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MAKING TRACKS: MODELLING DISTURBANCE BY MILITARY VEHICLES OF THE LANDSCAPE OF SALISBURY PLAIN

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Dedication

Thanks go to the following for their invaluable advice and assistance with this project:

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Richard Wadsworth, for his fund of good ideas and clarity of thought in helping me see the wood through the trees;
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Abstract

The chalk downlands of Salisbury Plain have been used by the Ministry of Defence as a training area since 1897. The Plain contains approximately one-third of all the calcareous grassland vegetation in western Europe. While this valuable and rare habitat has thus been preserved from agricultural intensification, it is highly vulnerable to disturbance by military training using armoured vehicles.

This paper describes research into:

a) estimating the vegetation resource and conservation value of the Plain by combining ground- and air-surveyed vegetation data into one image using correspondence values to decide on classification where the source data do not concur:

b) predicting the concentrations of military training vehicle traffic on the Plain by modelling factors relating to vegetation and topography perceived as likely to influence the tactical movement of armoured vehicles;

c) estimating the locations of sites of high conservation value at risk from military activities by combining conservation value with factors influencing vehicle movements and models of other risk factors.

This research shows how two disparate sources of data on the same subject can be utilised in conjunction with a combination of simple GIS operations to produce a useful predictive model, and some of the advantages of, and problems with, this type of approach. It provides an example of how the scope for decision making in the management of the Plain can be increased from that offered by more conventional approaches.

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1 Introduction

1.1 Context of Research

1.1.1 Why Salisbury Plain is Important

Salisbury Plain contains approximately one-third of the entire calcareous grassland habitat in western Europe. This habitat type supports a variety of rare flora and fauna and has diminished elsewhere over recent decades due to agricultural intensification (Porley 1986).

Calcareous grassland habitats exist on soils which are rich in calcium but comparatively deficient in nitrogen and phosphates, and are distinguished by their diversity of species (Proctor 1981). Traditional agricultural practices on this type of land generally involved extensive grazing of sheep. This tended to keep the nutrient balance at a suitable level for continuing survival of the calcareous grassland species.

Modern intensive agricultural practices involve applying fertilizers to the ground to increase the nutrient value of the soil and hence allow the production of greater yields. Fertilization alters the nutrient balance and causes the calcareous grassland species to be replaced by more common mesotrophic grassland species. Agricultural intensification has not happened on much of the Plain, allowing the continued survival of large areas of calcareous grassland.

1.1.2 Why Salisbury Plain is at Risk

The Ministry of Defence (MoD), and before them the Ministry of War, has used the Plain for the past hundred years. This has been a major factor in preventing agricultural intensification. Areas used for live firing exercises are unusable for agriculture for obvious reasons and cropping and management regimes on areas let to farmers are tightly regulated (Porley 1986).

The increasing reliance on armoured vehicles for protection, firepower and mobility since the Second World War has been reflected in the types of training exercises carried out on the Plain. Whilst foot-borne infantry and horse cavalry cause relatively little disturbance to the landscape unless concentrated in large numbers, armoured vehicles can weigh over 50 tonnes and a single vehicle can very easily compact and shred turf and underlying soil. Figure 1.1 shows examples of disturbance caused by vehicles on the Plain.

Ongoing research by the Institute of Terrestrial Ecology (ITE) (Hirst *et al.* 1998) using chronological sequences of aerial photographs suggests that an intensification of training activity on the Plain caused by loss of training sites elsewhere has resulted in an expanding network of trackways and areas of bare soil. Whilst grassland can often recover from disturbance, and low levels of disturbance may be beneficial to calcareous grassland, recovery times lengthen with the extent of damage. Too great a level of disturbance may result in permanent loss of habitat and severe soil erosion.

Figure 1.2 shows bare ground areas extracted from remotely-sensed data (Section 3.2.1.2) and gives a good impression of disturbance patterns across the Plain. The bare fields generally correspond with cultivated land. Although some of the linear patterns in the image follow the lines of mapped roads and tracks, the image gives a stark indication of which areas of the Plain are heavily trafficked.

Figure 1.1a: Imber Valley (SPTA West); OS grid ref. 396600 149100

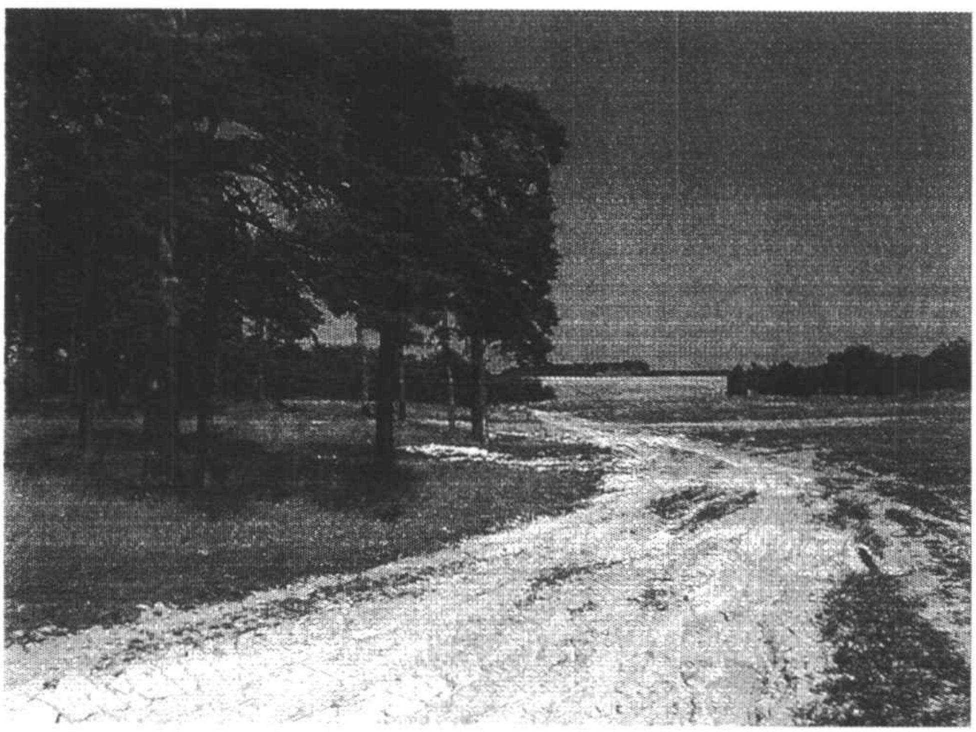


Figure 1.1b: Haxton O (SPTA East); OS grid ref. 419300, 150600

Figure 1.1: Typical areas of disturbance on the SPTA

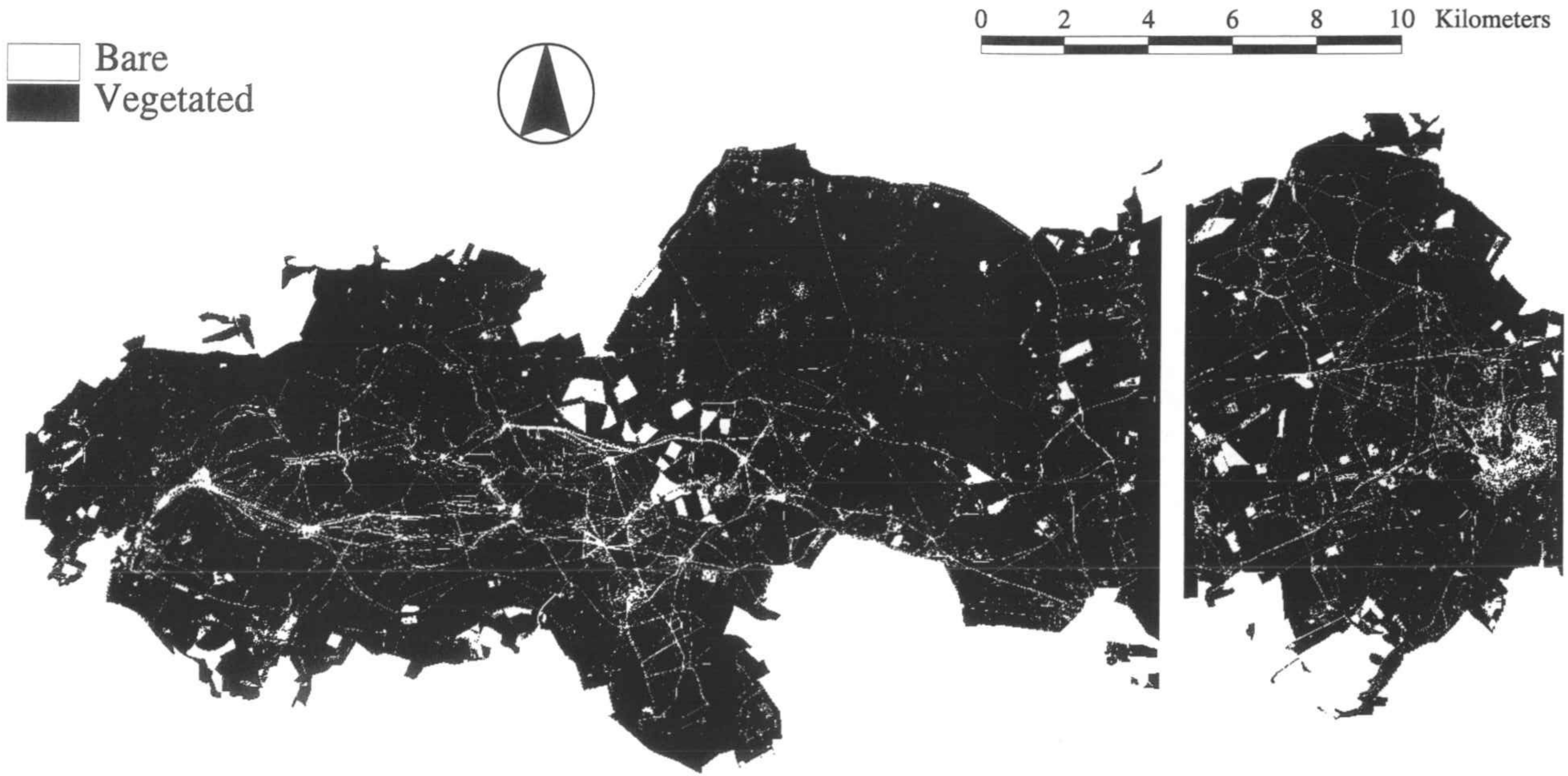


Figure 1.2: Disturbance patterns on Salisbury Plain Training Area

1.2 Research Objectives

This thesis has three objectives:

a) to estimate the vegetation resource of Salisbury Plain using data obtained from contemporaneous ground and air surveys, so that conservation values over the Plain can be derived.

a) to estimate the impact of military training on the Plain, by modelling factors perceived as likely to influence armoured vehicle movements during battle simulation exercises, in order to predict levels of traffic intensity and therefore risk of disturbance from this source.

b) to estimate the locations of sites of high conservation value at risk from military training activity using off-road vehicles.

1.3 The Salisbury Plain Training Area (SPTA)

1.3.1 Location

Salisbury Plain is an area of chalk upland covering about 128 000 ha, situated in the Counties of Wiltshire and Hampshire in southern England. It stretches between Ludgershall in the east and Warminster in the West, Amesbury in the south and Market Lavington in the north. The SPTA itself occupies just under 30% (36800 ha) of the Plain. (Porley 1986).

1.3.2 General description

Figure 1.3 shows typical Salisbury Plain landscapes. Geologically, the Plain consists of a block of chalk between 180 and 200 metres thick, dissected by two major river valleys. The topography is typically undulating, with rounded

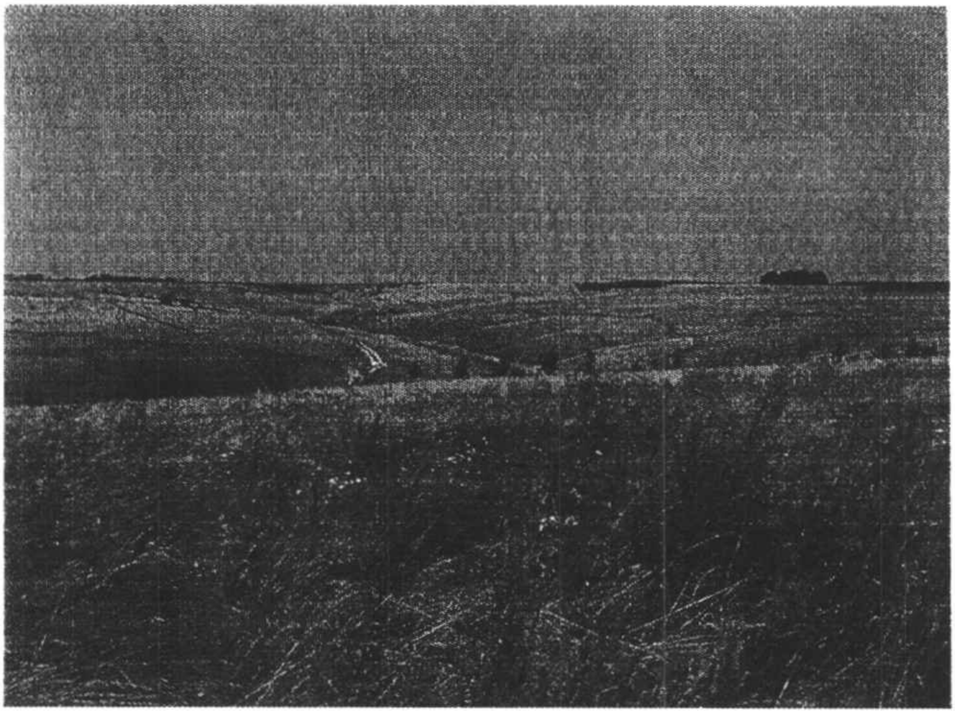


Figure 1.3a: SPTA West; OS grid ref. 398300 149000

Figure 1.3b: Sidbury Hill (SPTA East); OS grid ref. 421600, 150800

Figure 1.3: Typical Salisbury Plain landscapes

slopes and dry valleys. Altitudes range from less than 100m in the valleys to over 200m on the hilltops (Figure 1.4). The vegetation on the Plain consists of a mixture of calcareous and mesotrophic grassland, arable, scrub and woodland. The Plain was heavily occupied in pre-historic times and a large number of archaeological sites remain. Just over half (20000 ha) of the SPTA is within Sites of Special Scientific Interest (SSSIs).

1.3.3 Military and management activities

Use of the Plain as a military training ground commenced in 1897, when the War Department (now Ministry of Defence) recognised the terrain's suitability for cavalry and infantry training and purchased land around Market Lavington (Porley 1986). Over time, the Ministry's holding increased to its present size and the SPTA is now the Ministry's largest training area in the British Isles. Management of the SPTA is carried out by the Defence Estate Organisation (DEO) on behalf of the MoD.

The SPTA consists of three main areas, divided by the north-south valleys of the Rivers Avon and Till: SPTA West (Imber ranges), Larkhill and Westdown, and SPTA East. The west and east areas are used for training of military units, whilst much of the central Larkhill and Westdown area is termed the "Impact Area" and is used for live firing of artillery and missiles. Various restrictions on the types of training permitted are in force on areas such as SSSIs, archaeological sites, tenanted farmland, immature plantations and land close to public highways (Porley 1986).

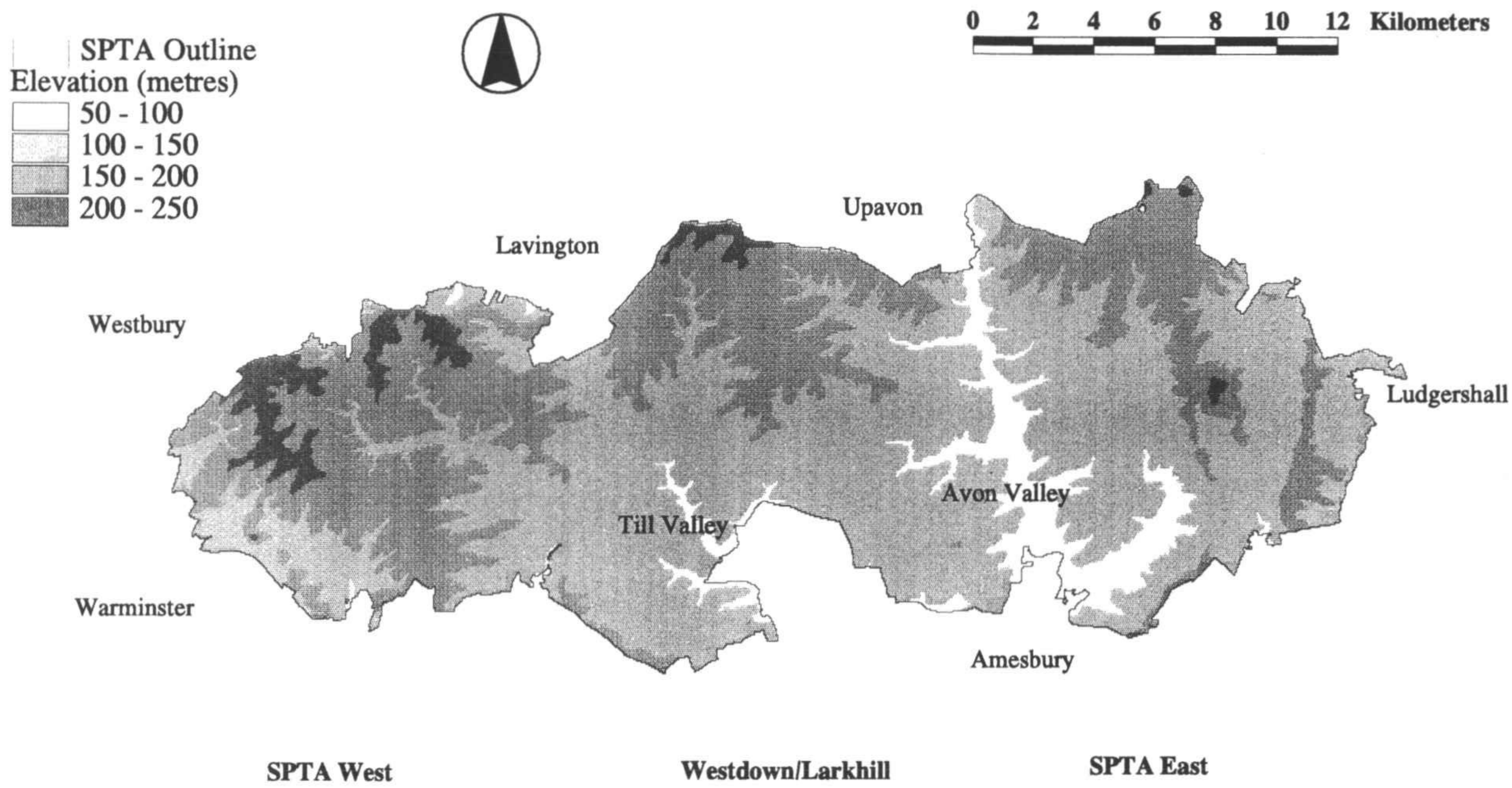


Figure 1.4: Topography of the Salisbury Plain Training Area

Approximately 8100ha of the SPTA are let on full agricultural tenancies, with full freedom of cropping and eligibility for compensation if damage caused by military activity (Schedule 1 land). Another 18200 ha are let on licence with restrictions on cropping and no eligibility for compensation (Schedule 3 land). Forestry occupies around 2000ha, consisting mostly of scattered plantations, established for training and amenity purposes. (Porley 1986).

1.3.4 Data available

Data available for this project consists of the following:

a) Ground surveyed vegetation data, classified in accordance with the National Vegetation Classification (NVC).

b) Air surveyed vegetation data, derived from airborne remote sensor and classified into categories broadly corresponding with NVC community types.

c) Data relating to management and military use of the SPTA, in digital and paper form.

d) Digital terrain model.

Items a and b in above were produced as part of a commission for the DEO, undertaken by the ITE in conjunction with Messrs. Frank Graham, Consulting Engineers. The commission's objectives were to;

a) map the present habitats of the SPTA
b) allow identification of future management requirements
c) establish a baseline from which to monitor future changes

(Pywell 1996). The methodologies of these surveys and the datasets in general are described in further detail in Chapter 3 of this paper.

1.3.5 Previous studies

A previous study of the vegetation of the Plain, concentrating on the chalk grasslands, was carried out by English Nature (Porley 1986) from May 1985 to September 1986. This concluded that much of the calcareous grassland on the Plain was in need of protection because of its scarcity elsewhere, and recommendations were made for the establishment of new SSSIs.

1.3.6 Other current studies

A study is currently being carried out by the ITE in conjunction with Liverpool University into habitat regeneration mechanisms and critical disturbance thresholds on the Plain. As part of this work, an examination of the disturbance regimes on sample tetrads were undertaken, using chronological sequences of aerial photographs (Hirst *et al.* 1998). This concluded that increases in training activity over several years had caused increased levels of disturbance to vegetation and soils.

2 Literature Review

2.1 Literature pertinent to objective A

Research objective A is to estimate the vegetation resource of the SPTA, so that estimates of conservation value can be made in furtherance of objective C. Air-surveyed and ground-surveyed data relating to the same area and gathered at approximately the same time are available, but the differences between the two survey techniques has inevitably resulted in discrepancies between the two datasets. This section of the literature review examines ways of handling error and uncertainty in spatial data.

Information about the methodologies of the ground and air surveys from which the vegetation data used in this project was obtained is contained in Pywell (1996). Wilson (1997) describes in general terms the remote sensing system used for the air survey.

Much has been written on the subject, and there seems to be some overlap between the terms "error" and "uncertainty." Chrisman (1989) defines error as "...the deviation of our representation from the actual state of affairs". Geertman and Ruddijs (1994) suggests that although error is usually perceived as a loss of accuracy, an alternative view is that of "...a form of inherent uncertainty in some abstracted characteristic of the real world." They make the point that "A map...forms a model of the real world, which is necessarily incomplete and generalised." In other words, a map is designed for a specific task by a specific user.

Hunter and Goodchild (1994) propose that a distinction should be made between "error" and "uncertainty," as the former implies that something is known about the differences between reality and results (and the reasons for those differences), whilst the latter suggests a lack of such knowledge. They suggest that the term "uncertainty" "...denotes a lack of sureness or definite knowledge about an outcome or result..." and offer the synonyms "doubt," dubiosity," "scepticism," and "mistrust."

A number of authors attempt to categorise the sources of error/uncertainty. Salski *et al* (1996) state that uncertainty in ecological research results from; "...presence of random variables, incomplete or inaccurate data, estimations instead of measurements...incompatibility of data...qualitative instead of quantitative information and subjectivity of expert knowledge." Goodchild (1989) and Goodchild and Wang (1989) detail a number of examples of error sources, including digitisation and representation of abstract objects.

A number of authors examine ways of assessing the accuracy of a classified raster image with reference to ground truth, so that allowances can be made in subsequent analyses. This is usually done by cross-tabulating encoded and actual values for a set of sample locations in a matrix (Forier and Canters, undated). Various indices of error can be derived from the fact that elements on the main NW-SE diagonal in the matrix are correct, whilst elements off this line are not. The most basic index is proportion correctly classified (PCC), which consists of the sum of the diagonal elements divided by the number of samples, i.e. $\theta_1 = \sum_i c_{ii} / N$

where c_{ii} is the total in each "correct" element on the main diagonal, and N is the total number across all elements.

A slightly more advanced measure is Cohen's coefficient of agreement, or Kappa (Cohen 1960, cited in Finn 1993). This adjusts for values which are correct by chance, and is calculated by the equation

$$\kappa = \frac{\theta_1 - \theta_2}{1 - \theta_2}$$

where θ_1 is the pcc value as defined above and $$\theta_2 = \sum_i \left(\sum_i c_{ij} \sum_i c_{ji} / N^2 \right),$$

i.e. the proportion correct by chance.

PCC and Kappa can also be applied to individual rows and columns in a matrix, thus allowing thematic differentiation of differences between the two sources.

A number of terms are used to describe the matrices resulting from cross-tabulating values. Forier and Canters (undated) refer to confusion or classification accuracy matrices to describe the correspondence between encoded and actual values; whilst Finn (1993) terms this type as an error matrix, and argues that this term is only valid where truth is one of the comparisons. Where one map is compared against another, he uses the terms "contingency table" and "comparison matrix".

