i) Progress has occurred in relation to each of the four approaches identified above. The I.T.E. survey sheets have been analysed, but it is intended in relation to some of the classes to explore the complete I.T.E. survey file. A start has been made on the on-site surveys and a proforma has been designed to provide a consistent basis for data collection, recording and analysis.

(ii) The appraisal of the data has begun but is at an early stage. The population information from CACI is awaited.

5.2 Alternative crops - Progress report, October 1987.

5.2.1. Identification of alternative crops

(i) The first stage in the project was to select the alternative crops which are to be incorporated into the study. This was done by reviewing the possibilites, and these were then narrowed down by making a selection of contrasting types of crops which also had different environmental requirements.

(ii) The crops chosen were:-

(a) Sunflower
(b) Lupins
(c) Chickpeas & Lentils
(d) Peppermint
(e) Flax
(f) Sea Buckthorn (for juice production)
(g) Blueberry

5.2.2 Assessment of crop requirements

(i) The second stage has been to identify the climatic and edaphic parameters which might govern the distribution of the crops, and then to determine how best to characterise these using the I.T.E. enviromental data available.

(ii) This stage is nearly completed, but is awaiting more precise information from the Scottish Crop Research Institute on the soil and climatic requirements of Sea Buckthorn and Blueberry.

5.2.3 Assessment of the area available for alternative crops

(i) The final stage of this study, which has yet to be done, is to annotate the sample $1km^2$ squares with the potential distribution of the alternative crops, making use of the chosen criteria.

(ii) Once this is complete, a brief assessment will be made of the social, economic and ecological consequences of such a level of planting of alternative crops, before transferring the database to I.T.E.

5.3 Socio-economic characteristics - Progress report, October 1987.

5.3.1 Objectives

(i) This part of the Project had to collate data from various sources so that distinctions could be made between I.T.E. Land Classes on the basis of some of the socio-economic characteristics of farmers and their farm businesses.

(ii) The basis was to be an existing CAS database supplemented from other sources where necessary, to provide adequate coverage of the 32 I.T.E. Land Classes.

(iii) Pertinent socio-economic characteristics were to be chosen, with the addition of a Land Class value for each observation. Where observations had not already been assigned a Land Class, these were to be specially calculated.

(iv) Finally, the nature of the various socio-economic characteristics were to be examined for each Land Class and generalisations made wherever the number of observations n each Land Class were sufficient to permit it.

5.3.2 Current job status

(i) Three databases were selected from which to draw the required socio-economic information. These were as follows:-

(a) A database from a project on information management in agriculture (Univ. of Reading, 1984/85).

(b) A database from a project on the impact of the CAP on agricultural development (N.E.R.C./E.S.R.C. 1986/87).

(c) A database from a project on the opportunities for growing trees for fuel (Univ. of Reading, 1986/87).

(ii) Of these databases, (a) and (b) above were specific to some of the 256 I.T.E. squares, but as database (c) was not, 140 farms had to be assigned Land Classes.

(iii) A review of the compatability of information between these databases yielded the following 13 soci-economic variables:-

(a) Farmer age.
(b) The year the farmer began farming on own account.
(c) The presence or otherwise of an heir willing to farm.
(d) Whether the farmer had any formal agricultural training or qualifications.
(e) Membership or otherwise of any farming organisation by the farmer.
(f) Presence or otherwise of any off-farm income.
(g) A code number to identify each individual farm.
(h) The total size of the farm holding.
(i) The area of the total holding which is owned.
(j) The area of the total holding which is rented.
(k) The number of full-time workers on the farm.
(l) The number of part-time workers on the farm.
(m) Farm production activities/farm type.

(iv) Each of these 13 variables were present on all 3 databases, but were often represented in different fashions. Thus, a homogenizing process had to be conducted changing variable names and the format of data representation to permit the merging of all 3 databases into a single unit containing the 13 variables listed above and Land Class (table 5.1.1)

Table 5.1.1 Details of farm ownership by landclass.