Visualisation of uncertainty is less well documented. Forier and Canters (undated) suggest a number of approaches, including showing not only the "most likely" classes for each pixel, but also the second "most likely" etc. Also, a probability image can show the highest (or second highest, etc...) membership probability value for each pixel, to allow study of the relationship between probability values and classes. Kiiveri (1997) suggests using a series of grey-scale images, each containing probability values for a different class; three of these could be displayed simultaneously by assigning one image to each colour gun of a colour display monitor.

A number of different approaches to extracting information relating to the differences between one map and truth, or between two maps, have been described. Whilst these would allow advanced and detailed analyses of the differences between the ground and air surveyed datasets to be carried out, the objective in this case is to combine information from both datasets and reduce levels of uncertainty. For simplicity, it was decided to adapt the PCC index (Forier and Canters, undated) for use in this project, but referring to "classification correspondence" rather than "classification correctness"

2.2 Literature pertinent to objective B.

Objective B is to measure the impact of military training involving armoured vehicles on the SPTA. For this, information is required on the nature of the impacts of the movement of vehicles across vegetated surfaces, and the factors determining travel routes during military training exercises.

Terminology relating to the sorts of vehicles involved in off-road military operations is complex. The word "tank" is often used as a generic term. The word was first used by the British forces in the First World War to conceal, as far as possible, the true purpose of the first machines before they saw action, and for want of any better description the term stuck thereafter (Harris 1995). However, the increased mechanisation of land warfare during and since the Second World War has resulted in the evolution of vehicles designed to support and complement tanks, such as armoured reconnaissance vehicles, armoured personnel carriers, self-propelled guns, mobile anti-aircraft systems, bridgelayers and armoured recovery vehicles (Foss 1992). The phrase "armoured vehicle" is a more appropriate generic term.

It might be assumed that information concerning the equipment used by armed forces in the interests of national security would not be readily available. However, much is published about the "vital statistics" of armoured vehicles. Aldino (1992) gives basic details of dimensions, performance and armaments for most types of armoured vehicles from many countries. Foss (1992) is more comprehensive in terms of information provided for each vehicle and in the numbers of vehicles covered.

Less information is available about the technological principles concerning armoured vehicle design. However, these are discussed in detail in Ogorkiewicz (1968). He describes the design process as a series of complex compromises between firepower, protection and mobility. For example, the apparently simple trade-off between weight of armour and vehicle performance is complicated by the fact that the weight of the vehicle determines its ability to absorb gun recoil forces and hence limits its potential firepower. He also discusses issues relating to tracks, suspension, transmission and steering systems, which all relate to ground disturbance. Whilst the technology has progressed since then, comparison with Foss (1992) suggests that radical developments have been more concerned with electronics for weapons control and communications, whilst propulsion technology has changed little.

Much information is available on the evolution of armoured warfare tactics from a historical perspective. Harris (1997) gives a detailed account of the development of tactics up to the second world war; however, armies at this time had yet to realise the true potential of mechanisation and tactics of the time differ greatly from those current.

Murray (1995) attributes the introduction of modern armoured vehicle tactics to the Germans, whose analyses of their defeat in the First World War led to innovative and forward-thinking use of technology in the Second, whilst the British army suffered from lack of funding and complacency. The German *panzer* divisions in the Second World War, combining tanks with infantry in armoured transport, and other mobile weaponry, geared the tempo of fighting to the tanks rather than the infantry, resulting in a versatile, powerful and highly mobile force.

Perhaps the most useful source of available current information on tactics is the U.S. army. Their field manual is published on the internet and gives detailed and up-to-date information on battlefield tactics (United States Army 1996). Emphasis is given for drivers to use terrain for cover and concealment, though operations in close terrain such as built-up areas and dense woodland increase vulnerability to attacks by concealed infantry at close quarters. In particular, travel along low ground is preferred to hilltops and ridges to prevent exposure, but high ground provides clearer fields of observation and fire. Another factor to be considered is that of selecting a site with a background such as trees, that will break up the silhouette of a vehicle. It can be reasonably assumed that the British Army follows similar principles.

Future developments in armoured warfare are discussed by Orme (1997). He forsees an increase in information technology to increase timely awareness of battle situations, reducing the numbers of manned weapons systems whilst increasing the power of those that remain, and moving from a linear to an areal approach in the context of increasing demand for peacekeeping and humanitarian relief operations.

The use of computers in modelling military activities is nothing new (Hardman 1998). Operational research techniques and system dynamics modelling have been used for some years to assist in developing tactical and strategic approaches to changes in technology and perceived threats. Hardman describes a newly developed system which uses MapInfo on a PC environment to simulate infantry battle situations, and intentions to extend this to armoured vehicles.

The increasing use and capabilities of electronic surveillance technology will bring new methods of detecting vehicles in the field, and thereafter new methods of avoidance of detection. However, it can be reasonably assumed that the use of terrain and vegetation for cover and concealment will remain fundamental factors in the movement of vehicles on the battlefield, and therefore these should be the significant components of the model.

2.3 Literature pertinent to objective C

The third research objective is to allow the identification of important sites at particular risk from military activity. This has two aspects; determining the importance of individual sites in terms of conservation value, as related to vegetation communities, and combining with the level of risk that each site is exposed to.

Most published information on management of military training areas comes from the US military. In particular, the United States Army Environmental Center (USAEC) (1997) provides detailed information on current policies and methodologies. Their approach is to allocate activities to sites based on criteria such as cover, concealment and trafficability, monitor levels of disturbance and carry out a rolling programme of resting sites using natural or artificial regeneration methods.

The selection of sites to rest, revegetation methods and durations is a difficult management problem. Removal of sites from active use increases pressures and therefore disturbance levels on other sites. Tucker *et al* (1998) describes an approach using linear programming techniques incorporating factors such as rehabilitation regime and vegetation type to produce an optimal schedule of treatment.

The vegetation data used in this project is categorised according to the National Vegetation Classification (NVC). The NVC was conceived in the 1970s as an overall framework to coordinate the increasing production of phyto-sociological data. The project was coordinated by Dr. J. S. Rodwell, with funding from the Nature Conservancy Council, and resulted in a systematic and comprehensive account of all natural, semi-natural and major artificial vegetation types found in the UK (excepting Northern Ireland). The classifications are described in a five-volume set (Rodwell 1992). The introduction to each volume documents efforts during the century to improve the way vegetation is described, culminating in a brief history of the NVC project.

The basic units of the NVC are termed "communities," with "sub-communities" and "variants" as second and third tiers. What defines a community is not just the combination of particular plants, but the abundances of those species. The main community type of interest for conservation in the context of this paper is what Rodwell (1992) terms "calcicolous grassland". He defines this community type as that in which calcicoles (plants restricted to soils containing high levels of calcium) are prominent. However, the term "calcareous grassland" is used by earlier authors (Porley 1986; Proctor 1981), as well as the project data, to describe this vegetation type; "calcicolous" refers to the individual plant species, "calcareous" to the plant communities. The term "calcareous" is used hereafter in this paper.

Whilst calcareous grasslands are commonly associated with limestone geology, Rodwell (1992) argues that "It is variations in climate...which appear to be of prime importance in determining the composition and distribution of the communities", these variations operating both directly upon the plants and indirectly through soil development. Also influential in maintaining calcareous grasslands is land use, such as continual grazing by herbivores. Mesotrophic grasslands are more productive than calcareous and tend to be found on more neutral and acid soils. Mesotrophic grassland species also tend to be found in areas with a greater level of agricultural interference, such as heavy grazing and improvements such as fertilization, reseeding and drainage.

Porley (1986) gives some useful contextual information about the Plain, particularly regarding the history of military use and land management policy, besides a basic description of the calcareous grassland vegetation type and arguments for its conservation.

To allow the risks and significances of environmental disturbance on SPTA to be assessed, information relating to different factors has to be processed and combined.

Krishnan (1994) documents the successful application of a GIS in modelling oil spill pollution in the Shetland Islands. The model consists of a series of thematic coverages, containing information such as coastal features and habitats. Each coverage can be analysed in isolation or in combination with any of the others. He describes the advantages of GIS use over paper maps, in terms of easier updating and potential for customised queries and analysis.

Some authors argue for an elaboration of this type of approach, using fuzzy methodologies. Heuvelink and Burrough (1993) state that "...Boolean methods of sieve mapping are much more prone to error propagation than the more robust continuous equivalents." They suggest transforming data to a continuous scale where the value refers to the degree of membership of a particular class or property. Besides a reduction in sensitivity, this approach allows greater flexibility by "...allowing users to define flexible class membership functions that match practical experience."

A simplified version of this approach is described by Bertozzi *et al* (1994), to model soil vulnerability to pollution in the Po Valley region of Italy. Thematic maps were produced for each factor in the analysis, each divided into classes representing different degrees of vulnerability. These ranked layers were weighted and combined, and the result reclassified to give an overall vulnerability map.

This section of the literature review has covered a variety of topics, related to the objective of assessing the risk of disturbance to SPTA and the significance of that risk. It can be concluded that the finished product should allow identification of areas that may be valuable and at risk, and areas of little value; activities should be diverted from the former to the latter. Areas of calcareous grassland are most important in terms of conservation value (Porley 1986); therefore disturbance in these areas is more significant than disturbance of mesotrophic grassland.

Arguments have been made for use of fuzzy methodologies; whilst an attractive concept, it was felt that limitations of time would preclude a suitably thorough approach and therefore a simple stratification of risk and significance values was adopted.

3 Methodology

3.1 Preamble

3.1.1 Restatement of objectives

a) To estimate the vegetation resource of Salisbury Plain so that conservation values can be derived.

b) To estimate the impact of military training on the Plain, by modelling factors likely to influence vehicle movements during battle simulation exercises to predict traffic intensities and hence likelihood of disturbance.

c) To estimate the significance of risk across the SPTA, by identifying and modelling perceived sources of risk and conservation values.

3.1.2 Hardware used

Sun Unix workstations were used for GIS analyses and production of imagery. Other work, such as spreadsheet and word processing, was carried out on PCs.

3.1.3 Software used

Processing of spatial data was mainly done using Arc/Info version 7.1.1. ArcView 3.0b was used for preparation of illustrations and converting stored data into suitable formats for import into Arc/Info. Spreadsheet work was done using Microsoft Excel 97 and word processing on Microsoft Word 97.

3.2 Estimating the vegetation resource of Salisbury Plain

3.2.1 Data

3.2.1.1 Ground surveyed vegetation data

This was carried out between May and September 1996 and 1997 by teams of botanical surveyors. The survey area had been divided into 1800 management compartments by the DEO for digitisation and generation as a vector polygon coverage in Arc/Info format prior to the survey. Each compartment was walked and quadrats taken to identify and map the NVC communities. Approximately 5000 quadrats were recorded, a random sample of which were located using a Global Positioning System (GPS). Data was entered onto Microsoft Excel 5.0 spreadsheets for error checking and basic statistical analyses, then transferred to an Arc/Info database to be linked to the compartment polygon coverage. Areas of highly disturbed vegetation varying greatly over a small area were recorded as mosaics of the component communities (Pywell 1996).

The spatial data had been stored as an ArcView shapefile. A database file had been created to provide legend categories, with other data files containing attributes and an ArcView project file in the same directory linking them together. Figure 3.1 shows the coverage. The shapefile, attribute and legend files were copied into the working directory and imported into Arc/Info, then joined to allow the legend categorisations to be used in processing.

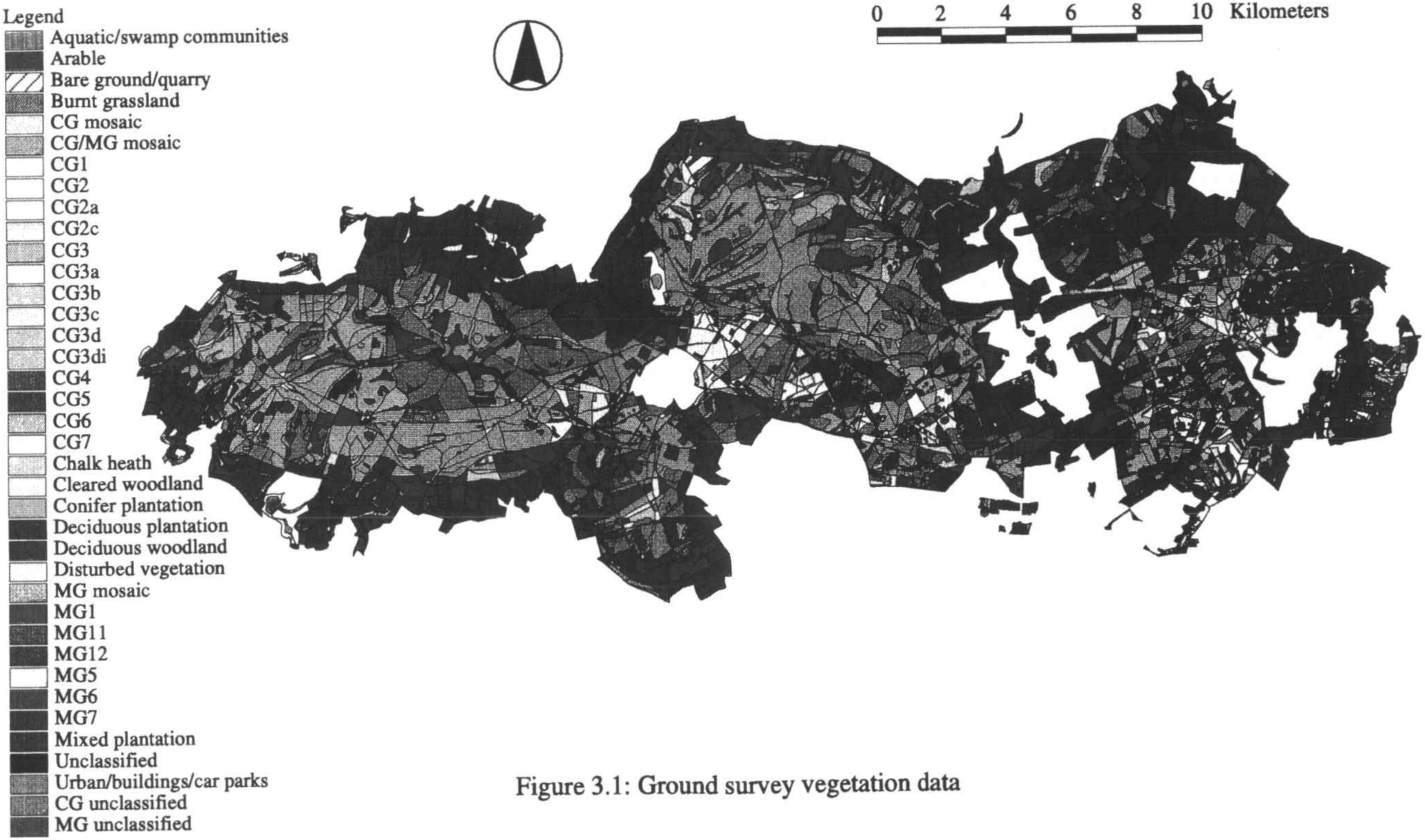


Figure 3.1: Ground survey vegetation data

3.2.1.2 Air surveyed vegetation data

This dataset was gathered as an exercise in evaluation of the use of remote sensing techniques for identification of NVC community types (Pywell 1996). The survey was made on a series of flights over two days in April 1996, using the Compact Airborne Spectrographic Imager (CASI) (Wilson 1997). Coverage of the area was obtained in a series of passes running from north to south and vice-versa. The images were taken from an altitude of approximately 2000m, resulting in a resolution at nadir of 2.5m recording reflectances in thirteen bands, from 450nm to 940nm.

The raw imagery was geo-corrected and adjusted for spectral variation, then mosaicked into two images; one covering SPTA West and the Larkill/Westdown areas, the other covering SPTA East. Two supervised classifications were run on the images, using data from the ground survey to define training areas; one of twelve classes, the other of twenty-five classes and the data filtered to remove noise. The classified images were stored in Erdas image format on CDRom, with ArcView legend files. Figure 3.2 shows the 12-class image. Both sets of images and legend files were copied into the workspace, imported into ArcView and converted to grid format for working in Arc/Info.

3.2.2 Analysis

The processes involved in this part of the project are summarized in Figure 3.3. Arc/Info commands used are documented as Arc Macro Language (AML) scripts in Appendix A1.

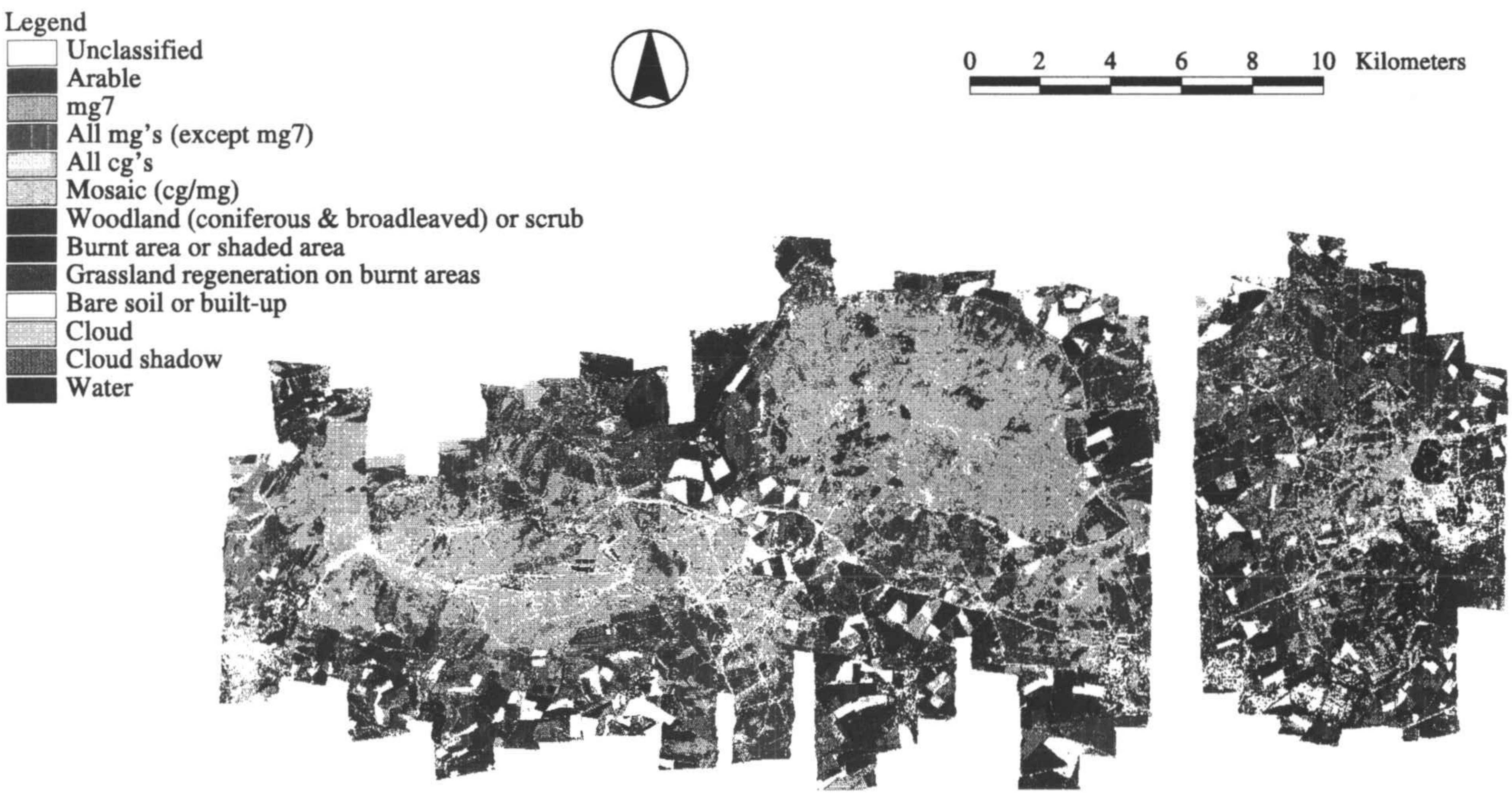
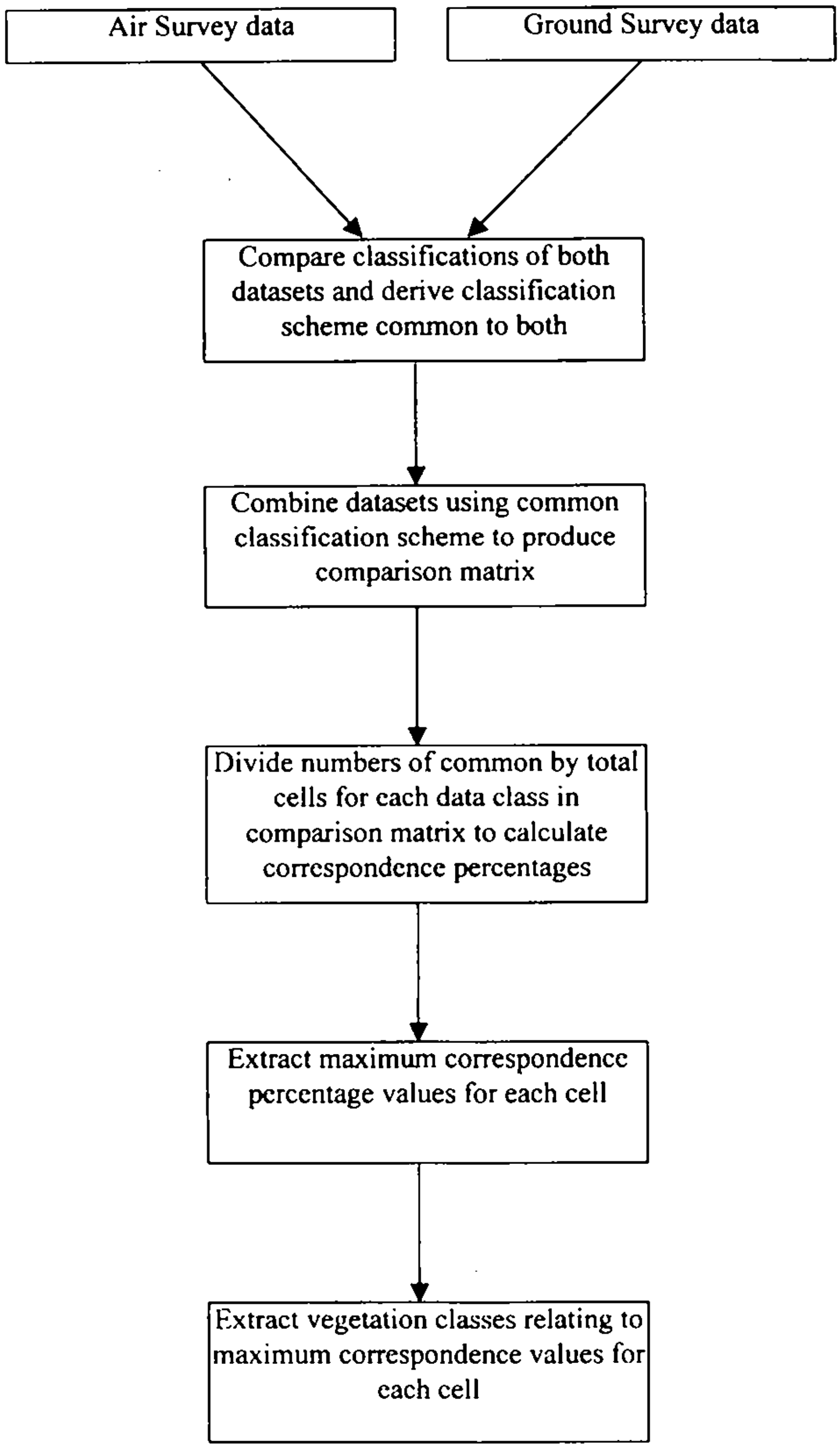


Figure 3.2: Air survey vegetation data

Figure 3.3: Flow Diagram of processes for Objective A



The geographical extents of the two datasets were examined and found to cover basically the same common area. However, the air surveyed data omitted a narrow section along the line of the Avon valley, and a larger section at the eastern end of the SPTA. As the air surveyed data was thus divided into non-contiguous East and West/Central areas, it was decided to process each area separately. This would allow comparisons between the two. Data within the common minimum enclosing rectangles were extracted and used for the remainder of the processing.