I.T.E. Land Class	Number of farm businesses/ Land Class	Mean farm size (ha)	Mean area owned (ha)	Mean area rented (ha)	Average year principal began farming on own account
1	8	139.8	75.6	64.2	1964
2	5	38.9	29.6	9.3	1968
3	6	151.8	95.2	56.7	1969
4	11	287.0	206.7	80.3	1959
5	4	156.5	104.2	52.3	1966
6	7	49.5	18.4	31.1	1966
7	3	141.6	76.8	64.7	1956
8	3	158.9	56.7	102.3	1969
9	6	233.4	136.6	96.8	1969
10	12	176.0	155.8	20.2	1961
11	12	161.6	86.1	75.4	1960
12	11	329.3	212.5	116.7	1962
13	6	245.7	114.9	130.8	1961
14	4	230.6	220.6	9.9	1955
15	21	158.0	126.6	31.4	1967
16	21	142.0	48.8	93.2	1965
17	22	562.9	107.3	455.7	1964
18	5	347.3	347.3	0.0	1967
19	16	609.1	441.7	166.7	1967
20	35	357.4	308.2	79.6	1967
21	9	8884.8	8442.6	442.1	1974
22	5	214.9	54.1	160.8	1962
25	32	170.8	98.5	72.2	1963
26	18	161.1	130.6	30.5	1967
27	24	123.9	94.8	29.2	1967
28	5	212.7	119.4	93.3	1977
29	1	470.6	0.0	470.6	1938
Total	315*				

* No observations for Land Classes 23, 24, 30, & 32.

5.4 Sub-contract report by the Soil Survey & Land Resource Centre W A D Whitfield

5.4 Validation and appraisal of soil and agroclimatic information for ITE sample areas

5.4.1 Introduction

The aims of this study are to examine the soil and agroclimatic data for 146 sample areas of the 1 Km^2 of England and Wales, and to allocate a dominant soil type either, from the data collected by ITE staff or from material published by the Soil Survey of England and Wales.

Identification should preferably be a soil series level, but where this is not possible, soil associations may be acceptable.

The ITE data consists of 8 sample areas from each 32 land classes (Appendix 1) of which 18 classes occur totally or dominantly (> 5 out of 8 sample areas in each class) in England and Wales and a further 6 are represented by 3 or fewer sample areas. Soil information has been recorded at 5 sites in each of 146 1Km^2 sample areas.

The Soil Survey information covering the sample areas is at varying levels of detail and reliability.

5.4.2 National Soil Map

The soils of each of the 146 squares are classified on the National Soil Map (1:250,000). This information is at association level, and in some squares more than one association occurs. Tables have been presented summarising this information.

5.4.3 Detailed Mapping

30 squares fall in areas mapped in Soil Survey staff at scales between 1:63,360 and 1:25,000. Tables have been presented covering this information.

At 1:63,360 scale soil maps mainly show soil series, although in the case of three sites which fall in the Luton and Bedford district soil associations are shown.

The slightly larger scale of 1:50,000 represents the most recent mapping carried out by Soil Survey staff, and in some areas the maps have not yet been published, although the field work is complete. Detailed mapping at a published scale of 1:25,000 is available for three ITE sites.

5.4.4 Confidence limits of Soil Survey information

the National Soil Map incorporated all previously published soil information, but where no published material existed between 150 and 250 points were examined over each 100 Km^2 sheet. A relatively high proportion of these points were clustered around four grid-determined points but approximately 60 per cent were randomly distributed in relation to changes in geology and land form.

The information given therefore is restricted by the scale of the map, and only general statements about workability and crop suitability can be made. The use of the association, however does often give a strong indication of the soil series. The 1:63,360 scale (1 inch to the mile) map of the Luton and Bedord district is essentially an association map.

The rest of the 1:63,360 scale maps show mostly soil series, although where the soil pattern is very varied soil complexes or composite units are delineated. The boundaries were based on sampling densities of between 20 and 40 samples per 1 Km^2, and in individual squares as many as 7 different soil series may be shown.

Maps published at a scale of 1:25,000 are very detailed and between 40 and 60 samples per 1 Km^2 were taken to determine the soil boundaries. This work also allowed statements to be made of the variabilitity of the soils in the map units which are about 70 per cent pure. Figure 1 shows an area of 100 hectares on the Rugby west sheet. The details of each site are fully recorded.

5.4.5 ITE soil data

The coded soil profile data for ITE Land Classes 1-5 was transcribed to determine whether soil series could be allocated to each description. In most cases this proved impossible for the following reasons :-

1. The data for each horizon was not sufficiently detailed to place the soil in a subgroup.

a) No distinction could be made between full gleys and soils with gleyic characteristics.

b) Inadequate information was available to distinguish argillic characteristics.

c) The depth criteria given do not enable rendzinas to be separated from calcareous brown earths in the SSEW system.

d) The horizon nomenclature differs from that used by SSEW and it is often difficult to determine clearly what the nomenclature means.