In order to combine the ground and air surveyed data in any meaningful way, classifications common to both had to be derived. Whilst both datasets had been classified with reference to the NVC scheme, the ground-surveyed classifications were more detailed than those of the air survey. In many cases, the ground-surveyed classes contained sub-communities which obviously referred to a single community class in the air-surveyed data. An initial common classification scheme for the ground-surveyed and 12-class air-surveyed data was derived. The twenty-five class air-survey classification was found to fit less well with the ground-survey classification and it was decided not to make further use of this part of the dataset. Appendix B shows the relationships between the various classification schemes.

To allow direct comparison of the two datasets, the ground surveyed data had to converted from vector to raster form. The Polygon Attribute Table (PAT) was joined with a new table containing a set of integer codes relating to the legend categories. The integer codes were used as cell values for the data in raster form.

For initial experimentation on ways of combining the two datasets, a set of six tetrads, each 2km square, were extracted from the datasets in raster form. These had been derived for other research (Hirst *et al* 1998) and the locations are given in Appendix C.

The air and ground surveyed data were combined using the Arc/Grid function COMBINE. The columns containing the attribute combinations and pixel counts in the resulting values attribute tables (VAT) were unloaded to ASCII files (AML script *Compare.aml* – Appendix A). These were transferred to PC, loaded into Excel and the records sorted to allow methodical entry to spreadsheets to form comparison matrices. The spreadsheets were set up to calculate percentage correspondence values for each intersecting classification and are contained in Appendices C and D. values were examined.

The approach using the original datasets was then varied to examine the relationship between them in terms of values for each land parcel rather than individual pixels. This was felt likely to result in a more useful product for management purposes. The ground-surveyed vector coverage was rasterised again, this time using the default polygon_id as cell value to identify vector polygons as raster zones. The zones image was combined with the air survey data using the Arc/Grid function ZONALMAJORITY to assign each pixel in a zone with the modal value of the air-surveyed pixels corresponding with that zone.

Following trials on the tetrads, comparison matrices were produced for both West/Central and East study areas, using both methods described above. Examination of these showed small areas classed as burnt grassland on the ground survey data and small areas of burnt/shaded and grassland regeneration on the air survey data, which corresponded well with the calcareous grassland classes. In view of the later objectives and to simplify processing, these were merged with the calcareous grasslands. Similarly, arable and mesotrophic grasslands were also merged. A number of unclassified pixels remained, as well as pixels on the air survey data classed as "cloud" or "cloud shadow." These were also designated unclassified. The air survey data also included a negligible proportion of pixels classed as water, which were ignored.

The final classification scheme is as follows;

0 - unclassified

3 - arable/mesotrophic grasslands

4 - calcareous grasslands

5 - calcareous/mesotrophic grassland mosaic

6 - woodland

9 - bare ground/built-up areas

Comparison matrices for the complete data were generated using this classification scheme (Appendix D).

Following production of the comparison matrices, levels of correspondence for each class were mapped, by producing a series of correspondence value images, each pertaining to a particular class, with four possible inputs for each pixel, according to the following decision rule;

Result of comparison	**Input to class X correspondence values image**
Both datasets show class X	100
Only air survey shows class X	Air-to-ground correspondence value for class X
Only ground survey shows class X	Ground-to-air correspondence value for class X
Neither survey shows class X	0

The individual class correspondence value images were then combined using the Arc/Grid MAXIMUM function to assign each pixel in the output image with the maximum value from all the input images. To extract the actual classes referred to by this image, the maximum correspondence values were compared back against each set of class correspondence values and relating classes extracted (AML script *Extract.aml* - Appendix A) to produce a combined vegetation class image.

3.2.3 Discussion

The compositions of the original data relating to the West/Central and East study areas are shown in Table 3.1 below, using the final common classification scheme.

Table 3.1: Compositions of original datasets

	Ground survey		Air survey	
Class	West/Central (%)	East (%)	West/Central (%)	East (%)
Arable/MG	43	54	39	51
Calcareous	37	24	38	16
Mosaic	14	6	5	4
Woodland	5	15	4	14
Bare/built-up	1	1	11	14
Cloud/shadow	-	-	3	1

According to the ground survey, the East area has a greater proportion of arable/MG and wooded land than the West/Central area, at the expense of of CG and mosaic. This pattern is repeated by the air survey, but the air survey also describes a much larger proportion of land as bare ground. This appears to be due to two main factors;

i) the air survey encompasses urban and barracks areas that the ground survey either ignores or treats as unclassified; and

ii) the fine resolution of the sensor identified pixels with the spectral signature of unvegetated ground corresponding with features such as roads, tracks and disturbed ground, which the ground survey tends to classify according to the predominant vegetation type within the land parcel.

As might be expected, extracting the zonal majority classes of the air survey had the effect of reducing the proportion of already poorly-represented classes, whilst increasing the proportion of already well-represented classes. The class breakdowns are shown below and show that the proportions of mosaic, woodland and bare ground pixels are all reduced. CG on the East study area is marginally reduced, but the much greater original proportion of CG on the West/Central area is drastically increased. The proportions of arable/MG have been affected in a similar way.

Table 3.2: Air survey data; modal class per land parcel

	Original data		As modal classes	
Class	West/Central (%)	East (%)	West/Central (%)	East (%)
Arable/MG	39	51	36	64
Calcareous	38	16	53	15
Mosaic	5	4	1	2
Woodland	4	14	2	12
Bare/built-up	11	14	4	6
Cloud/shadow	3	1	4	1

The comparison matrices for the tetrads and complete study areas, using the initial common classification (Appendix D) show the sensitivity to local variations and the effect on the process of converting the air survey data to modal value per land parcel.

The matrices for the study areas using the final common classification (Appendix D) show, not unexpectedly, considerable increases in overall correspondence value (between 34% and 83%), from those using the original classifications. As the number of categories decreases, the correspondence values tend to increase.

Maximum correspondence value and combined class images for the original and modal class air survey data are shown in figures 3.4 - 3.7. Comparison matrices showing the relationships between values and classes are contained in Appendix E. Initial examination of the correspondence value images shows a majority of areas have a high degree of correspondence. A few areas of low value are present; these generally relate to areas of mosaic or unclassified/bare ground on the original data. Banding effects are also visible in places on the correspondence value images. These appear to result from the uneven edges of the air surveyed dataset.

Visual analysis of the relationships between maximum correspondence values and relating classes suggests that strong correspondence between the datasets is generally related to calcareous class in the West/Central study area, and arable/MG class in the East study area. Mosaic class cells tend to be polarised between the highest and lowest value ranges, with the majority having low values. Wood class cells on the East area all have high values, whilst those on the West/Central area have a substantial minority with low values.

The compositions of the combined class images are shown in Table 3.3 below. When compared with the original datasets, they show quite clearly that the originally large proportions of arable/MG have increased on both

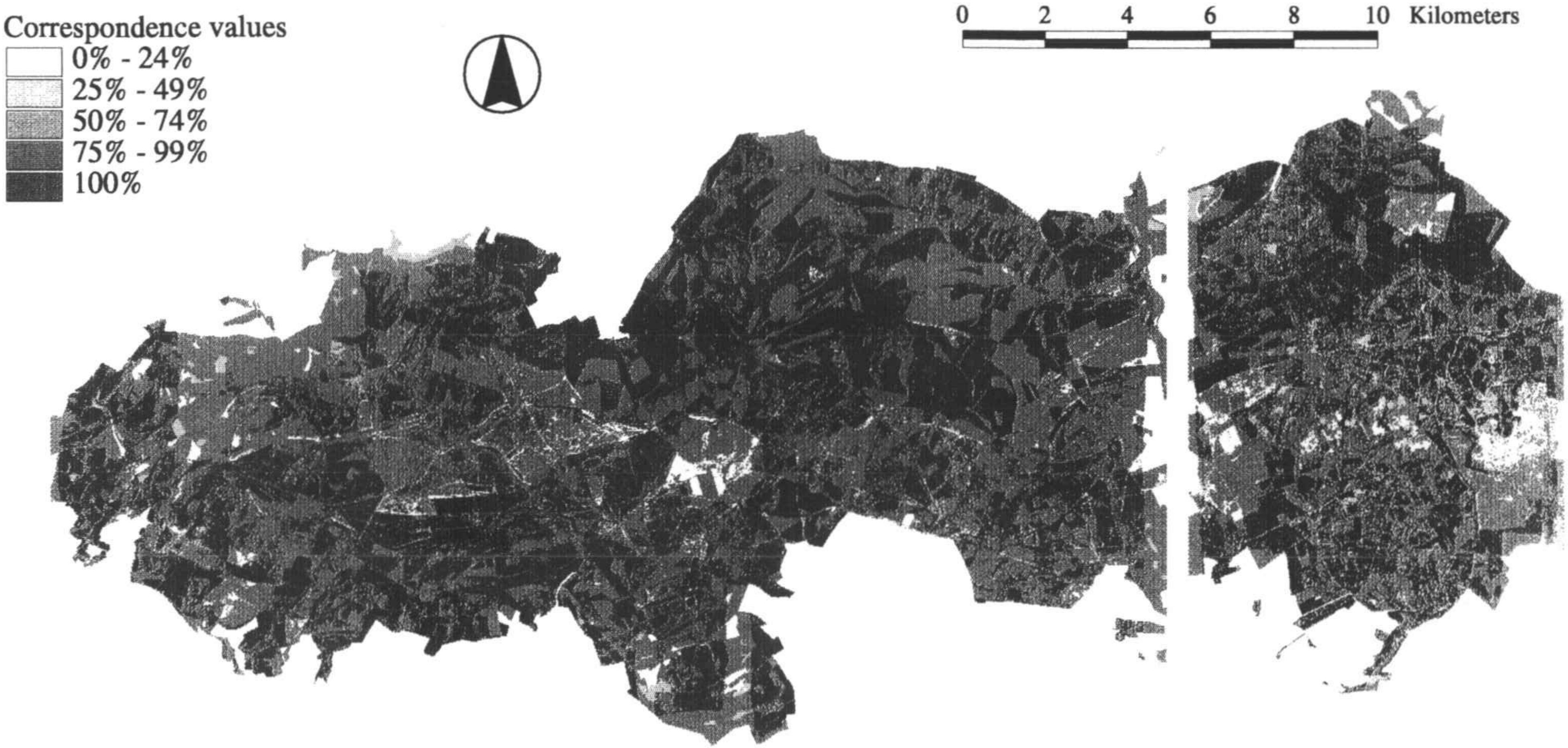


Figure 3.4: Maximum correspondence values between ground and original air survey vegetation data

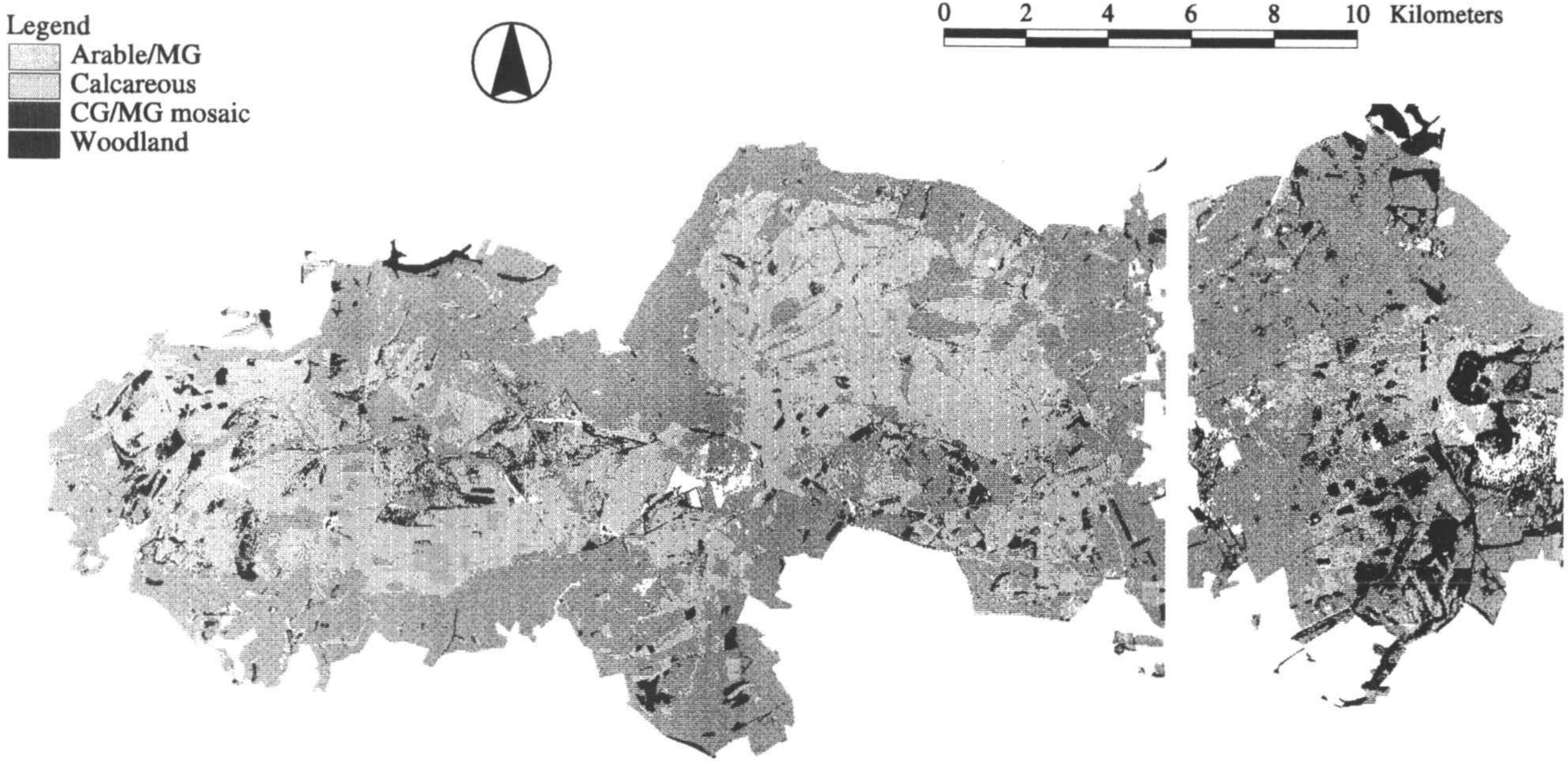


Figure 3.5: Vegetation map derived from maximum correspondence values (original air survey data)

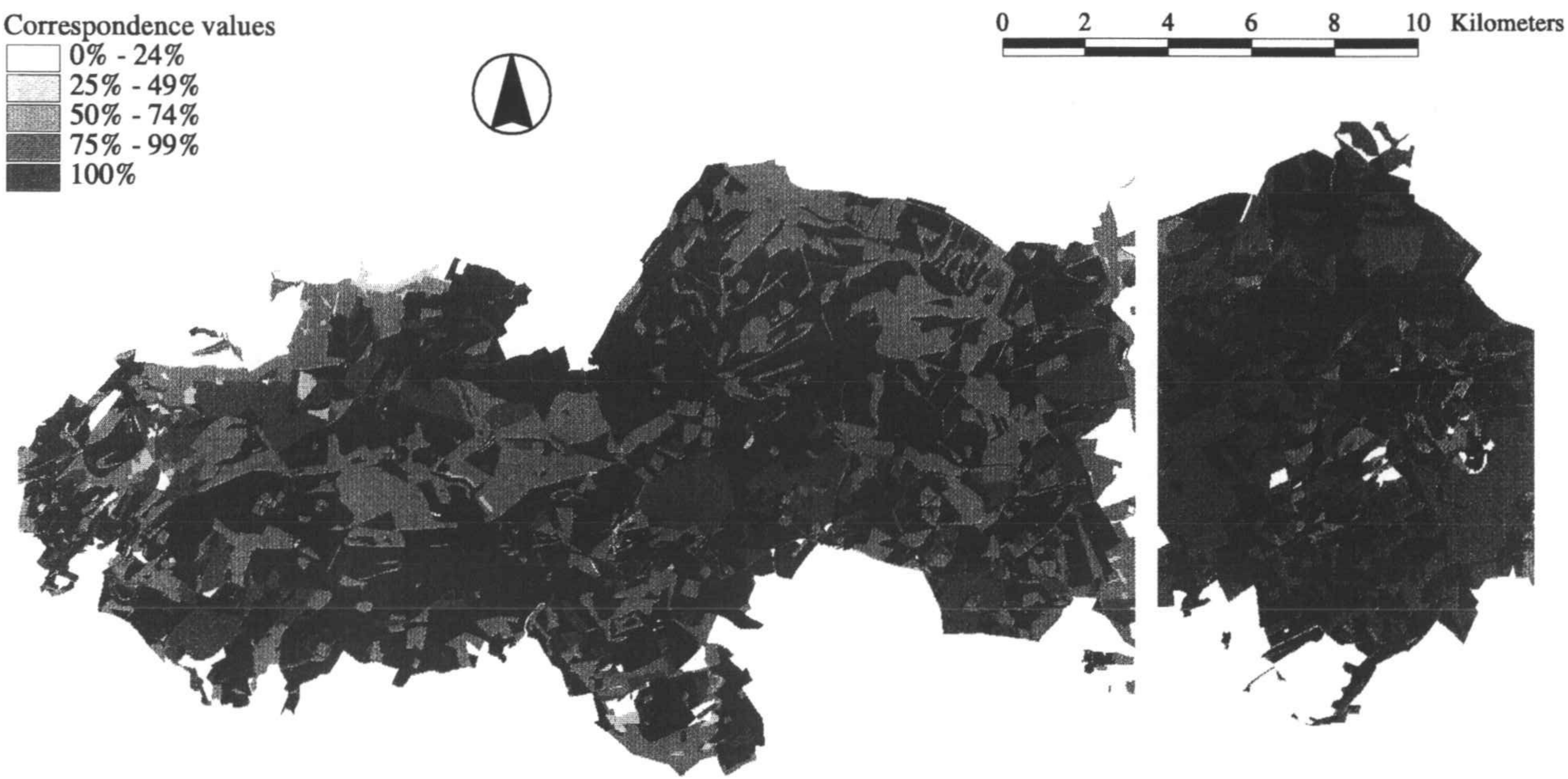


Figure 3.6: Maximum correspondence values between ground and air survey (modal class per land parcel) vegetation data

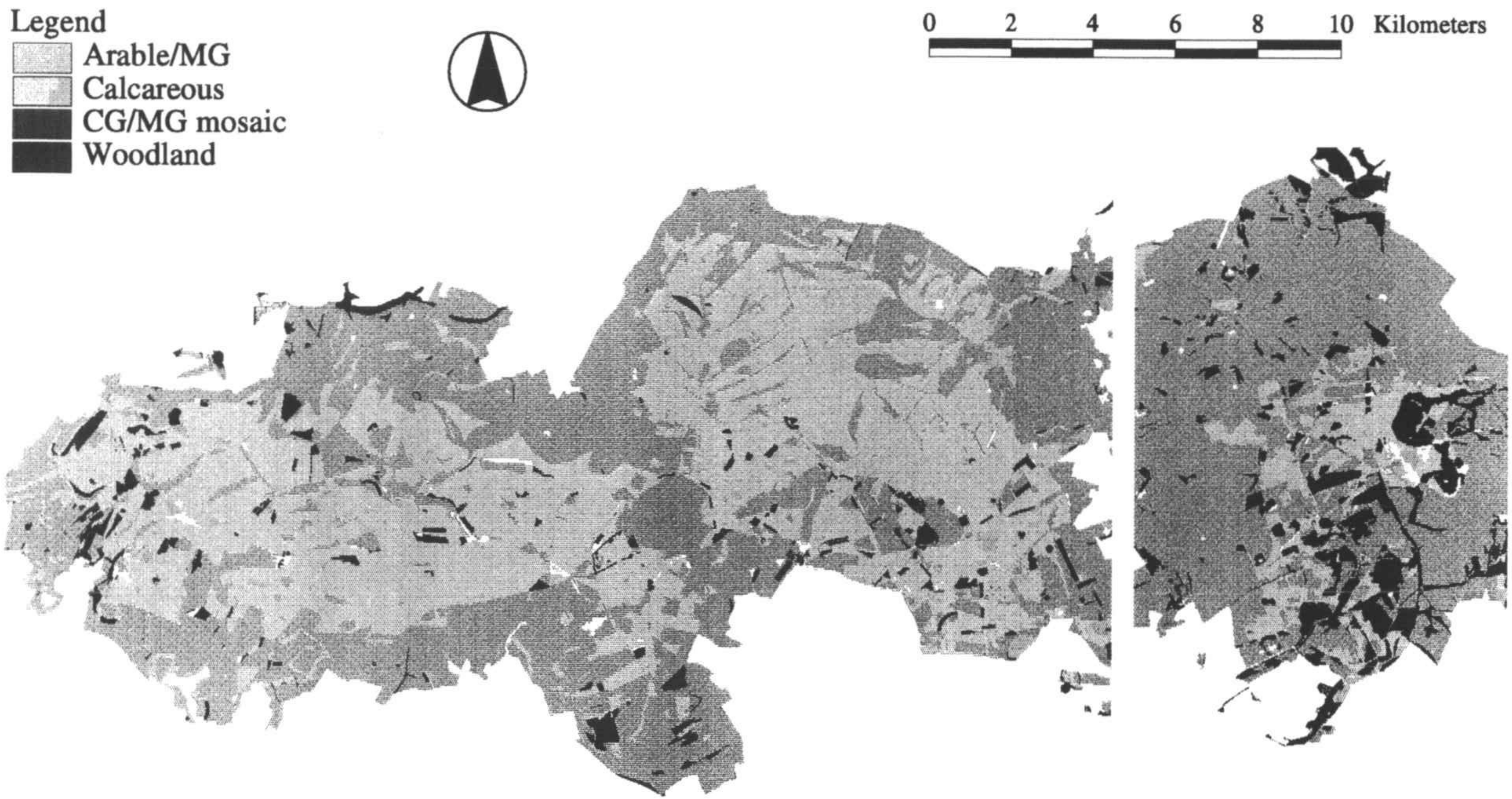


Figure 3.7: vegetation map derived from maximum correspondence values (air survey data as modal class per land parcel)

areas. Also, the large proportion of CG on the West/Central area has increased whilst the smaller proportion on the East area has decreased, the small proportions of woodland on both remaining relatively static. The most drastic effect has been the severe reduction in proportion of mosaic class cells.

Table 3.3: Compositions of combined vegetation data

	Original air survey data		Air survey data as modal classes per land parcel	
Class	West/Central (%)	East (%)	West/Central (%)	East (%)
Arable/MG	53	66	48	70
Calcareous	41	15	48	14
Mosaic	3	1	1	1
Woodland	3	18	3	15

This effect can be seen to be a function of the relationships between the classes as shown in the comparison matrices. Mosaic class cells in each dataset tend to be spread fairly evenly across arable/MG, CG and mosaic classes in the other. Therefore, correspondence values of mosaic class cells are low and occurrences of mosaic in the combined class images are limited to the small number of cases where the datasets concur for this class, and where the cells are unclassified in one dataset and mosaic in the other.

3.3 Prediction of relative levels of military training traffic

3.3.1 Mechanisms of disturbance by armoured vehicles

Ogorkiewicz (1968) states that a fundamental requirement for most armoured vehicles is the ability to travel over rough ground. For most, this is achieved by using tracks to spread the load of the vehicle over a greater area and thus improve traction. The weight of the vehicle is transferred to the tracks via a suspension system and set of undriven wheels. Most modern tracked armoured vehicles have steel tracks fitted with rubber pads to reduce damage to metalled roads.

The product of track "footprint" and vehicle weight gives the nominal ground pressure exerted by the vehicle. This can range from around $0.36 kg/cm^2$ for the Scorpion reconnaisance vehicle (total weight 8000kg) to $0.9 kg/cm^2$ for the Challenger main battle tank (total weight 62000kg) (Aldino 1992). Ogorkiewicz (1968) suggests a maximum ground pressure of around $0.7 kg/cm^2$ for reasonable performance on mud and soft sand. However, actual ground pressures tend to be higher in practice, because the projecting ribs or pads fitted to tracks reduce the contact area, and pressures are also higher directly under wheels. Also, these figures refer to static conditions; forces exerted would be higher under a moving vehicle.

The thrust that a vehicle can generate at the ground is limited by soil shear stresses (Ogorkiewicz 1968). When the soil is too weak to cope with the forces imposed on it, it breaks up. Steering of tracked vehicles is particularly damaging, being achieved by creating a difference in thrust between the tracks which slews the vehicle. This causes one or both of the tracks to skid across the ground surface.

Thus vehicles can cause disturbance to vegetation and soil directly by compaction and shredding, which can in turn lead to soil loss through erosion from water and wind. Figure 1.1a shows an example of gullying from water erosion on a track up a steep slope.

3.3.2 Influences of terrain and vegetation in armoured warfare

The general function of armoured vehicles is to provide protection and mobility in a battlefield situation (Ogorkiewicz 1968), in the context of their specific functions; many are designed for direct engagement of opposing forces, but some are designed for other roles such as reconnaissance or engineering tasks.

The US Army Field Manual for tank platoon commanders (US Army 1996) highlights the following factors where terrain and vegetation have influences;

Firepower: desirability of clear lines of aim and fire implies attraction to high ground offering views over territory.

Protection: the need to minimise chances of being detected by enemy implies repellance from conspicuous ridges and hilltops and attraction to perimeters of woods and forests providing cover and concealment.

Mobility: practical limitations on vehicle movement implies repellence from very steep slopes and densely wooded areas, and attraction towards open terrain.

3.3.3 Data

3.3.3.1 Digital Elevation Data

The digital elevation data used for this project was subset from the Institute of Hydrology's raster digital terrain model, with 50m horizontal and 0.1m vertical resolution, based on Ordnance Survey data. This was stored in Unix in Arc/Info format and the relevant areas subset into the working directory.

3.3.3.2 SPTA land management data

A data coverage showing areas such as schedule 1 land and out-of-bounds areas was available as an ArcView shapefile. This used the polygon boundaries of themanagement land parcels, with each polygon classified according to status with a floating point value. The data was imported into Arc/Info and an item added to the PAT. This item was assigned an integer value to match the original floating point status value, to allow conversion to raster format.

In order to test out the modelled factors influencing AFV movements, some assumptions were required to be made about traffic movements in terms of sources and destinations. Army maps at 1:50000 (MoD 1993 (1)) and 1:25000 (MoD 1993 (2 and 3)) scales containing specialist information pertaining to the SPTA such as firing range boundaries and designated crossing points of public roads were available.

To allow generation of least-cost paths to test the modelled movement factors, locations assumed to represent significant origins and destinations of military traffic on the SPTA were entered as a point coverage in Arc/Info. These included entry points onto the training area and other features that might be used as objectives for an exercise. Boundaries of areas such as firing ranges and the off-road driving area, where traffic movements were considered unlikely to conform to the vehicle movement factors as modelled, were digitised and set up as a polygon coverage in Arc/Info. Similarly, stretches of public roads crossing the SPTA were digitised as line coverages, with breaks to represent crossing points.

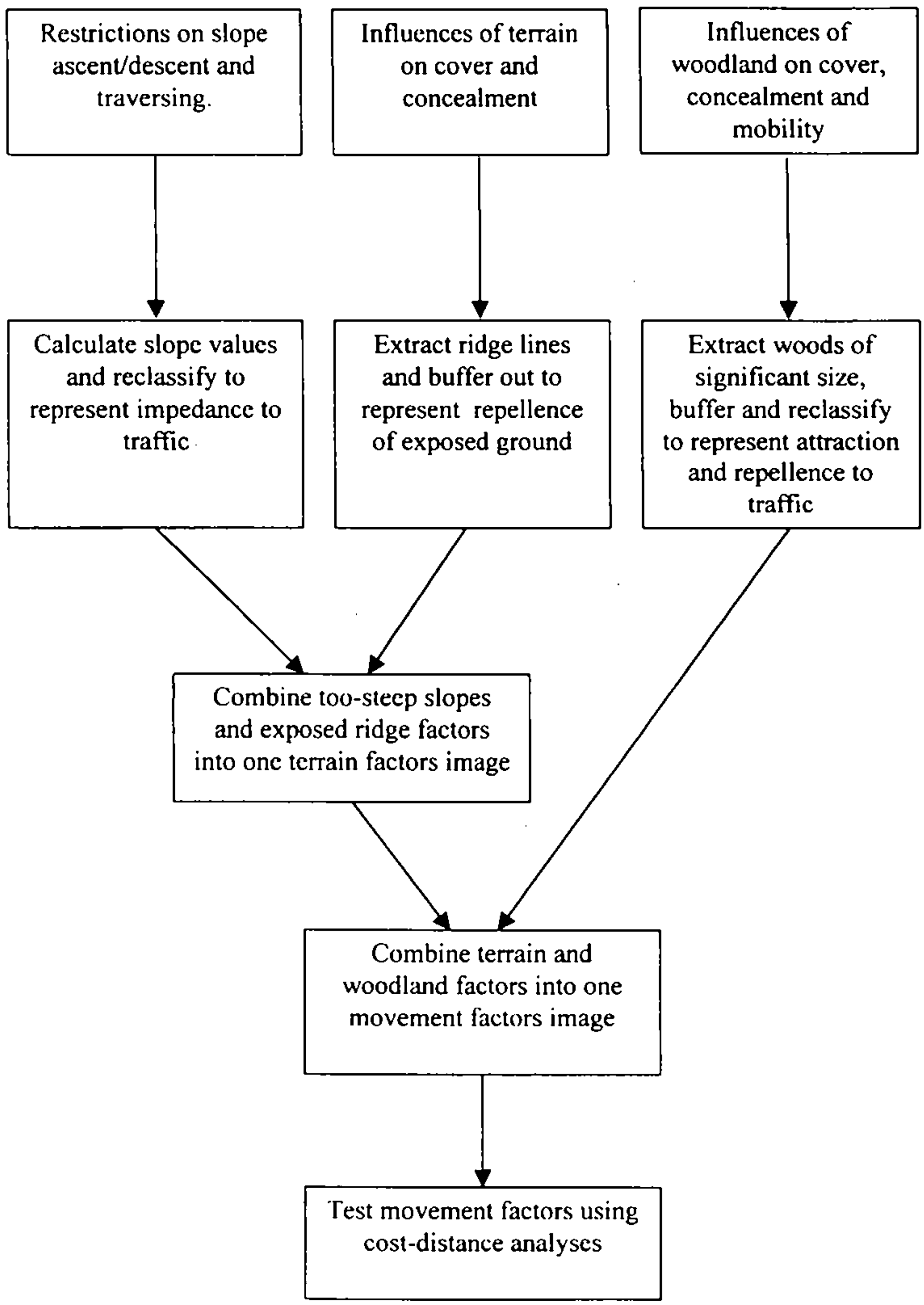
3.3.4. Analysis

The processes involved in this part of the project are summarized in Figure 3.8. Arc/Info commands used are documented as Arc Macro Language (AML) scripts in Appendix A.

Terrain factors were considered first. The elevation data was processed to provide slope values so that impassible slopes could be identified. Foss (1992) and Aldino (1992) suggest that the maximum slope angle climbable by most armoured vehicles was in the region of 60%, i.e about 31 degrees or 1 in 3. The Arc/Grid function SLOPE was run on the DTM, using a z-factor of 0.1 to compensate for the decimetre vertical resolution, and cells with slopes greater than 60% were extracted to a new coverage and given a value of 100 to represent their repellance of vehicle traffic.

In order to determine ridge lines and hilltops, a more complex approach utilising the hydrological functions in Arc/Grid was required. Initially, it was thought that segregating the drainage basins and adopting the watersheds between as barriers would yield suitable results. The elevation model was smoothed to remove isolated pits and peaks, then the flow directions calculated and basins extracted. However, on examination the basin boundaries were found to miss out a number of prominent hills and ridges on the DTM, whilst dips in ridges that might be used as "passes" between adjacent valleys were included.

Figure 3.8: Flow Diagram of processes for Objective B



A different approach was examined. The unsmoothed DTM was "inverted" by subtracting from a scalar value greater than the highest point. The flow direction and accumulation were determined for the inverted DTM and pixels with high accumulation values extracted to produce an "inverted" and segmented network. Some experimentation was required to set a suitable threshold value, but the final result (using a flow accumulation value of 150) extracted most ridges and hilltops, whilst allowing movement across passes.

The identified ridge lines then had to be expanded to reflect the horizontal distance required from the ridge line to conceal a vehicle. The US Army tank training manual (US Army 1996) refers to "turret down" and "hull down" positions; in the former, the whole tank is concealed behind the ridge, but is close enough to allow the tank commander to emerge from the turret and look over; for the latter, the tank is driven forward to expose the turret so that the main gun can be brought to bear on a target. The shape of a ridge will determine the horizontal distance from the ridge line required to achieve these positions; the more gradual the curve of the ridge, the greater the distance.

Aldino (1992) notes that the overall height of the British Army's Challenger tank is 2.88m, whilst that of the Scorpion armoured reconnaissance vehicle is 2.1m and the Warrior armoured fighting vehicle 2.82m. A vertical distance of 2.5m was considered a reasonable approximation for use in the model.

The ridge lines in raster form were expanded out by five cells (250m) in each direction to form a series of ridge zones. This also set an absolute limit on the horizontal extent of any ridge area. The cells within these zones were assigned the elevation values of the corresponding cells in the DEM, following which a filter was applied to extract the maximum value from a

5x5 cell moving window, to give the maximum adjacent ridge height for each cell in the zones. The maximum heights were then compared with the true heights and cells with a difference greater than 2.5m were eliminated. The remaining cells were combined with the slope factors to produce a terrain factors image.

The United States Army (1996) notes the tactical advantage of using wooded areas to provide visual concealment. Therefore, areas immediately surrounding woods required factors reflecting this attraction towards them, whilst the woods themselves required factors reflecting their status as barriers to movement.

Wood vegetation class pixels of the combined vegetation image using the original air survey data were extracted into a temporary image. To remove small areas and isolated pixels that were felt more likely to be scrub and not represent a worthwhile barrier or cover for an armoured vehicle, the pixels were grouped into contiguous regions and those less than an arbitrary 1000 pixels (0.625ha) in extent were removed.

Next, buffer zones 100 metres wide were generated around the remaining wooded areas, to represent a reasonable width of a potential high disturbance band. These were reclassified to reflect their attraction to traffic and the wooded areas image used to generate the buffer zones was reclassified to reflect the impedance of woodland. The two images were combined to produce a vegetation cover factors image. To allow combination at a 50m resolution for testing using least-cost paths, the image was filtered using a 20 x 20 window to set the modal value for each cell, then resampled using nearest neighbour assignment.

The terrain and vegetation cover factors were then combined to produce an overall movement factors image. Where attracting and repelling factors conflicted, for example at a woodland perimeter on a ridge, the vegetation cover factor was assigned.

To assess the validity of the modelled factors, a series of cost distances and least-cost paths and corridors were generated, on the West/Central and East areas separately. A few dispersed points in each area were selected to represent likely sources or destinations of traffic. Areas where traffic would be restricted such as cropped agricultural land, archaeological sites, airstrips, parachute drop zones, ranges and stretches of public road between crossing points were masked out from the movement factors image to produce a cost surface for testing. The off-road driving area on SPTA East was also masked out, as although heavily trafficked and disturbed, the factors influencing vehicle movement are different to those on the rest of the SPTA. To generate reasonably wide paths, as well as save processing time and file space, the paths and corridors were generated using the 50m resolution of the elevation data, rather than the 2.5m resolution of the vegetation data.

If the factors influencing movement had been realistically modelled, paths and corridors generated using these factors should encounter more disturbed ground than those generated using a smooth cost surface. Pixels identified by the air survey as bare ground but by the ground survey as vegetated were assumed to represent areas where vegetation had been disturbed.

Negative and zero values were unfeasible for testing using cost-distance surfaces. Therefore, areas attracting traffic were initially assigned the lowest positive integer value (1), neutral areas a value greater by a factor of 10 (10) and areas repelling traffic by a value greater by a factor of 10 again

(100). To test the sensitivity of the model to variations in the factor values, an initial series of paths was generated using cost values of 5 and 15, as well as 10, for neutral ground, retaining the values of 1 for attraction and 100 for repellence in each case. These differing factors were found to cause little variation in the path networks and the trials were continued using a factor of 10 for neutral ground.

Paths were generated from the source points previously identified, to give sample routes in different directions and across different parts of the SPTA. Using the Arc/Grid function CORRIDOR, pairs of cost distance surfaces were combined and the lowest 5th percentile values of each pair extracted. Using the function MAXIMUM, the 5th percentile corridors were combined to cover the path networks. The paths and corridors generated, together with the restricted and prohibited areas, are shown on Figure 3.9.

To act as a control sample, the process was repeated, using the same source points and prohibitions on movement, but eliminating the differential movement factors to produce an even cost surface.

To allow evaluation of the results, the paths and corridors generated were resampled to 2.5m resolution, and combined with the original air survey data to assess the proportions of each vegetation class covered. This was repeated with the control paths and corridors. The results are contained in tables 3.4 and 3.5 below.

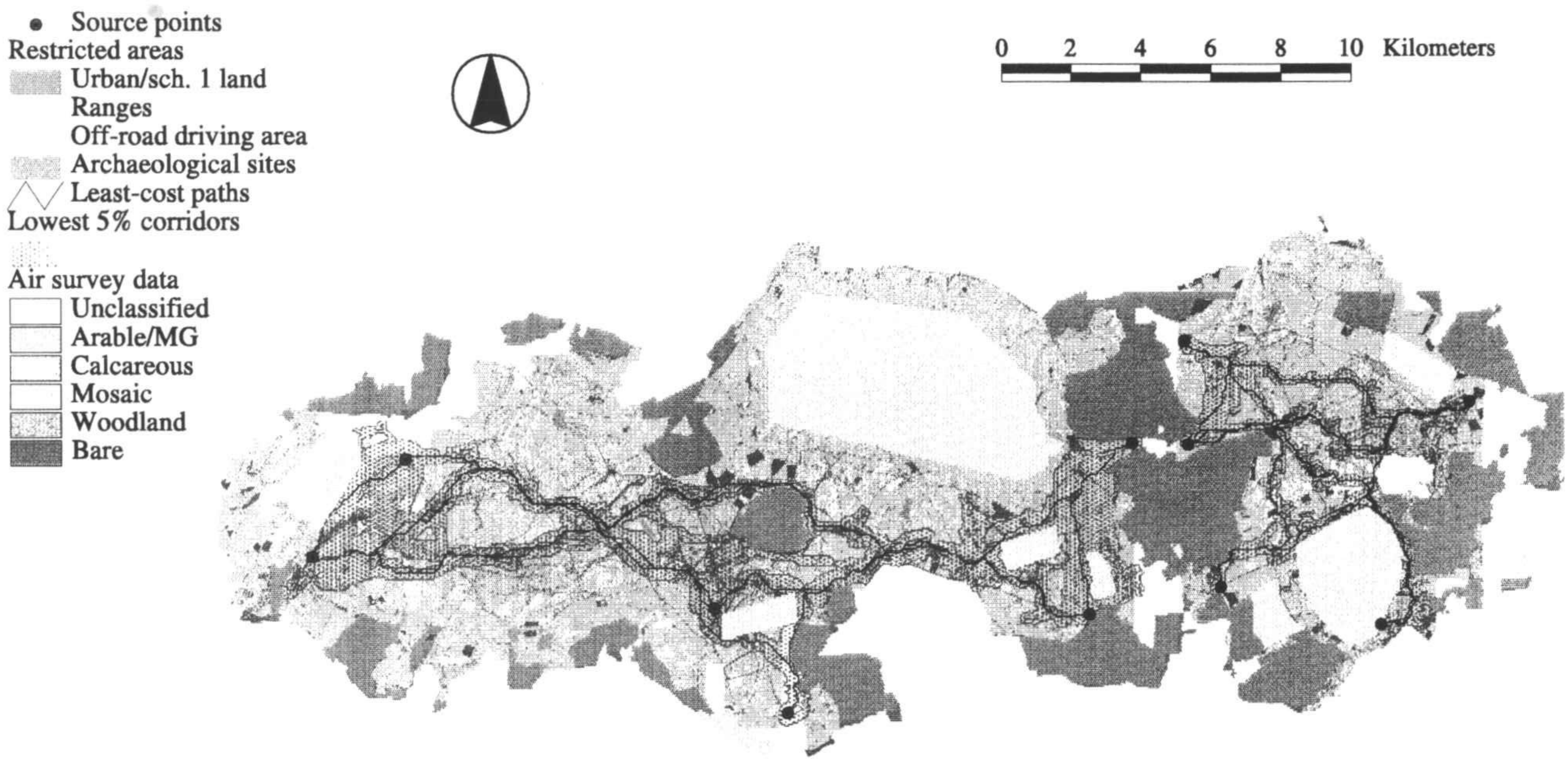


Figure 3.9: Results of cost-path analysis of armoured vehicle movement factors

Table 3.4: Results of least-cost path and corridor analyses on vehicle movement factors: SPTA West/Central					
	Air survey data* (%)	Control test		Factors test	
Class		Paths (%)	Corridors (%)	Paths (%)	Corridors (%)
Arable/MG	38	31	28	24	25
Calcareous	44	48	51	47	53
Mosaic	6	5	6	5	5
Woodland	4	3	5	6	4
Bare	**8**	**13**	**10**	**18**	**13**
*not including prohibited and restricted areas masked out from test surface					

Table 3.5: Results of least-cost path and corridor analyses on vehicle movement factors: SPTA East					
	Air survey data* (%)	Control test		Factors test	
Class		Paths (%)	Corridors (%)	Paths (%)	Corridors (%)
Arable/MG	53	45	49	44	50
Calcareous	21	22	25	29	27
Mosaic	5	5	5	7	6
Woodland	12	15	11	7	5
Bare	**9**	**13**	**10**	**13**	**12**
*not including prohibited and restricted areas masked out from test surface					

3.3.5 Discussion

Visual assessment of the path and corridor networks generated by the test shows a number of instances where paths can be seen to run close to each other, in clearly-defined corridors. On the Western area, the corridors from the western end can be seen to split and skirt around a large area of calcareous grassland before merging and splitting again. A number of areas of bare ground from the air survey data are visible outside the corridors. The large field-shaped areas were investigated by examination of the original ground survey notes and found generally to be cropped or ploughed. These were masked out of the test surface.

The tabulated test results show that the paths generated by each test cover a greater proportion of bare ground cells than the corresponding corridors, which in turn cover a greater proportion of bare ground cells than the test surfaces in general. The paths and corridors generated by the movement factors cover a greater proportion of bare ground cells than their control counterparts, except for the East area where both sets of paths cover an equal proportion.

Although the control path and corridor samples generated covered greater proportions of bare ground cells than contained in the test surfaces, the routes were generated between nodes considered likely to be substantial sources of traffic. In many cases the paths and corridors generated by the movement factors do not deviate far from those of the control samples, particularly close to nodes where areas of bare ground may be concentrated. Also, the paths and corridors generated by Arc/Grid follow "Queen's case" (i.e. vertical, horizontal or 45 degrees diagonal) directions only and this acts as a significant constraint on the process.

Woodland class cells are also covered by the factor-generated paths and corridors, particularly on the East area, although woodland areas carry a high repellence factor. This is due to the fact that the woodland cells used in the model were extracted from the combined vegetation image rather than the air survey data, and small stands eliminated.

Another effect shown by tables 3.4 and 3.5 is that both control and sample paths cover greater proportions of calcareous grassland and lesser proportions of arable/mesotrophic grasslands. This appears to be because the routes in general cross the central areas, where calcareous grassland is prevalent, rather than the peripheries, where mesotrophic grasses and arable land dominate.

3.4 Identification of sites of high conservation value at risk of disturbance

To identify sites of high conservation value which are at significant risk of disturbance from vehicle traffic, it is necessary to combine information on risk and value.

The previous two stages produced information on the vegetation resource and predicted relative traffic levels on the SPTA. The latter can be processed to represent the degree of risk of disturbance from that source, the former to represent significance of that risk. Other factors influencing risk are present and should also be incorporated.

3.4.1 Data

3.4.1.1 Data relating to risk

The vehicle movement factor images as described in the previous subsection were used, along with the DTM and range boundaries etc.

digitised from the Army maps (MoD 1993 (1, 2 and 3)). The vector polygon boundaries from the original ground survey vegetation data were also used.

3.4.1.2 Data relating to conservation value

The combined ground and air surveyed (modal class per land parcel) vegetation data produced in furtherance of the first objective were used in this stage of the project.

3.4.2 Analysis

The processes involved in this part of the project are summarized in Figure 3.10. Arc/Info commands used are documented as Arc Macro Language (AML) scripts in Appendix A.

3.4.2.1 Analysis of risk

The following sources of risk were identified:

i) Direct disturbance from military training using armoured vehicles, as modelled for objective B of this project.

ii) Increased risk of disturbance in valley bottoms; as conditions in these areas tend to be wetter than elsewhere, particularly during winters, a greater amount of disturbance can be caused by the same amount of traffic.

iii) Risk of disturbance from dust generated by traffic on all-weather tracks. These tracks have been installed by the MoD on some parts of the SPTA in an apparent attempt to prevent track spread, reduce direct disturbance of soil and vegetation and consequent problems of rutting and bogging-down. However, the crushed limestone surfaces of the tracks results in large volumes of dust being generated by each passing vehicle, in dry weather, which falls on surrounding vegetation.

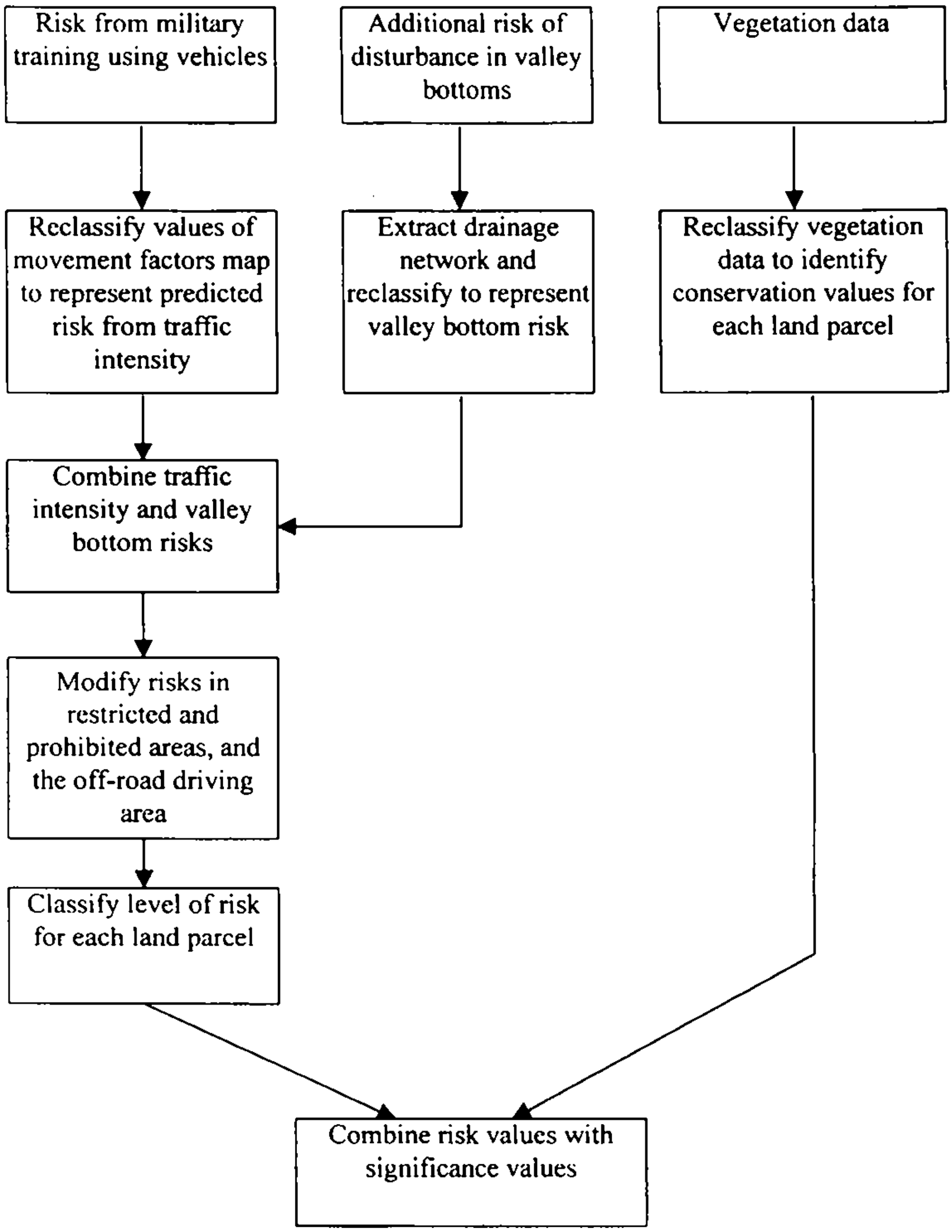
Available time only permitted the first two risk sources to be modelled; the problem of dust disturbance is listed as an area for further research in section 5.3 of this paper.