2. Classification. Use of only 6 soil groups is restrictive. There are insufficient categories to assist in trying to arrive at a series name from each description. The recording of parent material was sometimes a good clue to series identification, although the summary transcription was often confused and at times totally unrelated to the textural profile derived from the horizon data e.g. 1/188 describes a sandy loam brown earth on undifferentiated clayey drift of Eocene provenance.

5.4.6 Areas where soil series were identified.

In some landscapes the National Soil map and ITE data could be used with confidence to allocate soil series.

From profiles of the 5 land classes that were fully transcribed it was not possible with confidence to name a soil series for more than a few of the descriptions. The best matches were on areas where soils were not in drift, and to a certain extent on reddish parent materials. The lack of basic information about soil water regime and increase in clay down the profile in otherwise similarly textured soils makes identification impossible.

5.4.7 Conclusion

It was therefore concluded the SSEW would proceed to map using the best data available from their own data bases rather than using the ITE sample pit data. It was also agreed that the agroclimatic information for the squares would be produced in due course.

5.4.8 Appendix
Sample squares with detailed SSEW mapping cover

The following section examines ITE sample squares occurring in areas with detailed soil mapping.

1. 1/208 ST7287 Southern Cotswolds 1:63,360 Figure 3

This is a complex area with Carboniferous, Devonian, Jurassic and Triassic deposits 5 units have been distinguished on the soil map. ITE site 1 falls within the Lulsgate unit and the soil is described as a brown earth on Jurassic sandstone with stony silty horizons over bedrock at about 25 cm depth. This is probably a brown earth of the Malham series.

Site 2 falls in the Milbury Heath unit and is described as a brown earth. Milbury Heath soils are seasonally waterlogged loamy over clayey soils, which is not compatible with a brown earth label.

Sites 3,4 and 5 occur within the Denchworth map unit but only the soil description for site 3 is full compatible with Denchworth series. The soil at site 4 is something similar, but with some drift influence. Site 5 describes a brown earth on Jurassic sandstone, and is clearly not Denchworth series.

This is a very complex area of geology and landform, and it is expected that the soil variation will be equally complex. Therefore to agree on three descriptions is felt to indicate moderate level of confidence in the ITE data.

2. 22/743 NY8762 Hexham 1:63,360

The profiles described here are loamy over clayey soils on till derived from Carboniferous rocks. The soils are mapped mainly as Brickfield (Br) and Elrington series(eG). In the accompanying memoir, Jarvis (1977), states that Hallsworth soils are an important inclusion in the map unit in this particular area which supports the presence of clayey subsoils in the ITE descriptions. The essential difference between Brickfield and Elrington soils, that is the presence of gravelly substrates in the latter, is not brought out from the descriptions provided.

3. 1/355 SO8762 Worecester/Malverns 1:50,000

Three similar soils are described at sites 1, 2 and 5 and are identified as Whimple series. Site 1 falls within the Hodnet unit, but Whimple soils are often found intermixed with Hodnet soils. The soils on 2 and 5 fall within the Whimple map unit. The soils at sites 3 and 4 are described as a gley and a brown earth on calcareous Triassic mudstone. Their position in the landscape, however, indicates clearly that these soils are on alluvium and the soil map shows them to.

4. 9/389 SP 4777 Rugby west 1:25,000

This detailed square has 8 different soil types within it plus an area of disturbed ground where limestone has been extracted. The highest ground is uniformly covered by reddish till which has not been identified in ITE site 2. Site 1 is identified as Denchworth series, a common inclusion with Evesham soils, and most of the sites recorded within the Evesham map unit are calcareous throughout. Site 3 is almost exactly the same as the described profile at point 12 (Figure). Site 4 falls within a disturbed area, and 5 also in the same area is identified as an Evesham soil against the road where no excavation will have taken place. Aerial photographs confirm most of the ground in the map unit to be disturbed.

As with many of the ITE descriptions of drift soils the series cannot be clearly identified, but profiles on Jurassic clays can be correlated with SSEW map units.

5.5 Sub-contract report by the British Trust for Ornithology (BTO)

5.5.1 Introduction

The objective of the sub-contract is to provide estimates of breeding bird densities for 50 species which have been selected as being most sensitive to changes in land use.

5.5.2. BTO have visited Merlewood, discussed the methodology and identified appropriate species. Coastal and colonial species were excluded.

5.5.3. BTO have sent Merlewood the base data for the 50 species. Contour maps have been produced and returned to BTO. Some dificulties were experienced with the transfer of data which led to a delay in the programme. Two examples of the maps are provided below.