Other factors which modify the risks from vehicle training movements were identified as areas of the SPTA where such traffic is prohibited or restricted, such as rifle and artillery ranges and cultivated agricultural land.

The risks from vehicle traffic in general were assumed to be in inverse relationship to the vehicle movement factors identified for objective B. Based on this assumption, the movement factors image was reconstructed in 2.5m resolution (to allow later combination with the significance information) by resampling the 50m resolution terrain factors image and combining with the original 2.5m resolution woodland cover factors image. The result was then reclassified as follows to produce an interim risk image;

Movement factor	**Risk**
1 (attraction)	3 (high)
10 (neutral)	2 (moderate)
100 (repellence)	1 (low)

Figure 3.10: Flow Diagram of processes for Objective C



To represent the risk of disturbance in valley bottoms, the DTM was smoothed and Arc/Grid hydrological functions FLOWDIRECTION and FLOWACCUMULATION used. To identify a reasonable drainage network, cells with a flowaccumulation value of 150 (rounding the mean value of 167) or greater were extracted. The network was resampled to 2.5m resolution and combined with the first interim risk image, using the following decision rule;

	Valley bottom risk	
Traffic risk	**Low**	**High**
Low	Low	Low
Moderate	Moderate	High
High	High	High

The presence of areas within the study area where armoured vehicle traffic and manoeuvres are prohibited or restricted required modifications to the level of risk in those areas. Areas identified as urban, schedule 1 land, and out of bounds on the land use data coverage were deemed to have no risk of disturbance from vehicles. Rifle and artillery ranges in frequent use, parachute drop zones, cultivated areas, and defined archaeological remains were deemed to have a low risk of disturbance from vehicle traffic. The off-road driving area was deemed to carry a high risk of disturbance. These area-specific risks were combined with the general risks as follows:

Area-specific risk	**General risk**	**Output**
Nil	Any	Nil
Low	Any	Low
High	Any	High

The final risk map is shown in Figure 3.11.

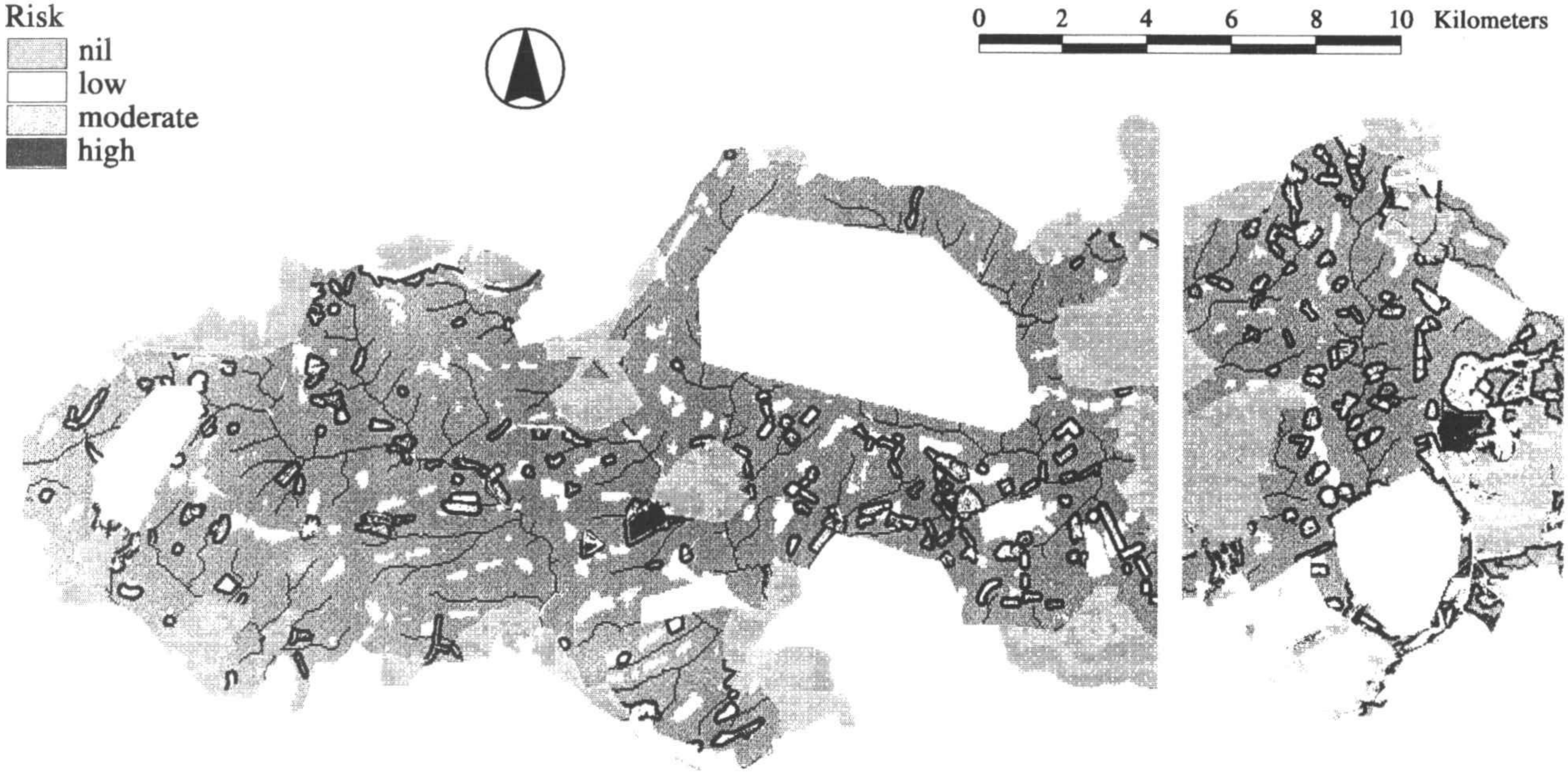


Figure 3.11: Risks of disturbance from off-road vehicular traffic

3.4.2.2 Analysis of conservation value

Conservation value, in the context of this project, is defined not in monetary terms, but in relation to the scarcity and fragility of particular habitats. The aim is to protect that which can be easily lost and which is not readily available elsewhere. In the case of Salisbury Plain, the calcareous grassland habitat is deemed the most valuable (Porley 1986). Therefore, "pure" calcareous grassland can be considered as being of high value, and calcareous/mesotrophic grassland mosaic as being of moderate value. For the purposes of this analysis, other vegetation types are deemed low value.

The conservation values across the SPTA were assumed to relate directly to vegetation type, and could therefore be simply derived by reclassifying one of the vegetation cover maps. To facilitate decision-making based on land parcels whilst utilising the data from both air and ground surveys, the combined ground and air surveyed (modal class per land parcel) image produced for objective A was selected. This was reclassified to identify areas of calcareous grassland, calcareous/mesotrophic mosaic, and other vegetation, as high, moderate and low value respectively.

Examination of the result showed that the maximum correspondence process had so marginalised the mosaic class areas that less than 1% of the initial conservation value image was classed as moderate. This was felt unsatisfactory in terms of providing an even spread of values for decision-making purposes. The process was repeated, but with mosaic class cells classed as high value, to produce a two-class conservation value map (Fig. 3.12).

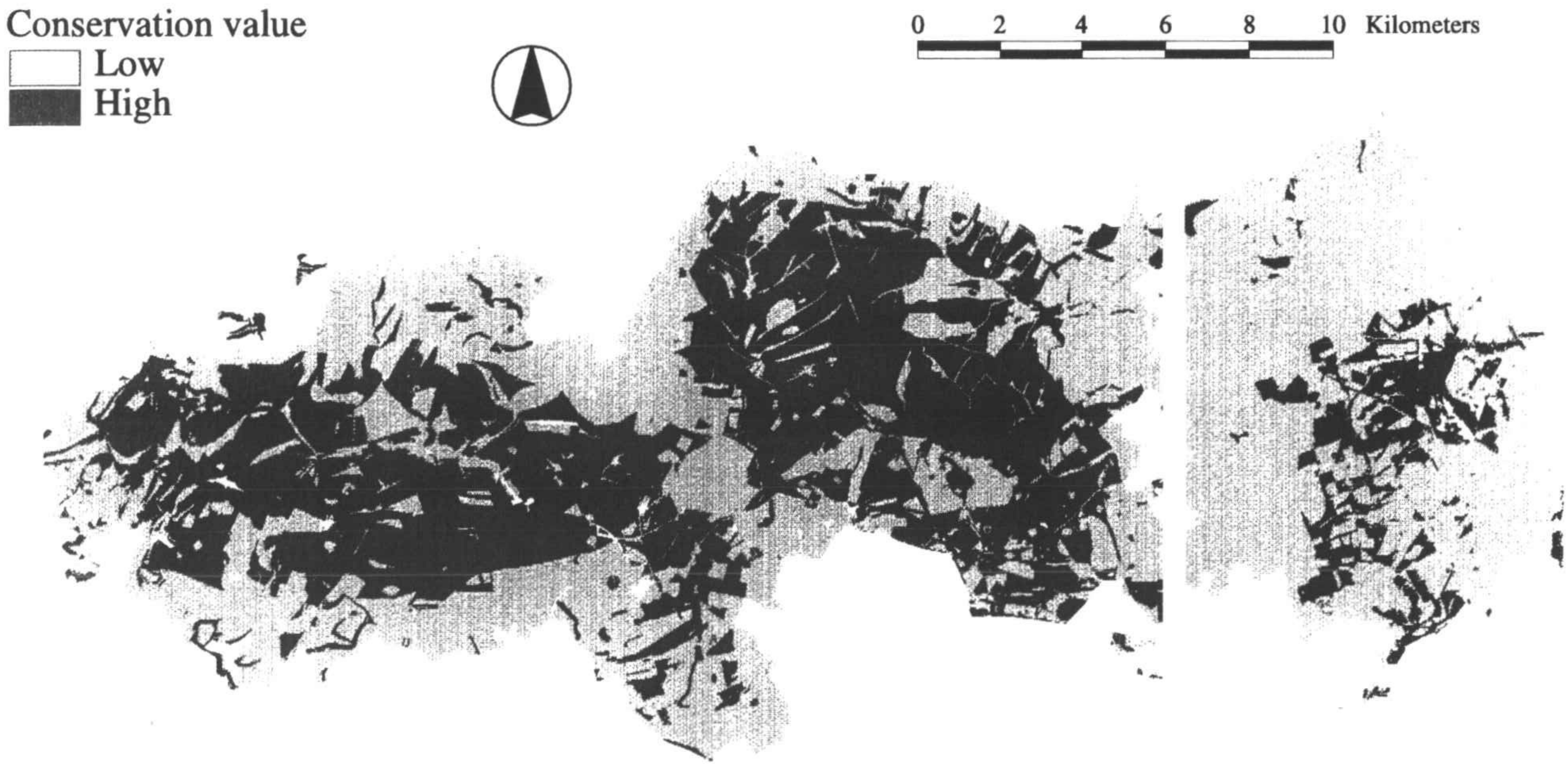


Figure 3.12: Conservation value map

3.4.2.3 Analysis of significance of risk.

Before the risk and value maps could be combined, the risk values needed to be expressed by parcel rather than by pixel, to allow reasonable decision-making. Running the Arc/Grid function ZONALMAJORITY, using the ground survey vector polygons as zones, was tested but it was found that this approach tended to eliminate most areas of high risk (the risk factors being no respecters of the polygon topology). Conversely, identifying polygons as being of high risk when any cell within was at high risk was found to identify nearly all polygons on the freely-trafficked areas of SPTA East.

A more complex decision rule was required, to identify a reasonable proportion of land parcels as high risk. Cells with high risk value were extracted and processed using the Arc/Grid function ZONALSUM to calculate the numbers of high-risk cells in each land parcel. Trials showed that identifying land parcels with a high risk area of 3ha or greater produced a reasonable proportion of high-risk areas. This process had the side-effect of identifying some urban areas as high-risk, presumably due to some overlap between the original risk image and the polygon boundaries. These areas were removed. The process also effectively ignored land parcels smaller than the threshold of 3ha. The ground survey polygon data was examined and it was found that 12% of the land parcels (approximately 2% of the overall area) were smaller than this threshold.

The final per-parcel risk image was produced by overlaying the high-risk areas identified using ZONALSUM onto the risk image produced using ZONALMAJORITY (Figure 3.13). This allowed any small land parcels with a majority of high-risk cells to be identified as high-risk.

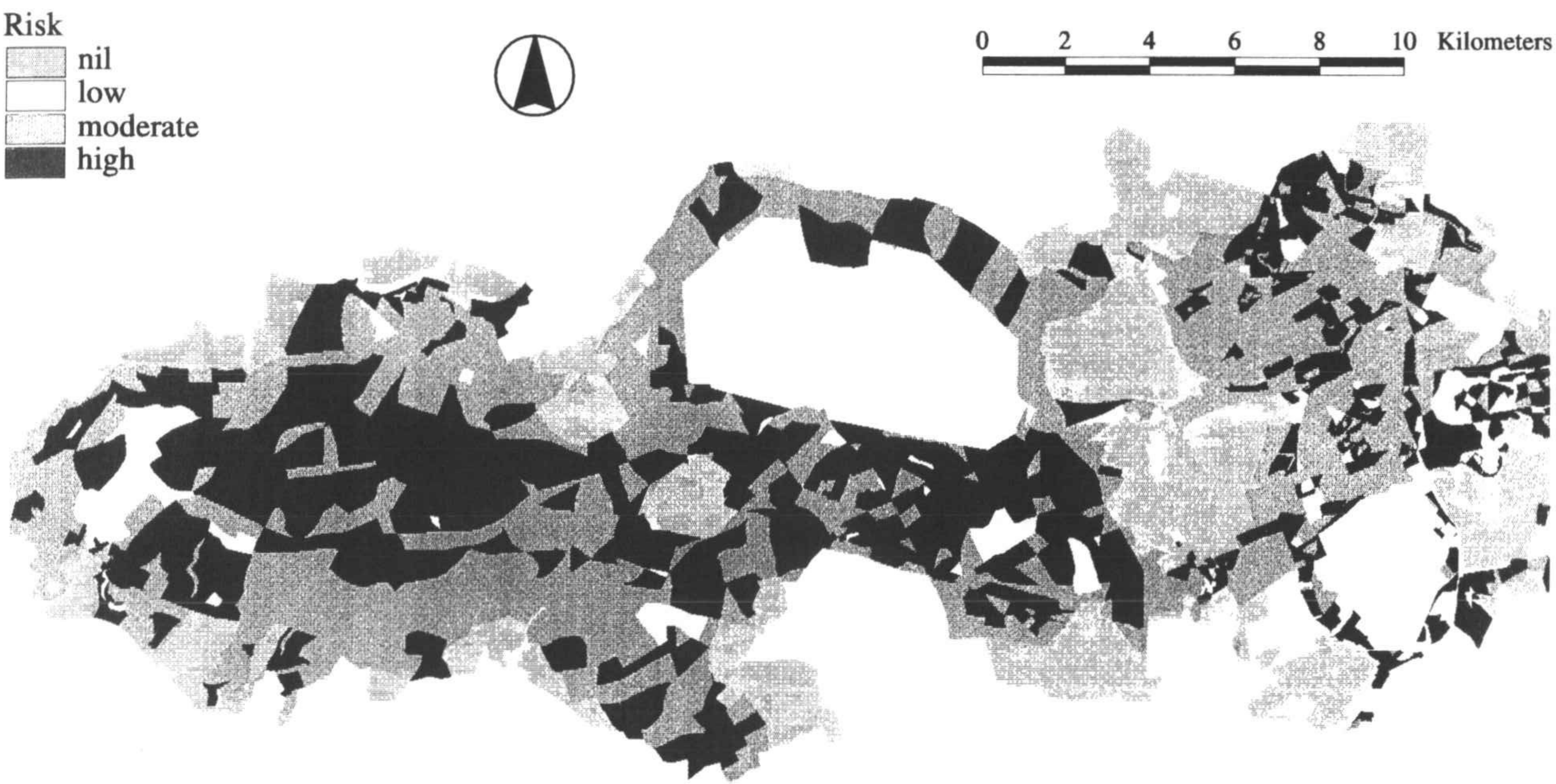


Figure 3.13: Risks of disturbance from off-road vehicular traffic; classified by land parcel

The final per-parcel risk image was combined with the conservation value image to produce an eight-class risk significance image, using the Arc/Grid function COMBINE (Figure 3.14).

Discussion

The per-pixel risk image shows clearly the high-risk areas around woodland perimeters and along valley bottoms, and the low-risk areas of ridges and within woods, on areas of the SPTA allowing free movement of traffic.

Consolidating the risks into parcels completely conceals the influences of the traffic movement factors, producing substantial bands of high risk area across the middle of the West area and to the east of the Central area. High risk areas on the East area are more fragmented, with a slight concentration on the northern edge. A few high risk parcels have intruded into range areas, where boundaries have not coincided.

This raises an issue of the appropriateness of the spatial resolution used for management of the SPTA. Simple procedures for identifying "high risk" parcels resulted in either a very small or very large proportion being identified, so a clumsy and arbitrary summing and thresholding procedure had to be used to extract a reasonable proportion.

Whatever the threshold used, this homogenisation procedure will inevitably result in the omission of below-threshold areas at high risk and the erroneous identification of low- or moderate-risk areas as high risk; due to the parcel boundaries being completely unrelated to, and at a larger scale than, the risk factors.

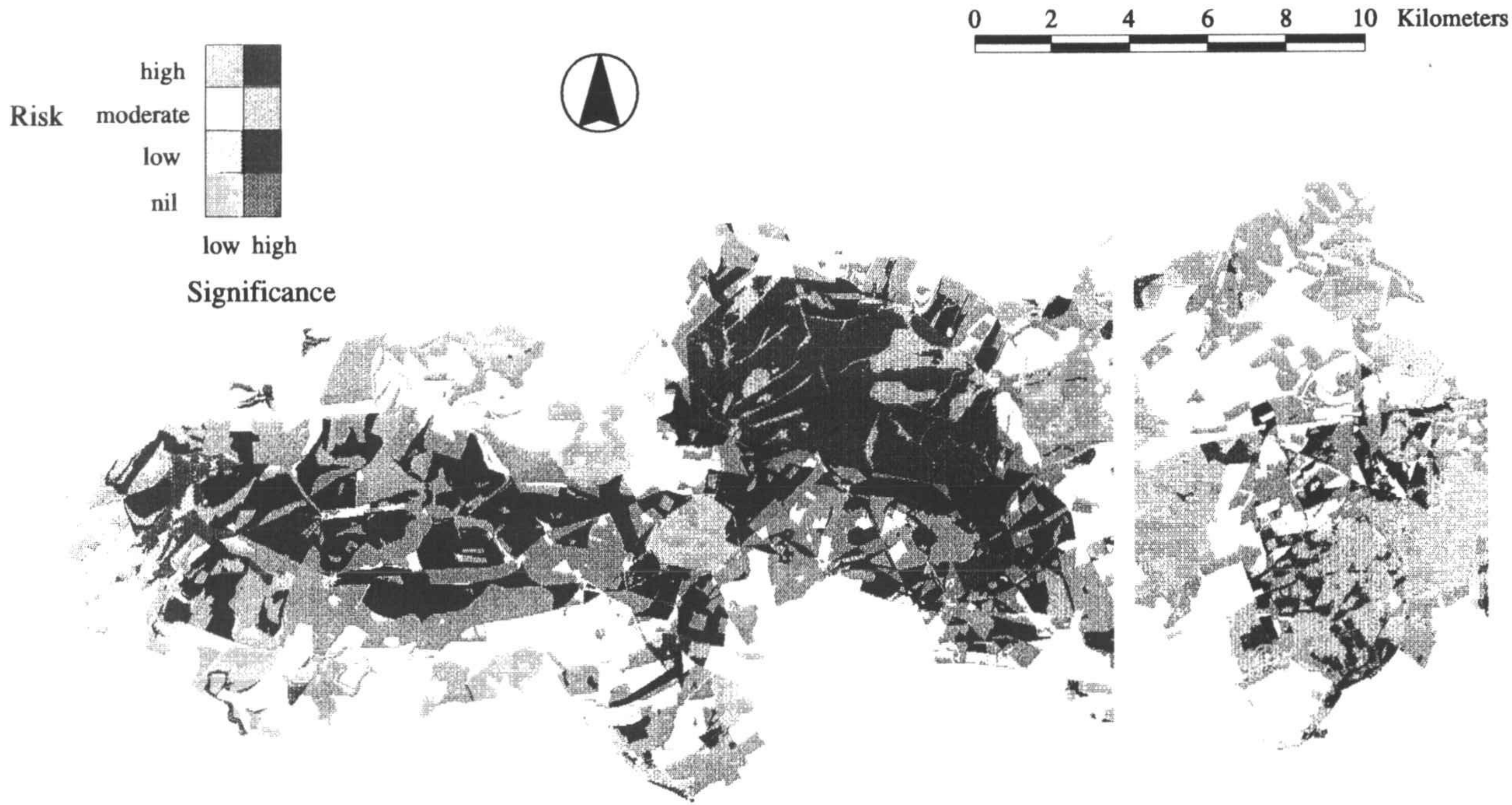


Fig. 3.14: Risk significance map

The compositions of the risk images are shown in Table 3.6 below.

Table 3.6: Composition of per-parcel and per-pixel risk images		
Risk	**Per-pixel (% of area)**	**Per-parcel (% of area)**
Nil	19	21
Low	21	17
Moderate	48	32
High	12	30

In the original per-pixel risk map, moderate values dominate. Thresholding large areas of high risk and classifying risk by parcel has considerably reduced the proportion of moderate risk values and increased the proportion of high risk area, resulting in a more even distribution of values.

The conservation value map clearly shows the dominance of high-value vegetation in the central parts of the West and Central areas of the SPTA. Areas of high risk in the Eastern area are more sparse and fragmented.

The risk significance image shows areas with high risk and high significance across the middle of the west area and the southern half of the central area, plus to a lesser extent in the southern half of the Eastern area. It can be seen that areas of low significance and low or moderate risk exist along the north and south edges of the western area and the northern half of the East area.

Much high value vegetation is present within the large shelling range on the Central area; although at low risk from vehicles, this is subject to a very different form of disturbance from live shell impacts.

The composition of the risk significance map is shown in Table 3.7 below;

Table 3.7 Composition of eight-class risk significance map				
Risk	**Nil** **(% of area)**	**Low** **(% of area)**	**Moderate** **(% of area)**	**High** **(% of area)**
Significance				
Low	12	8	23	17
High	1	10	12	17

The image has a fairly even spread of values, apart from the very low proportion of nil risk/high significance areas, which is not entirely unexpected due to the low occurrence of calcareous grassland in urban areas.

4 Conclusions

4.1 Estimation of the vegetation resource of Salisbury Plain

In combining the ground and air -surveyed vegetation data, neither were assumed to be necessarily "correct". The ground survey described the composition of sampled plant communities and mapped their extent, whilst the air survey inferred vegetation cover type from measurement of spectral reflectances.