5.5.4. BTO are currently about half way through the processing of the data and will shortly be producing some worked examples for ITE to comment on. These will be circulated at the advisory group meeting.

5.6 Sub-contract report by the University of Edinburgh

5.6.1 Solid geology and drift

The Department of Geography at the University of Edinburgh has a variety of databases and Geographical Information Systems (GIS). The contract involved the creation of a database containing information on both solid geology and drift based on $1km^2$ classified by the ITE Merlewood land classification system.

5.6.2 Programme

The work program consisted of :-

i. transferring data from ITE to Edinburgh giving details of the grid references and land classes of the $1km^2$.

ii. Designing and creating a data structure which was suitable for holding and manipulating the data and was acceptable to ITE. It was decided that the ORACLE database system was the most suitable system for holding the data since it provides excellent performance and flexibility. ORACLE had the added advantage in that it is used by both ITE and Edinburgh.

iii. Data capture. As there is no complete and uniform electronic database of either solid geology or drift which covers Great Britain data was captured from maps. To ensure even coverage the most recent edition (1979) of the BGS 1:625 000 Geological Map and the BGS 1:625 000 Quaternary Deposits were used. The grid coordinates were sampled in blocks of 100 km^2 using GIMMS mask files and the GEOLINK software overlays were produced either as acetates or for use at a light table. The geology or drift was then manually scored and entered into the database.

iv. Transfer of the data set to ITE. Using JANET (Joint Academic NETwork) the database was transfered within ORACLE onto the MicroVAX 2 at ITE Merlewood.

5.6.3 Conclusions and comments

Within the limitations of the method of data capture and the precision of the souce data the exercise has produced a uniform level of infomation for 5130 1km^2.

Addenda

Apendix 1. is in section 5.4.8

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TABLE

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	2 OILSEED RAPE	[illegible]	7	130
	3 OTHER CROP	18	8-15,21-23	121-128,131-133, 135
(B) ORCHARD			20	-
(C) GRASSLAND	1 LEY	10	31 (60-63)	101 (151,152)
	2 IMPROVED	57	32[30,37] (61,62,63)	102 (152)
	3 PERMANENT	8	32,34,35[30,37] (64-67,75-76)	102,106 (153-157)
	4 UPLAND/MARITIME	61	33,36 (75,76,[80-81])	103,107 (156-157[158])
(D) BRACKEN		41	57 (80-82)	103 (158)
(E) WETLAND	1 EUTROPHIC WETLAND	24	40,41,43-45,47 [46] (68,[83])	112-114 (159)
	2 BOG	21	42, [46,40] (84-88 [83])	111, 115 (165-168 [169])
(F) MOORLAND/HEATHLAND	1 GRASS MOOR	29	50 (77,78,83)	104 (160,161,164[169])
	2 DWARF-SHRUB	53	51,54 (89-92)	105,108 (162,163)
(G) WOODLAND	1 BROADLEAVED	48	110,111,113	221-231,234
	2 CONIFEROUS	46	110,111	211-220
	3 SHRUB	52	112	206
	4 CLEAR FELLED		118	263
(H) DEVELOPED LAND		69	140,145,24,25	351-362,401-407, 441-449,461-473
(I) QUARRIES		6	141	423
(J) OPEN WATER		27	134	36-42 , 109
(K) OTHER		[illegible]	55,56,130-133,135,147	

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NOTE: Improved distinguished from permanent by dominance of *Lolium perenne* (61) or other agricultural (ie. sown) grasses.

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			sinx/x	3-5	
	all	21.10.84*	n/n	1-7	
	all	02.05.85*	uncorrected		
01/24	all	12.04.84	n/n	1-5	3
	all	21.10.84	both	3-5	3
	all	02.06.85	uncorrected		
01/25	1,2	12.04.84	sinx/x(Q2)	3-5	3
02/23	all	04.02.83	uncorrected		10,11
	all	08.07.84	both	3-5	
	all	28.06.85*	uncorrected		
02/24	all	04.02.84	sinx/x	3-5	10,11
	4	20.06.84	sinx/x	3-5	
	2	08.07.84	uncorrected	3-5	
	3	08.05.85	sinx/x	3-5	
02/25	1,2	08.07.84	uncorrected		3
03/22	1,3	26.04.84*	uncorrected		20
	1,3	31.05.85	n/n	3-5	
			sinx/x	1-7	
	1,3	02.05.86	uncorrected		
03/23	all	26.04.84	sinx/x	3-5	10,11,20
	all	31.05.85*	uncorrected		
	all	02.05.86*	uncorrected		
	all	21.01.86*	uncorrected		
03/24	3	26.04.84	sinx/x	3-5	6
04/20	1	13.10.85*	sinx/x	3-5	26
04/21	1,3	14.09.86*	both	3-5	20
04/22	all	30.09.86	sinx/x	1-7	20
04/23	2	16.10.86	uncorrected		
04/24	all	22.07.84*	n/n	1-7	17
			sinx/x	3-5	

204/25	1,2	20.06.84	sinx/x	3-5	6
205/19	1	13.05.85•	sinx/x	1-7	32
205/21	4	23.10.86•	uncorrected		20
205/22	2	03.07.86	uncorrected		20
	2	15.05.86•	uncorrected		
206/18	2	24.06.86•	uncorrected		32
208/19	4	22.06.86	uncorrected		32

•Priority

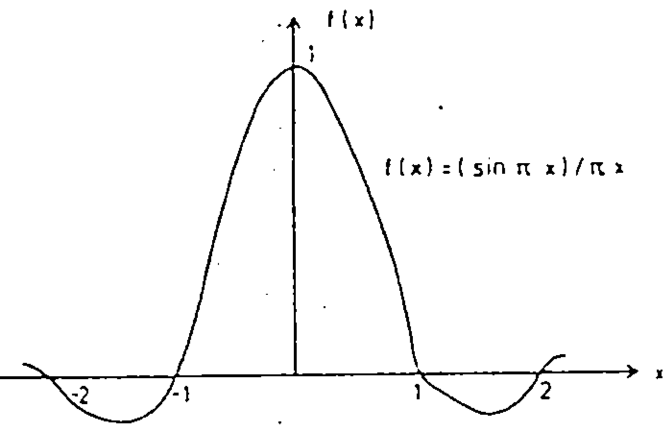
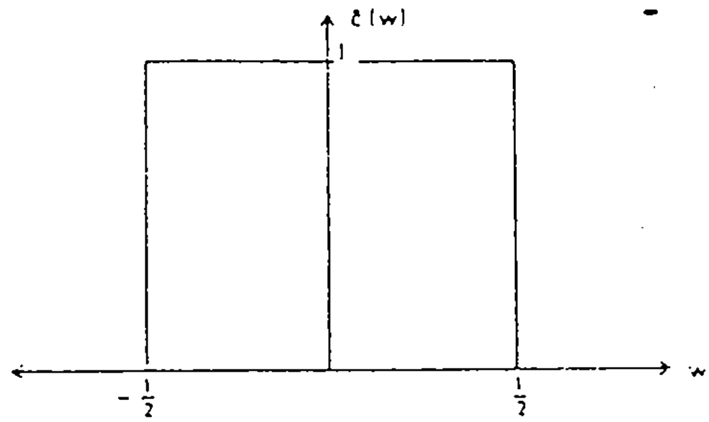


Fig 1 Ideal kernel



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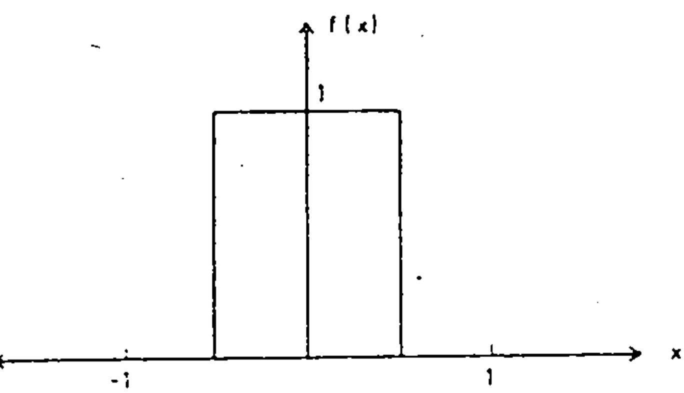