Whilst it may be reasonable to assume that the ground-surveyed data represents truth at those sample points which were examined, it is practically impossible for an exhaustive survey in such detail to be made and therefore generalizations must occur. Also, the division of the area into predetermined parcels based on factors not necessarily related to current vegetation cover requires the forcing of natural variations into homogeneous polygons. The classification of some areas as mosaics of different vegetation types underlines the difficulty in mapping small-scale complexity into larger scale units. The occurrence of vehicle disturbance can only increase small scale heterogeneity in vegetation cover. The subjective nature of much human decision-making also adds to the uncertainty in this data.

The air-surveyed data, on the other hand, is exhaustive, and in its raw form, purely objective. It recognises (within its resolution) the heterogeneous nature of the survey area. However, the processes required to make the data more meaningful involve geometric interpolation and other mathematical processing, plus reference to the ground-surveyed data for training, resulting in a coverage that has been distorted to fit a particular geographic model and classification scheme.

The results of combining the data for the tetrads and complete east and west sides show how sensitive the data is to local variations. However, the final result of the process can be seen to have the general effect of increasing the representation of classes on which the two datasets tend to agree strongly, whilst marginalising those with lower levels of correspondence, for example CG/MG mosaic. The diversity of the information is reduced, and this may not necessarily be desirable.

Considering the essentially experimental nature of the air survey methodology (section 3.2.1.1), it may have been more appropriate to have placed greater weight on the veracity of the ground surveyed data, rather than treating the two datasets as of equal merit. However, the air survey proved valuable in allowing identification of bare ground (and therefore possibly disturbed) areas which the ground survey overlooked through generalisation.

The combination of ground-surveyed and remotely-sensed data also allows quantification of the heterogeneity of land cover within management units. By comparison of a land parcel with the spatially-corresponding remotely-sensed pixel classes, more realistic estimates of conservation value and levels of disturbance could be made.

4.2 Prediction of relative levels of training traffic

Whilst the use of the tactical constants of terrain and woodland has been shown to produce a valid model of traffic concentration, it makes very broad assumptions about the influences on military training traffic, when the reality may well be much more complicated. It was derived from manuals of front-line tactical maneuvering, though other types of operation may be trained for; such as logistical support, which may respond differently to terrain and vegetation. The cost-path analysis carried out assumed that all traffic is running directly between tactical points, when vehicles may well be driving between disparate locations within an area, perhaps to defend or attack on a flank.

Another possible factor influencing heavily-used routes on the SPTA is that existing tracks tend to be followed, as tracks imply regular movement and therefore that they lead somewhere worthwhile. Past occupation has left its marks on the Plain, including lines of communication, which may not necessarily skirt woodlands and avoid ridges. These may have been followed and become established or re-established during exercises and other activities.

The technique of modelling a simple cost surface using topography and other factors allows general identification of areas already disturbed, and prediction of areas likely to be disturbed. It can also be used as in specific instances, for instance to predict traffic impacts as part of the exercise planning process.

4.3 Estimating significance of risk

The risks as modelled give an impression of areas where disturbance resulting from vehicle traffic is more or less likely to occur. However, the model is still quite simplistic; not only for reasons to do with the modelling of influences on vehicle movement as outlined above, but also because other factors could be modelled in more detail; for example, the risk of valley bottoms to disturbance should vary with season. Besides the risks of disturbance from dust already identified, other sources such as exhaust pollution and noise could be included.

The estimates of significance give a good impression of areas of high value. More detail could be added, perhaps by adding information relating to rare species and communities, or incorporating the correspondence values between the two datasets as fuzzy membership values.

Combining the risk and significance images shows distinct areas where training should be diverted from and where it could be diverted to. The model is intended to provide the first step in identifying areas at risk, allowing further investigations on site to be clearly targeted. However, the homogenisation of risk values within land parcels shows that a management policy based on the homogenous polygons will consistently underestimate risk. Thresholding of areas at risk to identify parcels at risk ignores smaller areas, and identifying complete parcels dilutes risk value and hampers precise targeting of management measures on areas in real need.

4.4 Overall Conclusion

There is some irony that the very land use which has resulted in the preservation of rare calcareous grassland habitats of much of Salisbury Plain, should now be seen as a threat. However, military training as a land use is not one that of necessity requires drastic changes to the natural environment, unlike arable agriculture or quarrying, for example. The unwanted disturbance is a side-effect of the land use rather than an avoidable outcome. It can therefore be controlled by careful management, to the mutual benefit of the landscape and the user.

It has been shown how GIS can be used to build up models of disturbance risk and habitat value at a landscape scale using multiple datasets, and to combine the two to facilitate the making of management decisions on which areas should be trained on and which should be rested.

The datasets used in this project are very large. The increasing use of high-resolution remote sensing technology and increasing amounts of spatially-referenced information available to managers make GIS a necessity for effective handling of the volumes of data in many applications.

This project forms a small part of a large portfolio of work, which ITE are carrying out on the SPTA. Research is or will be taking place on various aspects of the interactions between the land use and the natural environment, with the ultimate intention of improving the management of the rare and valuable landscape of Salisbury Plain.

5 Further Research

The following areas are identified as being of potential interest for further investigation:

5.1 Research Pertinent to Objective A:

- Spatial analysis of the differences between the ground and air surveyed datasets:- The maximum correspondence value images derived for objective A give some indication of spatial variation, which can be related back to the vegetation classes. Scope exists for detailed investigations into the spatial relationships between the different vegetation classes, particularly CG/MG mosaic.

- Spatial analysis of vegetation relating to land parcel boundaries:- The vector coverage of the ground-surveyed vegetation data assumes an infinitely thin and sudden transition between adjoining parcels of differing classes, when in truth there is likely to be a transition between the two. Comparisons with the classified and raw remotely-sensed data could be used to investigate variations in data coinciding with parcel boundaries.

- Influence of temporal variation in ground survey results:- The ground survey was spread over two periods of over four months in successive years; plants seen in April may not have been detected in September, and *vice-versa*. The relationship between the time of survey and results could be investigated.

- Influence of observers' knowledge and experience:- It can be argued that the categorisation of information based on subjective assessment is inevitably biased by human experience. The ground survey data and metadata could be used to investigate this hypothesis.

- Classification of remotely sensed imagery:- The raw data was classified into twelve and twenty-five categories, both including CG/MG mosaic. Other options are available and could be applied.

5.2 Research Pertinent to Objective B:

- Further analysis of vehicle movements and factors; including exercise objectives, differentiation between vehicle role and movement pattern, analysis of tracked mileage data and quantification of disturbance levels.

- Comparison of local and global optimisation of routes:- The cost-distance analysis assumed a "most efficient" route between source and destination, whereas in reality, route choice may be determined by previous personal experience or factors assisting with navigation.

- Validation of model against actual disturbance patterns from raw remotely sensed data:- Quantitative indices of vegetation cover can be readily derived from raw CASI data. These can be compared to the predicted levels of disturbance generated by the model.

5.3 Research Pertinent to Objective C:

- Analysis of disturbance from dust deposition from all-weather tracks:- Little is known about the extent of this problem (Section 3.4.2.1), in terms of the volume of dust created by a vehicle pass, range of deposition, influence of prevailing wind direction, effects on vegetation and possible ecological impacts.

- Investigation into current management policies:- Scope exists for research into the effects of current land management regimes, including allocation of training sites, on the landscape of SPTA in relation to disturbance patterns. The results could be used to investigate possible alternative policies and predict their effects on disturbance patterns.

- Cost-benefit analyses of methods of diverting training to allow recovery of disturbed areas, whilst minimising increased disturbance on other valuable areas and avoiding unacceptable logistical costs. This could be linked with other current research into regeneration times following disturbance.

- Analysis of spatial resolutions of risk pixels versus management parcels:- Forcing the risk values into homogenous polygons was shown to be detrimental to the model. Investigations into ways of resolving this conflict would be worthwhile.

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APPENDIX A: Arc Macro Language (AML) Scripts

Contents:

Compare.aml	Combines ground and air surveyed SPTA vegetation data and produces ASCII table of counts of each class combination.
Extract.aml	Produces maximum correspondence value and class images
Movefacs.aml	Produces vehicle movement factors image from DTM and vegetation data
Risksig.aml	Produces risk and conservation value images and risk significance image

NB. The processing carried out during the analysis stage of this project was generally done interactively. The scripts detail the Arc/Info commands used.

```
/* -----------------------------------------------------------
/* Compare.aml
/* -----------------------------------------------------------

/* Combines air-surveyed and ground-surveyed SPTA vegetation
/* data and produces ASCII table containing results to enter
/* into comparison matrix

/* -----------------------------------------------------------

/* Written by P.J. Langmaid, July 1998

/* ----------------------------------------------------------

/* Input required:

/* in_air -    air-surveyed vegetation data - GRID format
/*             with 12-class integer classification
/* in_ground - ground-surveyed vegetation data - GRID format
/*             with four-digit 32-class integer
/*             classification

/* remap_air -    ASCII remap table for air-surveyed data
/* remap_ground - ASCII remap table for ground-surveyed data

/* run program from arc prompt

/* -----------------------------------------------------------

/* reclassify data values into temporary files;

grid

temp_air = reclass (in_air, remap_air)
temp_ground = reclass (in_ground, remap_ground)

/* combine temporary grids;

temp_comb = combine (temp_air, temp_ground)
quit

/* enter Arc/Tables and export VAT to ASCII file;

tables
select temp_comb.vat
unload combdata.tab temp_air temp_ground count
quit

&return
```

```
/* remap_air

/* remap table for air-surveyed SPTA data
/* referred to by Compare.aml

/* merges the following classes;
/*        arable, MG7 and other MGs
/*        cloud, cloud shadow and burnt/shaded
/*        grassland regen and CG

0 : 0
1 : 3
2 : 3
3 : 3
4 : 4
5 : 5
6 : 6
7 : 11
8 : 5
9 : 9
10 : 11
11 : 11
12 : 12
```

```
/* remap_ground

/* remap table for ground-surveyed SPTA data
/* referred to by Compare.aml

/* merges the following classes;
/*       arable, MG7 and other MG communities
/*       CG communities and burnt grassland
/*       woodland communities
/*       bare/quarry and urban

/* NB Arc/Grid does not accept mixed ranges and single
/* values as remap table inputs; therefore all values
/* entered as ranges.

1000 3999 : 3000
4000 4999 : 4000
5000 5001 : 5000
6000 6999 : 6000
7000 7001 : 5000
9000 9999 : 9000
```

```
/* ---------------------------------------------------------------
/* Extract.aml
/* ---------------------------------------------------------------

/* Produces class correspondence images for SPTA data, then
/* extracts maximum correspondence value and class images.

/* ---------------------------------------------------------------

/* Written by P.J. Langmaid, July 1998

/* ---------------------------------------------------------------

/* Input required:

/* temp_air - air-surveyed vegetation data - raster format
/*            12 - band classification, reclassified to
/*            common scheme using remap_air table by
/*            Compare.aml

/* temp_ground - ground-surveyed vegetation data - raster
/*               format with four-digit 32-class integer
/*               classification,reclassified to common
/*               scheme using remap_ground table by
/*               Compare.aml

/* Variables - correspondence values from comparison matrix

/* run program from arc prompt

/* ---------------------------------------------------------------

/* assign variables; percentage correspondence values from
/*                   comparison matrix, in integer form

/* Air survey to ground survey (bottom row of matrix);
&setvar ag3 <value> /*arable/MG
&setvar ag4 <value> /*CG
&setvar ag5 <value> /*MG/CG mosaic
&setvar ag6 <value> /*woodland
&setvar ag9 <value> /*bare ground

/* Ground survey to air survey (right-hand column of
/*                              matrix);
&setvar ga3 <value> /*arable/MG
&setvar ga4 <value> /*CG
&setvar ga5 <value> /*MG/CG mosaic
&setvar ga6 <value> /*woodland
&setvar ga9 <value> /*bare ground
```

```
/* produce correspondence value images for each class in
turn...

grid

/* arable/MG...

     if (temp_air eq 3 and temp_ground eq 3000)
                                              corrval3 = 100
else if (temp_air eq 3 and temp_ground ne 3000)
                                              corrval3 = %ag3%
else if (temp_air ne 3 and temp_ground eq 3000)
                                              corrval3 = %ga3%
else                                          corrval3 = 0
endif

/* CG...

     if (temp_air eq 4 and temp_ground eq 4000)
                                              corrval4 = 100
else if (temp_air eq 4 and temp_ground ne 4000)
                                              corrval4 = %ag4%
else if (temp_air ne 4 and temp_ground eq 4000)
                                              corrval4 = %ga4%
else                                          corrval4 = 0
endif

/* CG/MG mosaic

     if (temp_air eq 5 and temp_ground eq 5000)
                                              corrval5 = 100
else if (temp_air eq 5 and temp_ground ne 5000)
                                              corrval5 = %ag5%
else if (temp_air ne 5 and temp_ground eq 5000)
                                              corrval5 = %ga5%
else                                          corrval5 = 0
endif


/* woodland

     if (temp_air eq 6 and temp_ground eq 6000)
                                              corrval6 = 100
else if (temp_air eq 6 and temp_ground ne 6000)
                                              corrval6 = %ag6%
else if (temp_air ne 6 and temp_ground eq 6000)
                                              corrval6 = %ga6%
else                                          corrval6 = 0
endif
```

```
/* Extract the maximum correspondence values…

maxcorva = max (corrval3, corrval4, corrval5, corrval6)

/* Compare the maximum and class correspondence values to
/* extract vegetation classes carrying maximum
/* correspondence values.
/* Note classes of greatest interest extracted first in
/* case of tied values

     if (maxcorva eq corrval4) maxcorcl = 4
else if (maxcorva eq corrval5) maxcorcl = 5
else if (maxcorva eq corrval3) maxcorcl = 3
else if (maxcorva eq corrval6) maxcorcl = 6
endif

/* delete temporary files

kill temp_air all
kill temp_ground all
kill corrval3 all
kill corrval4 all
kill corrval5 all
kill corrval6 all

/* end program

quit

&return
```

```
/* -----------------------------------------------------------
/* Movefacs.aml
/* -----------------------------------------------------------

/* Extracts factors perceived as attracting or repelling
/* armoured vehicle traffic during training exercise on the
/* SPTA.

/* -----------------------------------------------------------

/* Written by P.J. Langmaid, August 1998

/* -----------------------------------------------------------

/* Input required:

/* maxcorcl_pix - maximum correspondence class image
/* produced by running Compare.aml and Extract.aml for
/* objective A.

/* dtm - digital terrain model, in GRID format with 50m
/* horizontal and 0.1m vertical resolution (heights as
/* integer values in decimetres)

/* area_mask - boolean mask of study area - in GRID format
/* with 2.5m resolution

/* Variables required:

/* %higher% - integer scalar greater than highest value on
/* dem.

/* run program from arc prompt

/* -----------------------------------------------------------

/* Extract gradient restrictions

&setvar higher <value> /* greater than highest point on dem

grid

slopes = slope (dtm, percentrise, 0.1)

if   (slopes ge 60) too_steep = 1
else                too_steep = 0
endif

kill slopes all
```

```
/* extract ridge network and identify exposed ridge lines

invdtm = %higher% - dtm
invflow = flowdirection (invdem, #, normal)
invdrain = flowaccumulation (invflow)

if    (invdrain ge 150) ridges = 1
endif

/* Buffer out around ridge lines and extract exposed cells

ridgebuf = expand (ridges, 5, list, 1)
ridgehts = dtm * ridgebuf
ridgemax = focalmax (ridgehts, rectangle, 10, 10, data)

if    (ridgehts lt (ridgemax - 25)) temp = 1
endif

/* convert NODATA values to zero

exposed = con(isnull(temp), 0, temp)

/* combine steep slopes and exposed ridges

terrfac = max (too_steep, exposed)

/* resample to match resolution of vegetation data

terrfac25 = resample (terrfac, 2.5)

/* delete temporary files

kill temp all
kill invdtm all
kill invflow all
kill invdrain all
kill ridges all
kill ridgebuf all
kill ridgehts all
kill ridgemax all
kill terrfac all

/* Extract factors relating to woodland cover

if (maxcorcl_pix eq 6) tempwoods = 1
endif
```

```
/* group wood pixels and remove scrub areas

tempwoods2 = regiongroup (tempwoods)
tempwoods3 = select (tempwoods2, 'count gt 1000')

/* form 100m buffers around woods

woodsbuf = expand (tempwoods3, 20, list, 1)
if       (tempwoods3 eq 1 and woodsbuf eq 1) woodsfac = 100
else if (tempwoods3 ne 1 and woodsbuf eq 1) woodsfac = 1
endif

/* eliminate NODATA values from woods cover image

woodsfac2 = con(isnull(woodsfac), 0, woodsfac)

/* combine terrain and woods cover factors

if        (woodsfac2 eq 1)    tempfacs = 1
else if  (woodsfac2 eq 100)  tempfacs = 100
else                          tempfacs = terrfac25

/* identify cells outside study area as NODATA

if    (area_mask ge 1) allfacs = tempfacs
endif

/* delete temporary files

kill tempfacs all
kill woodsfac2 all
kill woodsfac all
kill tempwoods all
kill tempwoods2 all
kill tempwoods3 all
kill woodsbuf all

/* end program

quit
&return
```

```
/* ----------------------------------------------------------
/* Risksig.aml
/* ----------------------------------------------------------

/* Produces risk and conservation value maps and combines
/* them to produce risk significance map.
/* ----------------------------------------------------------

/* Written by P.J. Langmaid, August 1998

/* ----------------------------------------------------------

/* Input GRIDS required:
/* movefacs - movement factors image produced by Movefac.aml
/* areafacs - areas where vehicle movements do not conform
/*            to general movement factors (eg urban, ranges)
/* DTM -      digital terrain model
/* maxcorcl_par - combined ground and air survey (modal
/*                classes per land parcel)image

/* All images in grid format with 2.5m resolution except for
/* DTM in 50m resolution

/* Input coverages required:
/* land_parcels - land parcel polygon boundaries

/* run program from arc prompt

/* ----------------------------------------------------------
grid
```

```
/* Calculate risk from general traffic movements

if (movefacs eq 1) moverisk = 3
else if (movefacs eq 10) moverisk = 2
else if (movefacs eq 1) moverisk = 1
endif

/* Calculate additional risk for valley bottoms

fill dtm smoothdtm sink
flow_dir = flowdirection (smoothdtm, #, normal)
flow_acc = flowaccumulation (flow_dir)
valrisk = con((flow_acc ge 150), 3, 2)
valrisk25 = resample (valleys, 2.5)

/* combine vehicle movement and valley bottom risks

     if (moverisk eq 1 or moverisk eq 3) genrisk = moverisk
else if (val_risk25 eq 1)                genrisk = 3
else                                     genrisk = 2

/* combine with area-specific risks;
/* prohibited areas (nil risk)
if (areafacs eq 0) allrisk = 0
/* restricted areas (low risk)
if (areafacs eq 1) allrisk = 1
/* off-road driving area (high risk)
if (areafacs eq 3) allrisk = 3
else allrisk = genrisk

/* convert by-pixel risks to homogenous values for land
parcels
zones = polygrid (land_parcels, #, #, #, 2.5)
```

```
     if (allrisk eq 3) highrisk = 1
endif

hr_count = zonalsum (zones, highrisk)

     if (hr_count ge 4800) hr_parcels = 3
else hr_parcels = 0

zmrisk = zonalmajority (zones, genrisk)
pcl_risk = max (zmrisk, hr_parcels)
/* Extract conservation values
      if (maxcorcl_par eq 4 or maxcorcl_par eq 5)
                                                    consval = 3
else                                                consval = 1

/* produce risk significance map
temprsig = combine (pcl_risk, consval)

/* Reclassify values in ascending order of risk and
significance
if ('temprsig.pcl_risk eq 0' and 'temprsig.consval eq 1')
                                                     risksig = 1
if ('temprsig.pcl_risk eq 0' and 'temprsig.consval eq 3')
                                                     risksig = 2
if ('temprsig.pcl_risk eq 1' and 'temprsig.consval eq 1')
                                                     risksig = 3
if ('temprsig.pcl_risk eq 1' and 'temprsig.consval eq 3')
                                                     risksig = 4
if ('temprsig.pcl_risk eq 2' and 'temprsig.consval eq 1')
                                                     risksig = 5
if ('temprsig.pcl_risk eq 2' and 'temprsig.consval eq 3')
                                                     risksig = 6
```

```
if ('temprsig.pcl_risk eq 3' and 'temprsig.consval eq 1')
                                                    risksig = 7
if ('temprsig.pcl_risk eq 3' and 'temprsig.consval eq 3')
                                                    risksig = 8

/* delete temporary files
kill moverisk all
kill smoothdtm all
kill flow_dir all
kill flow_acc all
kill valrisk all
kill valrisk25 all
kill genrisk all
kill zones all
kill highrisk all
kill hr_count all
kill hr_parcels all
kill zmrisk all
kill temprsig all

/* end program

quit
&return
```

APPENDIX B: Relationships between classifications of vegetation data

Relationships between classifications of Salisbury Plain vegetation data

Ground Survey		Air Survey (12-class)		Air Survey (25-class)		Combined Data	
Integer code	Description	Value	Description	Value	Description	Value	Description
0	Unclassified	0	Unclassified	0	Unclassified	0	Unclassified
1000	Arable	1	Arable	11	Arable	3	Arable/MG
2000	MG7	2	MG7	3	MG7	3	Arable/MG
						3	Arable/MG
3100	MG1	3	All MGs (except MG7)	2	MG1	3	Arable/MG
3110	MG11	3	All MGs (except MG7)		-	3	Arable/MG
3120	MG12	3	All MGs (except MG7)		-	3	Arable/MG
3500	MG5	3	All MGs (except MG7)	24	MG5	3	Arable/MG
3600	MG6	3	All MGs (except MG7)	25	MG6	3	Arable/MG
3010	MG mosaic	3	All MGs (except MG7)		-	3	Arable/MG
3020	MG unclassified	3	All MGs (except MG7)		-	3	Arable/MG
3030	Cleared woodland	3	All MGs (except MG7)		-	3	Arable/MG
3040	Disturbed vegetation	3	All MGs (except MG7)		-	3	Arable/MG
3050	Aquatic/swamp	3	All MGs (except MG7)		-	3	Arable/MG
4100	CG1	4	All CGs		-	4	CG
4200	CG2	4	All CGs	4	CG2	4	CG
4210	CG2a	4	All CGs	4	CG2	4	CG
4230	CG2c	4	All CGs	4	CG2	4	CG
4300	CG3	4	All CGs		-	4	CG
4310	CG3a	4	All CGs	5	CG3a	4	CG
4320	CG3b	4	All CGs		-	4	CG
4330	CG3c	4	All CGs		-	4	CG
4340	CG3d	4	All CGs	6	CG3d	4	CG
4345	CG3di	4	All CGs	6	CG3di	4	CG

4400	CG4	4	All CGs	7	CG4	4	CG
4500	CG5	4	All CGs		-	4	CG
4600	CG6	4	All CGs		-	4	CG
4700	CG7	4	All CGs	8	CG7	4	CG
4010	CG mosaic	4	All CGs	10	Mosaic (CGs)	4	CG
4020	CG unclassified	4	All CGs		-	4	CG
4030	Chalk heath	4	All CGs		-	4	CG
5000	CG/MG mosaic	5	Mosaic (cg/mg)	9	Mosaic (cg/mg)	5	Mosaic (cg/mg)
6100	Deciduous woodland	6	Woodland (conif. and b.l.)	12	Scrub or b.l. woodland	6	Woodland
6200	Deciduous plantation	6	Woodland (conif. and b.l.)	12	Scrub or b.l. woodland	6	Woodland
6300	Conifer plantation	6	Woodland (conif. and b.l.)	13	Coniferous woodland	6	Woodland
6400	Mixed plantation	6	Woodland (conif. and b.l.)		-	6	Woodland
							-
7000	Burnt grassland		-		-	4	CG
	-		-	15	Shade		-
9100	Bare ground/quarry	9	Bare soil or built-up	16	Bare/built-up/shade	9	Bare ground
9200	Urban/buildings/carparks	9	Bare soil or built-up	16	Bare/built-up/shade	9	Bare ground
	-	7	Burnt or shaded area		-		-
	-	8	Grassland regen. on burnt/shade		-	4	CG
	-	10	Cloud	17	Cloud		-
	-	11	Cloud shadow	18	Cloud shade		-
	-	12	Water	14	Water		-
	-		-	22	CG3 regen. on burnt area	4	CG
	-		-	1	Improved grassland	3	MG
	-		-	19	Recent plantn. or disturbed		-

APPENDIX C: Comparison matrices for sample tetrads.