Fig 2 Nearest neighbour kernel

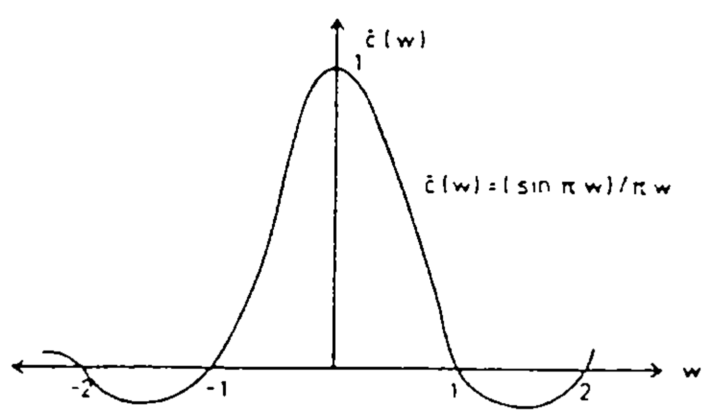


Fig 2 Nearest neighbour transform

SOURCE: WILLIAMS, 1979

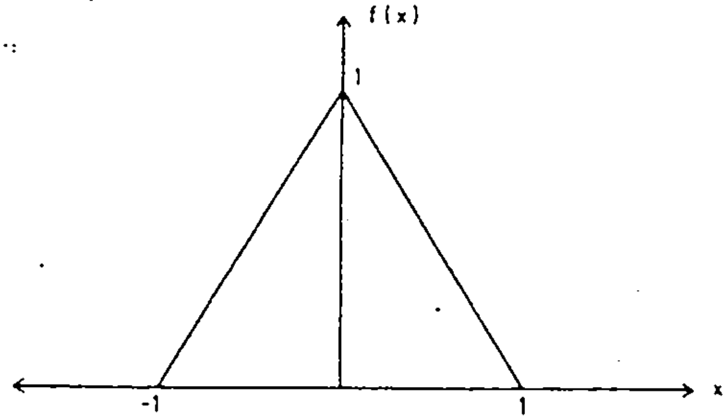
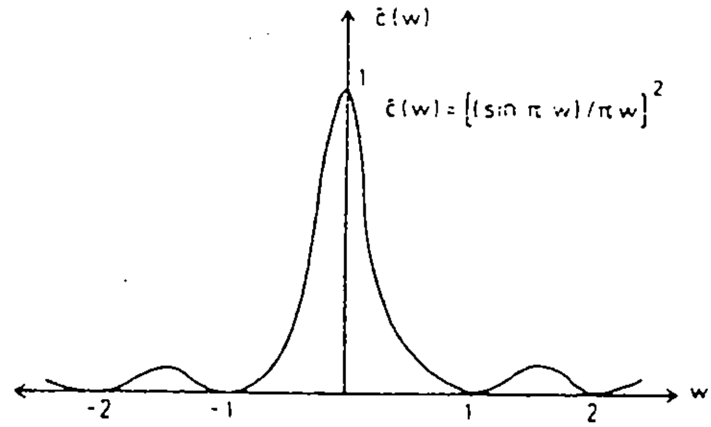


Fig 3 Linear kernel



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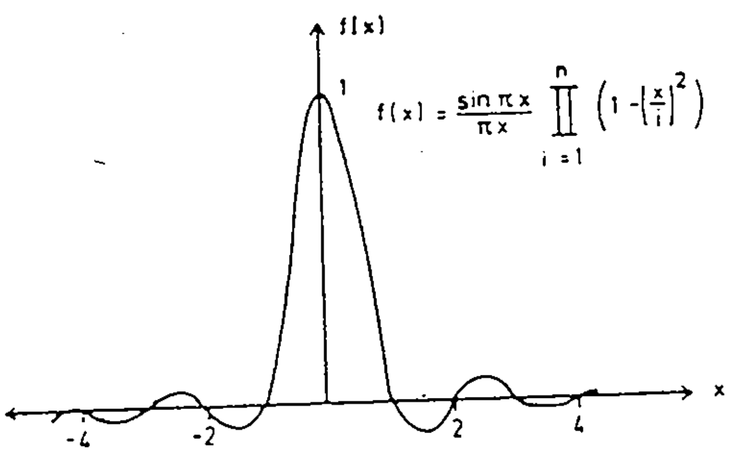