Each tetrad consists of a 2km by 2km square, corresponding with the tetrads selected for other current research on the SPTA (Hirst *et al* 1998). Locations of the south-west and north-east corners of the tetrads are given below:

SPTA West

A: 396000 149000, 398000 151000
B: 394000 147000, 396000 149000
C: 402000 145000, 404000 147000

SPTA East

D: 416000 151000, 418000 153000
E: 418000 149000, 420000 151000
F: 418000 147000, 420000 149000

Matrices are included for comparisons by pixel (using original data) and by land parcel (using original ground survey data and air survey data reclassified to majority class in each land parcel).

Comparison matrix of pixel counts between ground and original air survey vegetation data: Tetrad A

Ground survey Classes	Air survey Classes Codes	Unclass 0	Arable 1	MG7 2	All MGs (except MG7) 3	All CGs 4	Mosaic (cg/mg) 5	Woodland (con & b.l.) 6
Unclass.	**0**							
Arable	**1000**							
MG7	**2000**		**4**	**21895**	**28287**	**6226**	**979**	**676**
MG1	3100		1	630	51950	45416	11197	909
MG11	3110							
MG12	3120							
MG5	3500							
MG6	3600							
MG mosaic	3010			510	6027	9322	1086	909
MG unclass.	3020			8127	1480	3825	247	8
Cleared wd.	3030							
Dist. veg.	3040							
Aquatic/sw.	3050							
All MGs (except MG7)		**0**	**1**	**9267**	**59457**	**58563**	**12530**	**1826**
CG1	4100							
CG2	4200							
CG2a	4210							
CG2c	4230							
CG3	4300			21	17	1923	210	327
CG3a	4310				19	1312	137	
CG3b	4320							
CG3c	4330							
CG3d	4340		11	45047	114489	111693	25493	14728
CG3di	4345			4	4479	41902	4656	3921
CG4	4400							
CG5	4500							
CG6	4600							
CG7	4700							
CG mosaic	4010				54	6743	4661	832
CG unclass	4020							
Ch. heath	4030							
All CGs		**0**	**11**	**45072**	**119058**	**163573**	**35157**	**19808**
CG/MG mosaic	**5000**			**258**	**3602**	**9695**	**5557**	**971**
Decid. wd.	6100					387	202	844
Decid. pl.	6200			5	222	554	368	998
Conif. pl.	6300			9	801	1172	89	389
Mixed pl.	6400			189	1252	2432	1348	1487
Woodland (conif & b.l.)		**0**	**0**	**203**	**2275**	**4545**	**2007**	**3718**
Burnt gslnd.	**7000**							
Bare/quarry	9100							
Urban etc	9200							
Bare soil or built-up		**0**	**0**	**0**	**0**	**0**	**0**	**0**
Air to ground	Common	**0**	**0**	**21895**	**59457**	**163573**	**5557**	**3718**
Correspondence	Total	**0**	**16**	**76695**	**212679**	**242602**	**56230**	**26999**
	Percentage		**0**	**28.55**	**27.96**	**67.42**	**9.88**	**13.77**

Ground survey classes in normal type are summed to common classes in bold type.
Items 8, 10, 11 and 12 in the air survey classification (in italics) have no equivalent in the ground survey classification and are omitted from the calculations of correspondence.

Tetrad A: original air survey data

Burnt or shaded 7	*Grassland regen* 8	Bare soil or built-up 9	*Cloud 10*	*Cloud shadow 11*	*Water 12*	**Ground to air Correspondence** Common	Total	Percentage
						0	0	
						0	0	
		4127				21895	62194	35.2
		4642					114745	
							0	
							0	
							0	
							0	
		2811					20665	
		956					14643	
							0	
							0	
							0	
0	*0*	**8409**	*0*	*0*	*0*	**59457**	**150053**	**39.62**
							0	
							0	
							0	
							0	
		464					2962	
		172					1640	
							0	
							0	
		8294					319755	
		1055					56017	
							0	
							0	
							0	
							0	
		256					12546	
							0	
							0	
0	*0*	**10241**	*0*	*0*	*0*	**163573**	**392920**	**41.63**
		1738				5557	**21821**	**25.47**
							1433	
		19					2166	
		97					2557	
		148					6856	
0	*0*	**264**	*0*	*0*	*0*	**3718**	**13012**	**28.57**
						0	**0**	
							0	
							0	
0	*0*	**0**	*0*	*0*	*0*	**0**	**0**	
0	*n/a*	**0**	*n/a*	*n/a*	*n/a*	**254200**	**640000**	
0	*0*	**24779**	*0*	*0*	*0*	**254200**	**640000**	
		0						**39.72**

(O.C.C.)

(Overall Classification Correspondence)

Comparison matrix of pixel counts between ground and original air survey data: Tetrad B

Ground survey Classes	Air survey Classes Codes	Unclass 0	Arable 1	MG7 2	All MGs (except MG7 3	All CGs 4	Mosaic (cg/mg) 5	Woodland (con & b.l.) 6
Unclass.	**0**							
Arable	**1000**							
MG7	**2000**							
MG1	3100			462	14770	72466	7502	3002
MG11	3110							
MG12	3120							
MG5	3500							
MG6	3600							
MG mosaic	3010			136	482	5502	976	10
MG unclass.	3020							
Cleared wd.	3030							
Dist. veg.	3040							
Aquatic/sw.	3050							
All MGs (except MG7)		**0**	**0**	**598**	**15252**	**77968**	**8478**	**3012**
CG1	4100							
CG2	4200							
CG2a	4210							
CG2c	4230							
CG3	4300							
CG3a	4310			8	526	2331	340	
CG3b	4320							
CG3c	4330							
CG3d	4340			24	6183	36552	3325	129
CG3di	4345	29		11	972	132822	6188	3126
CG4	4400							
CG5	4500							
CG6	4600							
CG7	4700							
CG mosaic	4010			15	216	60727	2272	73
CG unclass	4020							
Ch. heath	4030							
All CGs		**29**	**0**	**58**	**7897**	**232432**	**12125**	**3328**
CG/MG mosaic	**5000**	**95**	**3**	**1221**	**28221**	**158640**	**20726**	**1132**
Decid. wd.	6100				8	11	1	25
Decid. pl.	6200			39	318	354	13	160
Conif. pl.	6300	31		21	555	6054	798	2273
Mixed pl.	6400					111	41	145
Woodland (conif & b.l.)		**31**	**0**	**60**	**881**	**6530**	**853**	**2603**
Burnt gslnd.	**7000**							
Bare/quarry	9100				253	581	39	367
Urban etc	9200							
Bare soil or built-up		**0**	**0**	**0**	**253**	**581**	**39**	**367**
Raster	Common	**0**	**0**	**0**	**15252**	**232432**	**20726**	**2603**
Correspondence	Total	**155**	**3**	**1937**	**52504**	**476151**	**42221**	**10442**
	Percentage	**0**	**0**	**0**	**29.05**	**48.81**	**49.09**	**24.93**

Ground survey classes in normal type are summed to common classes in bold type
Items 8, 10, 11 and 12 in the air survey classification (in italics) have no equivalent in the ground survey classification and are omitted from the calculations of correspondence.

Tetrad B: original air survey data

Burnt or shaded 7	*Grassland regen* 8	Bare soil or built-up 9	*Cloud* 10	*Cloud shadow* 11	*Water* 12	**Ground to air correspondence** Common	Total	Percentage
						0	**0**	
						0	**0**	
						0	**0**	
		18792					116994	
							0	
							0	
							0	
							0	
		1998					9104	
							0	
							0	
							0	
							0	
0	*0*	**20790**	*0*	*0*	*0*	**15252**	**126098**	**12.1**
							0	
							0	
							0	
							0	
							0	
		693					3898	
							0	
							0	
		8259					54472	
		9928					153076	
							0	
							0	
							0	
							0	
		3980					67283	
							0	
							0	
0	*0*	**22860**	*0*	*0*	*0*	**232432**	**278729**	**83.39**
		9844				**20726**	**219882**	**9.43**
							45	
		6					890	
		2321					12053	
							297	
0	*0*	**2327**	*0*	*0*	*0*	**2603**	**13285**	**19.59**
						0	**0**	
		766					2006	
							0	
0	*0*	**766**	*0*	*0*	*0*	**766**	**2006**	**38.19**
0	*n/a*	**766**	*n/a*	*n/a*	*n/a*	**271779**	**640000**	
0	*0*	**56587**	*0*	*0*	*0*	**271779**	**640000**	
		1.35						**42.47**

(O.C.C.)

(Overall Classification Correspondence)

Comparison matrix of pixel counts between ground and original air survey vegetation data
Tetrad C

	Air survey				All MGs		Mosaic	Woodland
Ground survey	Classes	Unclass	Arable	MG7	(except MG7)	All CGs	(cg/mg)	(con & b.l.)
Classes	Codes	**0**	**1**	**2**	**3**	**4**	**5**	**6**
Unclass.	**0**				**2**	**9**	**2**	
Arable	**1000**		**6062**	**1788**	**1291**	**1588**	**32**	**1722**
MG7	**2000**	**548**		**341**	**4741**	**8196**	**423**	**63**
MG1	3100		298	85	6546	47550	1092	787
MG11	3110		1	9	468	1928		1
MG12	3120							
MG5	3500							
MG6	3600		4	89	4900	1425	187	
MG mosaic	3010	1556	8	276	7671	5024	16	30
MG unclass.	3020		2	21	3283	5039	105	150
Cleared wd.	3030							
Dist. veg.	3040							
Aquatic/sw.	3050							
All MGs (except MG7)		**1556**	**313**	**480**	**22868**	**60966**	**1400**	**968**
CG1	4100							
CG2	4200		16	10	1889	711	25	128
CG2a	4210							
CG2c	4230							
CG3	4300							
CG3a	4310		1		47	845		93
CG3b	4320							
CG3c	4330							
CG3d	4340		634	1507	37759	199705	31945	1746
CG3di	4345		8		380	6028		1
CG4	4400							
CG5	4500							
CG6	4600							
CG7	4700							
CG mosaic	4010		158	3	5860	51589	18	699
CG unclass	4020							
Ch. heath	4030							
All CGs		**0**	**817**	**1520**	**45935**	**258878**	**31988**	**2667**
CG/MG mosaic	**5000**		**169**	**260**	**14335**	**48480**	**1184**	**106**
Decid. wd.	6100							
Decid. pl.	6200		22	38	124	720	12	149
Conif. pl.	6300							
Mixed pl.	6400		79	2	497	10580		5903
Woodland (conif & b.l.)		**0**	**101**	**40**	**621**	**11300**	**12**	**6052**
Burnt gslnd.	**7000**							
Bare/quarry	9100					237		23
Urban etc	9200				245	329	22	3
Bare soil or built-up		**0**	**0**	**0**	**245**	**566**	**22**	**26**
Air to ground	Common	**0**	**6062**	**341**	**22868**	**258878**	**1184**	**6052**
Correspondence	Total	**2104**	**7462**	**4429**	**90038**	**389983**	**35063**	**11604**
	Percentage	**0**	**81.24**	**7.7**	**25.4**	**66.38**	**3.38**	**52.15**

Ground survey classes in normal type are summed to common classes in bold type.
Items 8, 10, 11 and 12 in the air survey classification (in italics) have no equivalent in the ground survey classification and are omitted from the calculations of correspondence.

Tetrad C: original air survey data

Burnt or shaded 7	*Grassland regen 8*	Bare soil or built-up 9	*Cloud 10*	*Cloud shadow 11*	*Water 12*	Ground to air correspondence Common	Total	Percentage
		3				**0**	**16**	**0**
17	*31*	**903**				**6062**	**13403**	**45.23**
1	*3*	**11885**				**341**	**26198**	**1.3**
29	*219*	14618	*26*				71005	
	1	1921					4328	
							0	
							0	
	18	48					6653	
	9	3180	*3*				17761	
4	*4*	3504					12108	
							0	
							0	
							0	
33	*251*	**23271**	*29*	*0*	*0*	**22868**	**111855**	**20.44**
							0	
1	*3*	79					2859	
							0	
							0	
							0	
5	*71*	111					1102	
							0	
							0	
76	*1813*	32068	*77*				305440	
	7	808					7225	
							0	
							0	
							0	
							0	
26	*618*	8076					66429	
							0	
							0	
108	*2512*	**41142**	*77*	*0*	*0*	**258878**	**383055**	**67.58**
27	*460*	**11223**	*9*			**1184**	**75784**	**1.56**
							0	
1	*15*	21					1087	
							0	
6	*320*	4489					21556	
7	*335*	**4510**	*0*	*0*	*0*	**6052**	**22643**	**26.73**
						0	**0**	
		1463					1723	
		1017					1616	
0	*0*	**2480**	*0*	*0*	*0*	**2480**	**3339**	**74.27**
0	*n/a*	**2480**	*n/a*	*n/a*	*n/a*	**297865**	**636293**	
193	*3592*	**95417**	*115*	*0*	*0*	**297865**	**636293**	
0		**2.6**						**46.81**

(O.C.C.)

(Overall Classification Correspondence)

Comparison matrix of pixel counts between ground and original air survey vegetation data: Tetrad D

Ground survey Classes	Air survey Classes Codes	Unclass 0	Arable 1	MG7 2	All MGs (except MG7) 3	All CGs 4	Mosaic (cg/mg) 5	Woodland (con & b.l.) 6
Unclass.	**0**							
Arable	**1000**		**10312**	**5527**	**5290**	**10764**	**1193**	**1488**
MG7	**2000**		**2757**	**102338**	**106191**	**14293**	**15084**	**1507**
MG1	3100		371	31679	25400	17628	10994	1618
MG11	3110							
MG12	3120							
MG5	3500							
MG6	3600							
MG mosaic	3010		155	19492	37541	10755	3686	398
MG unclass.	3020		175	31978	8823	4652	7307	747
Cleared wd.	3030							
Dist. veg.	3040			35	266	179	20	
Aquatic/sw.	3050							
All MGs (except MG7)		**0**	**701**	**83184**	**72030**	**33214**	**22007**	**2763**
CG1	4100							
CG2	4200							
CG2a	4210							
CG2c	4230							
CG3	4300							
CG3a	4310			200		222	56	
CG3b	4320							
CG3c	4330							
CG3d	4340		4	639	699	2747	1725	85
CG3di	4345							
CG4	4400							
CG5	4500							
CG6	4600		6	1103	9017	7762	4764	107
CG7	4700							
CG mosaic	4010			1	1880	17		
CG unclass	4020			80	1069	3449	3056	4
Ch. heath	4030							
All CGs		**0**	**10**	**2023**	**12665**	**14197**	**9601**	**196**
CG/MG mosaic	**5000**		**4**	**974**	**10418**	**3365**	**1414**	**50**
Decid. wd.	6100			1183	1354	496	596	3360
Decid. pl.	6200		25	4364	3079	781	298	1666
Conif. pl.	6300			7		21		759
Mixed pl.	6400		169	5255	10884	1076	1756	717
Woodland (conif & b.l.)		**0**	**194**	**10809**	**15317**	**2374**	**2650**	**6502**
Burnt gslnd.	**7000**							
Bare/quarry	9100			172	448	255	204	
Urban etc	9200			61	193	31	95	22
Bare soil or built-up		0	0	233	641	286	299	22
Air to ground	Common	**0**	**10312**	**102338**	**72030**	**14197**	**1414**	**6502**
Correspondence	Total	**0**	**13978**	**205088**	**222552**	**78493**	**52248**	**12528**
	Percentage		73.77	49.9	32.37	18.09	2.71	51.9

Ground survey classes in normal type are summed to common classes in bold type.
Items 8, 10, 11 and 12 in the air survey classification (in italics) have no equivalent in the ground survey classification and are omitted from the calculations of correspondence.

Tetrad D: original air survey data

Burnt or shaded 7	*Grassland regen 8*	Bare soil or built-up 9	*Cloud 10*	*Cloud shadow 11*	*Water 12*	**Ground to air correspondence** Common	Total	Percentage
						0	**0**	
		1851		*15*		**10312**	**36425**	**28.31**
		12759	*6*	*32*		**102338**	**254929**	**40.14**
		11165	*8*				98855	
							0	
							0	
							0	
							0	
		3653		*11*			75680	
		10879		*38*			64561	
							0	
		811					1311	
							0	
0	*0*	**26508**	*8*	*49*	*0*	**72030**	**240407**	**29.96**
							0	
							0	
							0	
							0	
							0	
		100					578	
							0	
							0	
		261					6160	
							0	
							0	
							0	
		1549	*10*				24308	
							0	
		6					1904	
		142					7800	
							0	
0	*0*	**2058**	*10*	*0*	*0*	**14197**	**40750**	**34.84**
		464	*8*			**1414**	**16689**	**8.47**
		1972					8961	
		2165					12378	
		91					878	
		3238		*90*			23095	
0	*0*	**7466**	*0*	*90*	*0*	**6502**	**45312**	**14.35**
						0	**0**	
		3246					4325	
		543					945	
0	*0*	3789	*0*	*0*	*0*	3789	5270	71.9
0	*n/a*	**3789**	*n/a*	*n/a*	*n/a*	**210582**	**639782**	
0	*0*	**54895**	*32*	*186*	*0*	**210582**	**639782**	
		6.9						32.91

(O.C.C.)

(O.C.C. = Overall Classification Correspondence)

Comparison matrix between ground and original air survey vegetation data: Tetrad E

Vector Classes	Raster Classes Codes	Unclass 0	Arable 1	MG7 2	All MGs (except MG7) 3	All CGs 4	Mosaic (cg/mg) 5	Woodland (con & b.l.) 6
Unclass.	**0**							
Arable	**1000**			**20**	**10**	**224**	**23**	**64**
MG7	**2000**							
MG1	3100		232	1841	21927	31248	2005	2599
MG11	3110							
MG12	3120							
MG5	3500							
MG6	3600							
MG mosaic	3010		4	3	18794	8506	62	19
MG unclass.	3020			25	7844	3872	270	6
Cleared wd.	3030							
Dist. veg.	3040							
Aquatic/sw.	3050							
All MGs (except MG7)		**0**	**236**	**1869**	**48565**	**43626**	**2337**	**2624**
CG1	4100							
CG2	4200		1	71	134	1098	299	237
CG2a	4210			366	547	4146	1122	1603
CG2c	4230				464	502	16	
CG3	4300							
CG3a	4310		39	745	25466	54155	1104	3480
CG3b	4320							
CG3c	4330		8	80	5408	8414	13	155
CG3d	4340		249	3606	62858	110502	12055	8042
CG3di	4345							
CG4	4400							
CG5	4500							
CG6	4600				392	1451	3	9
CG7	4700							
CG mosaic	4010		4	118	2641	8791	30	495
CG unclass	4020							
Ch. heath	4030							
All CGs		**0**	**301**	**4986**	**97910**	**189059**	**14642**	**14021**
CG/MG mosaic	**5000**		**144**	**919**	**33337**	**35206**	**3229**	**2923**
Decid. wd.	6100		25	152	283	3565	145	1314
Decid. pl.	6200			12	82	380	49	2231
Conif. pl.	6300							
Mixed pl.	6400		115	3512	2215	10278	386	23242
Woodland (conif & b.l.)		**0**	**140**	**3676**	**2580**	**14223**	**580**	**26787**
Burnt gslnd.	**7000**							
Bare/quarry	9100		19	73	302	785	19	449
Urban etc	9200							
Bare soil or built-up		**0**	**19**	**73**	**302**	**785**	**19**	**449**
Air to ground	Common	**0**	**0**	**0**	**48565**	**189059**	**3229**	**26787**
Correspondence	Total	**0**	**840**	**11543**	**182704**	**283123**	**20830**	**46868**
	Percentage		**0**	**0**	**26.58**	**66.78**	**15.5**	**57.15**

Ground survey classes in normal type are summed to common classes in bold type
Items 8, 10, 11 and 12 in the air survey classification (italic) have no equivalent in the vector classification and are omitted from the calculations of correspondence.

Tetrad E: original air survey data

Burnt or shaded 7	*Grassland regen 8*	Bare soil or built-up 9	*Cloud 10*	*Cloud shadow 11*	*Water 12*	**Ground to air correspondence** Common	Total	Percentage
						0	**0**	
		9582				**0**	**9923**	**0**
						0	**0**	
		9542	*1142*	*53*			69394	
							0	
							0	
							0	
							0	
		679	*1478*	*1*			28067	
		478					12495	
							0	
							0	
							0	
0	*0*	**10699**	*2620*	*54*	*0*	**48565**	**109956**	**44.17**
							0	
		175					2015	
		2863					10647	
		75					1057	
							0	
		5471	*2167*	*1*			90460	
							0	
		93	*168*				14171	
		18625	*15029*	*351*			215937	
							0	
							0	
							0	
		100					1955	
							0	
		1039		*8*			13118	
							0	
							0	
0	*0*	**28441**	*17364*	*360*	*0*	**189059**	**349360**	**54.12**
		4045	*6301*	*92*		**3229**	**79803**	**4.05**
		831	*4484*	*20*			6315	
		558					3312	
							0	
		6034	*103*	*42*			45782	
0	*0*	**7423**	*4587*	*62*	*0*	**26787**	**55409**	**48.34**
						0	**0**	
		2461	*1*				4108	
							0	
0	*0*	**2461**	*1*	*0*	*0*	**2461**	**4108**	**59.91**
0	*n/a*	**2461**	*n/a*	*n/a*	*n/a*	**270101**	**608559**	
0	*0*	**62651**	*30873*	*568*	*0*	**270101**	**608559**	
		3.93						**44.38**

(O.C.C.)

(Overall Classification Correspondence)

Comparison matrix between ground and original air survey vegetation data
Tetrad F

Ground survey Classes	Air survey Classes Codes	Unclass 0	Arable 1	MG7 2	All MGs (except MG7) 3	All CGs 4	Mosaic (cg/mg) 5	Woodland (con & b.l.) 6
Unclass.	**0**							
Arable	**1000**		**2**	**166**	**4458**	**9263**	**2759**	**314**
MG7	**2000**		**25**	**2987**	**5755**	**14176**	**1230**	**2433**
MG1	3100		286	596	30799	16445	1143	3191
MG11	3110		292	1566	10138	1418	129	733
MG12	3120							
MG5	3500							
MG6	3600							
MG mosaic	3010		130	1	5342	1625	4	16
MG unclass.	3020			6	38	234	738	1
Cleared wd.	3030							
Dist. veg.	3040		41	336	1819	2991	133	97
Aquatic/sw.	3050							
All MGs (except MG7)		**0**	**749**	**2505**	**48136**	**22713**	**2147**	**4038**
CG1	4100							
CG2	4200		6	311	1805	5388	1819	1657
CG2a	4210		11	114	2048	3886	122	474
CG2c	4230		30	274	557	2144	433	980
CG3	4300				4	63		25
CG3a	4310		20	463	8262	35196	4226	3272
CG3b	4320							
CG3c	4330			58	4450	3334	287	
CG3d	4340		161	1034	28866	28115	1922	1598
CG3di	4345		26	180	4219	4809	268	124
CG4	4400							
CG5	4500							
CG6	4600		5	32	4212	273	1	4
CG7	4700							
CG mosaic	4010		4	543	4017	13184	3903	1488
CG unclass	4020							
Ch. heath	4030							
All CGs		**0**	**263**	**3009**	**58440**	**96392**	**12981**	**9622**
CG/MG mosaic	**5000**		**108**	**592**	**34822**	**42969**	**11555**	**2635**
Decid. wd.	6100		9	329	828	3222	37	2211
Decid. pl.	6200		1	219	17	359	11	4728
Conif. pl.	6300		91	2777	2248	4561	1231	44259
Mixed pl.	6400		91	211	901	1948	44	22163
Woodland (conif & b.l.)		**0**	**192**	**3536**	**3994**	**10090**	**1323**	**73361**
Burnt gslnd.	**7000**							
Bare/quarry	9100			11	496	344	104	163
Urban etc	9200							
Bare soil or built-up		**0**	**0**	**11**	**496**	**344**	**104**	**163**
Air to ground	Common	**0**	**2**	**2987**	**48136**	**96392**	**11555**	**73361**
Correspondence	Total	**0**	**1339**	**12806**	**156101**	**195947**	**32099**	**92566**
	Percentage		**0.15**	**23.33**	**30.84**	**49.19**	**36**	**79.25**

Ground survey classes in normal type are summed to common classes in bold type.
Items 8, 10, 11 and 12 in the air survey classification (in italics) have no equivalent in the ground survey classification and are omitted from the calculations of correspondence.