Fig 4 Shlien kernel

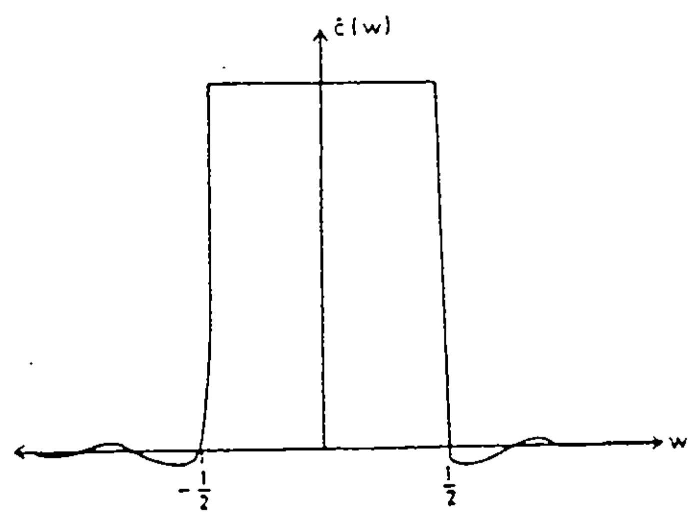

Fig 4 Shlien transform

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Workshops - arranged

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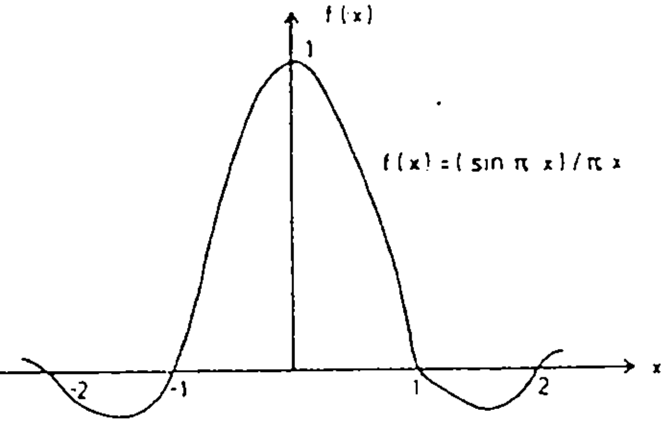
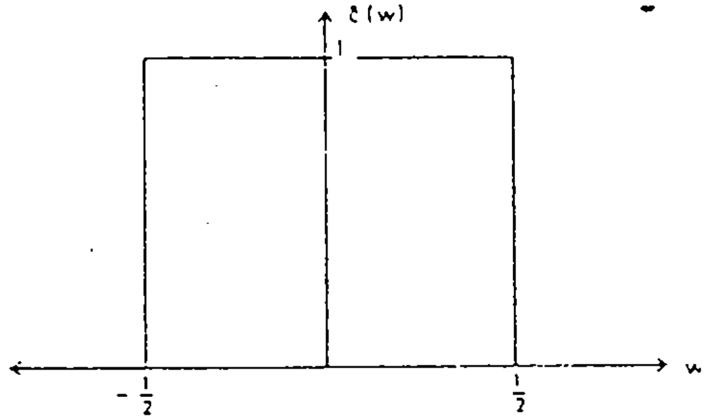


Fig 1 Ideal kernel



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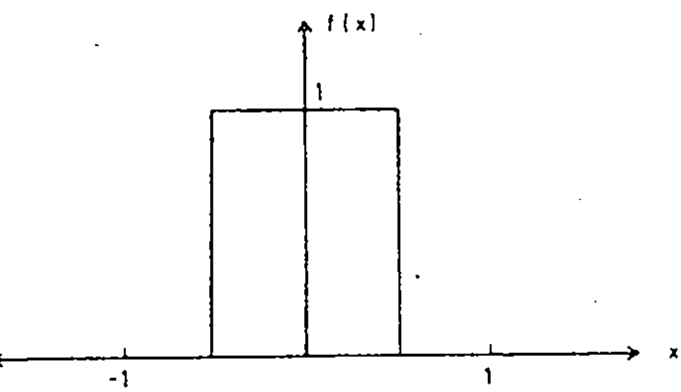
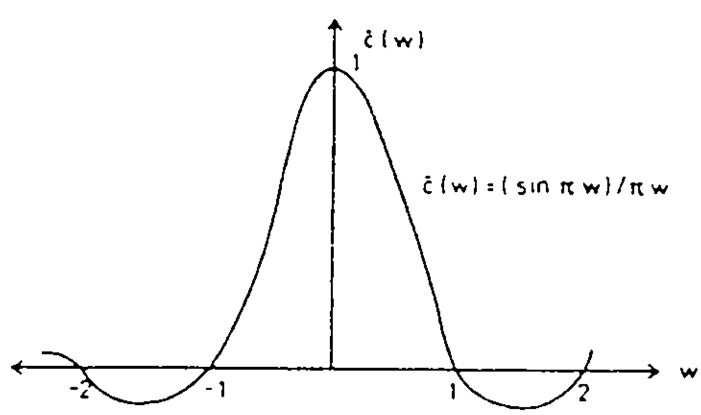


Fig 2 Nearest neighbour kernel



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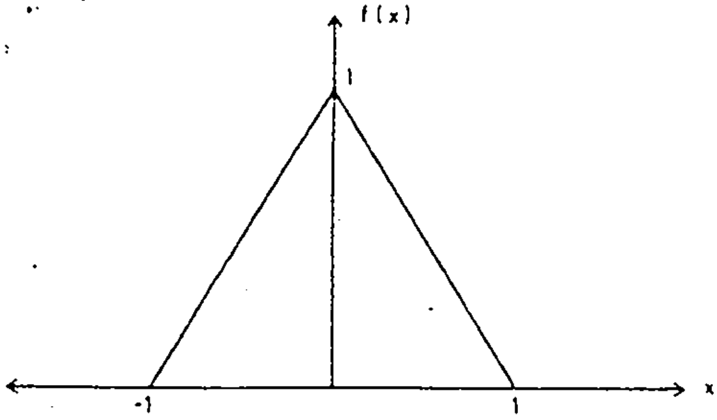
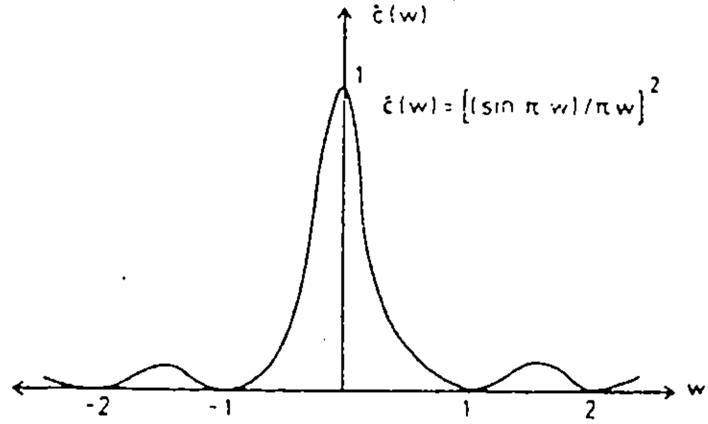


Fig 3 Linear kernel



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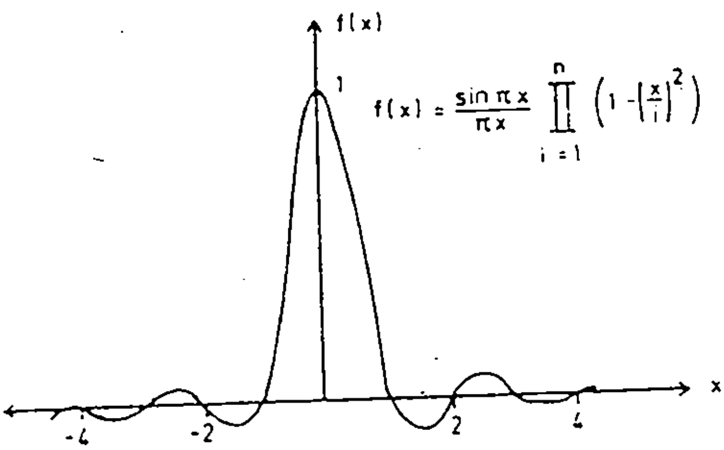
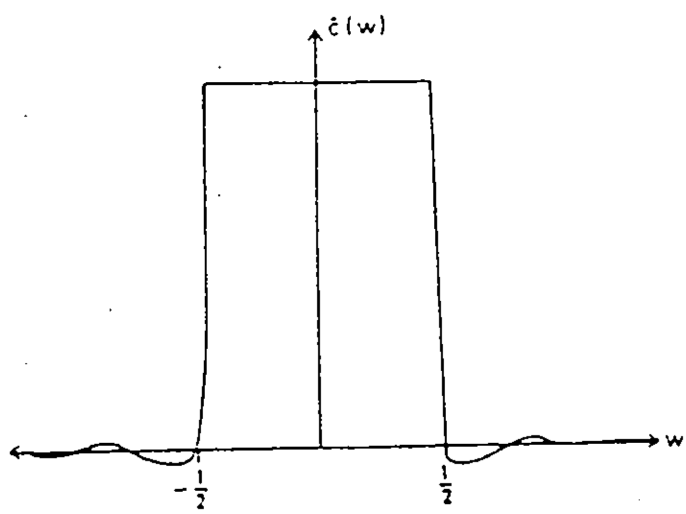


Fig 4 Shlien kernel



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