Tetrad F: original air survey data

Burnt or shaded 7	*Grassland regen 8*	Bare soil or built-up 9	*Cloud 10*	*Cloud shadow 11*	*Water 12*	Ground to air correspondence Common	Total	Percentage
						0	0	
		26305	3590			2	43267	0
		8643	4116	2		2987	35249	8.47
		4964	3559	6			57424	
		1491	724				15767	
							0	
							0	
							0	
		570	1062				7688	
		76					1093	
							0	
		2304					7721	
							0	
0	0	9405	5345	6	0	48136	89693	53.67
							0	
		2085	4				13071	
		518		35			7173	
		926			2		5344	
							92	
		9911	3132	4			61350	
							0	
		301	5046				8430	
		4122	6122	10			65818	
		1239					10865	
							0	
							0	
		256					4783	
							0	
		5301	50				28440	
							0	
							0	
0	0	24659	14354	49	2	96392	205366	46.94
		15432	20914	11		11555	108113	10.69
		657	958				7293	
		770					6105	
		5852	4	10			61019	
		5356	88	2			30714	
0	0	12635	1050	12	0	73361	105131	69.78
						0	0	
		2592	20				3710	
							0	
0	0	2592	20	0	0	2592	3710	69.87
0	n/a	2592	n/a	n/a	n/a	235025	590529	
0	0	99671	49389	80	2	235025	590529	
		2.6						39.8

(O.C.C.)

(Overall Classification Correspondence)

Comparison matrix between ground and air survey (modal class per land parcel) data
Tetrad A

Ground survey Classes	Air survey Classes Codes	Unclass 0	Arable 1	MG7 2	All MGs (except MG7) 3	All CGs 4	Mosaic (cg/mg) 5	Woodland (con & b.l.) 6
Unclass.	**0**							
Arable	**1000**							
MG7	**2000**			**13512**	**46105**	**1740**		
MG1	3100				62010	52735		
MG11	3110							
MG12	3120							
MG5	3500							
MG6	3600							
MG mosaic	3010					20665		
MG unclass.	3020			14643				
Cleared wd.	3030							
Dist. veg.	3040							
Aquatic/sw.	3050							
All MGs (except MG7)		**0**	**0**	**14643**	**62010**	**73400**	**0**	**0**
CG1	4100							
CG2	4200							
CG2a	4210							
CG2c	4230							
CG3	4300					2962		
CG3a	4310					1640		
CG3b	4320							
CG3c	4330							
CG3d	4340				178420	141335		
CG3di	4345					56017		
CG4	4400							
CG5	4500							
CG6	4600							
CG7	4700							
CG mosaic	4010					12546		
CG unclass	4020							
Ch. heath	4030							
All CGs		**0**	**0**	**0**	**178420**	**214500**	**0**	**0**
CG/MG mosaic	**5000**				**4710**	**17111**		
Decid. wd.	6100							1433
Decid. pl.	6200							2166
Conif. pl.	6300				1056	1438		
Mixed pl.	6400				1006	2907	605	2338
Woodland (conif & b.l.)		**0**	**0**	**0**	**2062**	**4345**	**605**	**5937**
Burnt gslnd.	**7000**							
Bare/quarry	9100							
Urban etc	9200							
Bare soil or built-up		**0**	**0**	**0**	**0**	**0**	**0**	**0**
Air to ground	Common	**0**	**0**	**13512**	**62010**	**214500**	**0**	**5937**
Correspondence	Total	**0**	**0**	**28155**	**293307**	**311096**	**605**	**5937**
	Percentage			**47.99**	**21.14**	**68.95**	**0**	**100**

Ground survey classes in normal type are summed to common classes in bold type.
Items 8, 10, 11 and 12 in the air survey classification (in italics) have no equivalent in the ground survey classification and are omitted from the calculations of correspondence.

Tetrad A: air survey, modal class per land parcel

Burnt or shaded 7	*Grassland regen* 8	Bare soil or built-up 9	*Cloud* 10	*Cloud shadow* 11	*Water* 12	**Ground to air correspondence** Common	Total	Percentage
						0	**0**	
						0	**0**	
		837				**13512**	**62194**	**21.73**
							114745	
							0	
							0	
							0	
							0	
							20665	
							14643	
							0	
							0	
							0	
0	*0*	**0**	*0*	*0*	*0*	**62010**	**150053**	**41.33**
							0	
							0	
							0	
							0	
							2962	
							1640	
							0	
							0	
							319755	
							56017	
							0	
							0	
							0	
							0	
							12546	
							0	
							0	
0	*0*	**0**	*0*	*0*	*0*	**214500**	**392920**	**54.59**
						0	**21821**	**0**
							1433	
							2166	
		63					2557	
							6856	
0	*0*	**63**	*0*	*0*	*0*	**5937**	**13012**	**45.63**
						0	**0**	
							0	
							0	
0	*0*	**0**	*0*	*0*	*0*	**0**	**0**	
0	*n/a*	**0**	*n/a*	*n/a*	*n/a*	**295959**	**640000**	
0	*0*	**900**	*0*	*0*	*0*	**295959**	**640000**	
		0						**46.24**

(O.C.C.)

(Overall Classification Correspondence)

Comparison matrix between ground and air survey (modal class per land parcel) data
Tetrad B

Ground survey Classes	**Air survey** Classes Codes	Unclass 0	Arable 1	MG7 2	All MGs (except MG7) 3	All CGs 4	Mosaic (cg/mg) 5	Woodland (con & b.l.) 6
Unclass.	**0**							
Arable	**1000**							
MG7	**2000**							
MG1	3100				17715	99235		
MG11	3110							
MG12	3120							
MG5	3500							
MG6	3600							
MG mosaic	3010					9104		
MG unclass.	3020							
Cleared wd.	3030							
Dist. veg.	3040							
Aquatic/sw.	3050							
All MGs (except MG7)		**0**	**0**	**0**	**17715**	**108339**	**0**	**0**
CG1	4100							
CG2	4200							
CG2a	4210							
CG2c	4230							
CG3	4300							
CG3a	4310					3898		
CG3b	4320							
CG3c	4330							
CG3d	4340					52827		
CG3di	4345					153076		
CG4	4400							
CG5	4500							
CG6	4600							
CG7	4700							
CG mosaic	4010					67112		
CG unclass	4020							
Ch. heath	4030							
All CGs		**0**	**0**	**0**	**0**	**276913**	**0**	**0**
CG/MG mosaic	**5000**					**219854**		
Decid. wd.	6100							45
Decid. pl.	6200					890		
Conif. pl.	6300					11208		845
Mixed pl.	6400					109		188
Woodland (conif & b.l.)		**0**	**0**	**0**	**0**	**12207**	**0**	**1078**
Burnt gslnd.	**7000**							
Bare/quarry	9100							
Urban etc	9200							
Bare soil or built-up		**0**	**0**	**0**	**0**	**0**	**0**	**0**
Air to ground	Common	**0**	**0**	**0**	**17715**	**276913**	**0**	**1078**
Correspondence	Total	**0**	**0**	**0**	**17715**	**617313**	**0**	**1078**
	Percentage				**100**	**44.86**		**100**

Ground survey classes in normal type are summed to common classes in bold type
Items 8, 10, 11 and 12 in the air survey classification (in italics) have no equivalent in the ground survey classification and are omitted from the calculations of correspondence.

Tetrad B: air survey data as modal class per land parcel

Burnt or shaded 7	*Grassland regen 8*	Bare soil or built-up 9	*Cloud 10*	*Cloud shadow 11*	*Water 12*	**Ground to air correspondence** Common	Total	Percentage
						0	**0**	
						0	**0**	
						0	**0**	
		44					116994	
							0	
							0	
							0	
							0	
							9104	
							0	
							0	
							0	
							0	
0	*0*	**44**	*0*	*0*	*0*	**17715**	**126098**	**14.05**
							0	
							0	
							0	
							0	
							0	
							3898	
							0	
							0	
		1645					54472	
							153076	
							0	
							0	
							0	
							0	
		171					67283	
							0	
							0	
0	*0*	**1816**	*0*	*0*	*0*	**276913**	**278729**	**99.35**
		28				**0**	**219882**	**0**
							45	
							890	
							12053	
							297	
0	*0*	**0**	*0*	*0*	*0*	**1078**	**13285**	**8.11**
						0	**0**	**#DIV/0!**
		2006					2006	
							0	
0	*0*	**2006**	*0*	*0*	*0*	**2006**	**2006**	**100**
0	*n/a*	**2006**	*n/a*	*n/a*	*n/a*	**297712**	**640000**	
0	*0*	**3894**	*0*	*0*	*0*	**297712**	**640000**	
		51.52						**46.52**

(O.C.C.)

(Overall Classification Correspondence)

Comparison matrix between ground and air survey (modal class per land parcel) data
Tetrad C

Ground survey Classes	Air survey Classes Codes	Unclass 0	Arable 1	MG7 2	All MGs (except MG7) 3	All CGs 4	Mosaic (cg/mg) 5	Woodland (con & b.l.) 6
Unclass.	**0**					**16**		
Arable	**1000**		**11331**		**519**	**1372**	**1**	
MG7	**2000**				**2109**	**2**		
MG1	3100					66528		11
MG11	3110					4329		
MG12	3120							
MG5	3500							
MG6	3600				6670	1		
MG mosaic	3010				6264	11509		
MG unclass.	3020				740	7941		
Cleared wd.	3030							
Dist. veg.	3040							
Aquatic/sw.	3050							
All MGs (except MG7)		**0**	**0**	**0**	**13674**	**90308**	**0**	**11**
CG1	4100							
CG2	4200				2861	1		
CG2a	4210							
CG2c	4230							
CG3	4300							
CG3a	4310					1173		
CG3b	4320							
CG3c	4330							
CG3d	4340			426	1541	299801		
CG3di	4345					7232		
CG4	4400							
CG5	4500							
CG6	4600							
CG7	4700							
CG mosaic	4010					67045		1
CG unclass	4020							
Ch. heath	4030							
All CGs		**0**	**0**	**426**	**4402**	**375252**	**0**	**1**
CG/MG mosaic	**5000**				**10642**	**64444**	**167**	
Decid. wd.	6100							
Decid. pl.	6200				140	740		222
Conif. pl.	6300							
Mixed pl.	6400					13181		6029
Woodland (conif & b.l.)		**0**	**0**	**0**	**140**	**13921**	**0**	**6251**
Burnt gslnd.	**7000**							
Bare/quarry	9100					1		
Urban etc	9200							
Bare soil or built-up		**0**	**0**	**0**	**0**	**1**	**0**	**0**
Raster	Common	**0**	**11331**	**0**	**13674**	**375252**	**167**	**6251**
Correspondence	Total	**0**	**11331**	**426**	**31486**	**545316**	**168**	**6263**
			100	**0**	**43.43**	**68.81**	**99.4**	**99.81**

Ground survey classes in normal type are summed to common classes in bold type.
Items 8, 10, 11 and 12 in the air survey classification (in italics) have no equivalent in the ground survey classification and are omitted from the calculations of correspondence.

Tetrad C: air survey data as modal class per land parcel

Burnt or shaded 7	*Grassland regen 8*	Bare soil or built-up 9	*Cloud 10*	*Cloud shadow 11*	*Water 12*	**Ground to air correspondence** Common	Total	Percentage
						0	**16**	**0**
		211				**11331**	**13434**	**84.35**
		24090				**0**	**26201**	**0**
		4711					71250	
							4329	
							0	
							0	
							6671	
							17773	
		3431					12112	
							0	
							0	
							0	
0	*0*	**8142**	*0*	*0*	*0*	**13674**	**112135**	**12.19**
							0	
							2862	
							0	
							0	
							0	
							1173	
							0	
							0	
		5562					307330	
							7232	
							0	
							0	
							0	
							0	
		1					67047	
							0	
							0	
0	*0*	**5563**	*0*	*0*	*0*	**375252**	**385644**	**97.31**
		1000				**167**	**76253**	**0.22**
							0	
							1102	
							0	
		2666					21876	
0	*0*	**2666**	*0*	*0*	*0*	**6251**	**22978**	**27.2**
						0	**0**	
		1722					1723	
		1616					1616	
0	*0*	**3338**	*0*	*0*	*0*	**3338**	**3339**	**99.97**
0	*n/a*	**3338**	*n/a*	*n/a*	*n/a*	**410013**	**640000**	
0	*0*	**45010**	*0*	*0*	*0*	**410013**	**640000**	
		7.42						**64.06**

(O.C.C.)

(Overall Classification Correspondence)

Comparison matrix between ground and air survey (modal class per land parcel) data
Tetrad D

Ground survey Classes	Air survey Classes Codes	Unclass 0	Arable 1	MG7 2	All MGs (except MG7) 3	All CGs 4	Mosaic (cg/mg) 5	Woodland (con & b.l.) 6
Unclass.	**0**							
Arable	**1000**		**22095**	**5254**	**839**	**7695**		
MG7	**2000**		**6**	**128031**	**117652**	**3**	**9103**	**82**
MG1	3100		345	46085	36324	575	15212	273
MG11	3110							
MG12	3120							
MG5	3500							
MG6	3600							
MG mosaic	3010		4	17628	58051		5	
MG unclass.	3020			49267	7973	2	4	
Cleared wd.	3030							
Dist. veg.	3040			1				
Aquatic/sw.	3050							
All MGs (except MG7)		**0**	**349**	**112981**	**102348**	**577**	**15221**	**273**
CG1	4100							
CG2	4200							
CG2a	4210							
CG2c	4230							
CG3	4300							
CG3a	4310					578		
CG3b	4320							
CG3c	4330							
CG3d	4340				3	2856	3219	
CG3di	4345							
CG4	4400							
CG5	4500							
CG6	4600				16909	574	6835	
CG7	4700							
CG mosaic	4010				1904			
CG unclass	4020			6		7792	2	
Ch. heath	4030							
All CGs		**0**	**0**	**6**	**18816**	**11800**	**10056**	**0**
CG/MG mosaic	**5000**			**611**	**11881**	**3334**	**427**	
Decid. wd.	6100				2114	304	1097	5446
Decid. pl.	6200			7785	2124	675	1142	
Conif. pl.	6300			3				875
Mixed pl.	6400			1695	17333	1	949	74
Woodland (conif & b.l.)		**0**	**0**	**9483**	**21571**	**980**	**3188**	**6395**
Burnt gslnd.	**7000**							
Bare/quarry	9100		9	9				
Urban etc	9200			4	289		245	
Bare soil or built-up		**0**	**9**	**13**	**289**	**0**	**245**	**0**
Air to ground	Common	**0**	**22095**	**128031**	**102348**	**11800**	**427**	**6395**
Correspondence	Total	**0**	**22459**	**256379**	**273396**	**24389**	**38240**	**6750**
	Percentage		**98.38**	**49.94**	**37.44**	**48.38**	**1.12**	**94.74**

Ground survey classes in normal type are summed to common classes in bold type.
Items 8, 10, 11 and 12 in the air survey classification (in italics) have no equivalent in the ground survey classification and are omitted from the calculations of correspondence.

Tetrad d: air survey data as modal class per land parcel

Burnt or shaded 7	*Grassland regen 8*	Bare soil or built-up 9	*Cloud 10*	*Cloud shadow 11*	*Water 12*	Ground to air correspondence Common	Total	Percentage
						0	**0**	
		557				**22095**	**36440**	**60.63**
		90				**128031**	**254967**	**50.21**
		49					98863	
							0	
							0	
							0	
							0	
		3					75691	
		7353					64599	
							0	
		1310					1311	
							0	
0	*0*	**8715**	*0*	*0*	*0*	**102348**	**240464**	**42.56**
							0	
							0	
							0	
							0	
							0	
							578	
							0	
							0	
		82					6160	
							0	
							0	
							0	
							24318	
							0	
							1904	
							7800	
							0	
0	*0*	**82**	*0*	*0*	*0*	**11800**	**40760**	**28.95**
		444				**427**	**16697**	**2.56**
							8961	
		652					12378	
							878	
		3133					23185	
0	*0*	**3785**	*0*	*0*	*0*	**6395**	**45402**	**14.09**
						0	**0**	
		4307					4325	
		407					945	
0	*0*	**4714**	*0*	*0*	*0*	**4714**	**5270**	**89.45**
0	*n/a*	**4714**	*n/a*	*n/a*	*n/a*	**275810**	**640000**	
0	*0*	**18387**	*0*	*0*	*0*	**275810**	**640000**	
		25.64						**43.1**

(O.C.C.)
(Overall Classification Correspondence)

Comparison matrix between ground and air survey (modal class per land parcel) data
Tetrad E

Ground survey Classes	Air survey Classes Codes	Unclass 0	Arable 1	MG7 2	All MGs (except MG7) 3	All CGs 4	Mosaic (cg/mg) 5	Woodland (con & b.l.) 6
Unclass.	**0**							
Arable	**1000**					12		
MG7	**2000**							
MG1	3100				23746	43199	6	
MG11	3110							
MG12	3120							
MG5	3500							
MG6	3600							
MG mosaic	3010				29539	4		
MG unclass.	3020				11603	155		
Cleared wd.	3030							
Dist. veg.	3040							
Aquatic/sw.	3050							
All MGs (except MG7)		**0**	**0**	**0**	**64888**	**43358**	**6**	**0**
CG1	4100							
CG2	4200					2015		
CG2a	4210				2	4692		1934
CG2c	4230				2	1055		
CG3	4300							
CG3a	4310				23749	68871		1
CG3b	4320							
CG3c	4330				5850	8489		
CG3d	4340				78316	133832	9747	30
CG3di	4345							
CG4	4400							
CG5	4500							
CG6	4600					1929		
CG7	4700							
CG mosaic	4010				3861	8870		5
CG unclass	4020							
Ch. heath	4030							
All CGs		**0**	**0**	**0**	**111780**	**229753**	**9747**	**1970**
CG/MG mosaic	**5000**				**36514**	**35118**	**3**	**1631**
Decid. wd.	6100					5563		553
Decid. pl.	6200					2		3309
Conif. pl.	6300				1969			
Mixed pl.	6400					5941		38004
Woodland (conif & b.l.)		**0**	**0**	**0**	**1969**	**11506**	**0**	**41866**
Burnt gslnd.	**7000**							
Bare/quarry	9100				7	397		3
Urban etc	9200							
Bare soil or built-up		**0**	**0**	**0**	**7**	**397**	**0**	**3**
Air to ground	Common	**0**	**0**	**0**	**64888**	**229753**	**3**	**41866**
Correspondence	Total	**0**	**0**	**0**	**215158**	**320144**	**9756**	**45470**
	Percentage				**30.16**	**71.77**	**0.03**	**92.07**

Ground survey classes in normal type are summed to common classes in bold type.
Items 8, 10, 11 and 12 in the air survey classification (in italics) have no equivalent in the ground survey classification and are omitted from the calculations of correspondence.

Tetrad E: air survey data as modal class per land parcel

Burnt or shaded 7	*Grassland regen* 8	Bare soil or built-up 9	*Cloud* 10	*Cloud shadow* 11	*Water* 12	Ground to air correspondence Common	Total	Percentage
						0	**0**	
		9911				**0**	**9923**	**0**
						0	**0**	
		3275	*1*				70226	
							0	
							0	
							0	
							0	
			3				29543	
		737					12495	
							0	
							0	
							0	
0	*0*	**4012**	*4*	*0*	*0*	**64888**	**112264**	**57.8**
							0	
							2015	
		4019					10647	
							1057	
							0	
		7					92628	
							0	
							14339	
		1167	*8225*				223092	
							0	
							0	
							0	
		26					1955	
							0	
		390					13126	
							0	
							0	
0	*0*	**5609**	*8225*	*0*	*0*	**229753**	**358859**	**64.02**
		2	*12928*			**3**	**73268**	**0**
		2	*4701*				6118	
			1				3311	
							1969	
		13					43958	
0	*0*	**15**	*4702*	*0*	*0*	**41866**	**55356**	**75.63**
						0	**0**	
		3702					4109	
							0	
0	*0*	**3702**	*0*	*0*	*0*	**3702**	**4109**	**90.09**
0	*n/a*	**3702**	*n/a*	*n/a*	*n/a*	**340212**	**613779**	
0	*0*	**23251**	*25859*	*0*	*0*	**340212**	**613779**	
		15.92						**55.43**

(O.C.C.)

(Overall Classification Correspondence)

Tetrad F: air survey data as modal class per land parcel

Burnt or shaded 7	*Grassland regen 8*	Bare soil or built-up 9	*Cloud 10*	*Cloud shadow 11*	*Water 12*	**Ground to air correspondence** Common	Total	Percentage
						0	**0**	
		33250	*7877*			**0**	**38980**	**0**
		12529	*8764*			**0**	**30603**	**0**
		732	*1932*				59057	
							16491	
							0	
							0	
							0	
			1				8749	
		152					1093	
							0	
		3					7721	
							0	
0	*0*	**887**	*1933*	*0*	*0*	**71118**	**93111**	**76.38**
							0	
		229					13075	
		418					7208	
							5346	
							92	
		960					64486	
							0	
			13467				9	
		835	*277*				71673	
							10865	
							0	
							0	
							4783	
							0	
		1295					28490	
							0	
							0	
0	*0*	**3737**	*13744*	*0*	*0*	**136259**	**206027**	**66.14**
		2204	*18839*			**39911**	**110199**	**36.22**
			946				7305	
		2026					6105	
		6					61033	
		9					30804	
0	*0*	**2041**	*946*	*0*	*0*	**92699**	**105247**	**88.08**
						0	**0**	
		3058					3730	
							0	
0	*0*	**3058**	*0*	*0*	*0*	**3058**	**3730**	**81.98**
0	*n/a*	**3058**	*n/a*	*n/a*	*n/a*	**343045**	**587897**	
0	*0*	57706	*52103*	*0*	*0*	**343045**	**587897**	
		5.3						58.35

(O.C.C.)

(Overall Classification Correspondence)

APPENDIX D: Comparison matrices between air and ground survey data for complete study areas.

The south-west and north-east corners of the study areas are:

SPTA West/Central; 387298 141148, 423891 156833

SPTA East; 414875 142297, 423891 156833

Matrices are included for comparisons by pixel (using original data) and by land parcel (using original ground survey data and air survey data reclassified to majority class in each land parcel), using both the initial and final common classification schemes.

Comparison matrix between ground and original air survey data
East study area

Ground survey Classes	Air survey Classes Codes	Unclass 0	Arable 1	MG7 2	All MGs (except MG7) 3	All CGs 4	Mosaic (cg/mg) 5	Woodland (con & b.l.) 6
Unclass.	**0**	**165484**	**416685**	**144278**	**453706**	**105567**	**32697**	**291327**
Arable	**1000**	**99340**	**378391**	**49736**	**324695**	**105653**	**24051**	**21156**
MG7	**2000**	**147547**	**156890**	**608314**	**946930**	**159271**	**46748**	**47972**
MG1	3100	76195	27878	162461	795016	388702	92321	87465
MG11	3110	3321	6965	11443	107462	30398	15243	7418
MG12	3120	4236						
MG5	3500							
MG6	3600			1370	5818	157	29	788
MG mosaic	3010	32801	4417	57271	317419	78301	15604	10239
MG unclass.	3020	37667	29446	80869	247362	72995	47677	16667
Cleared wd.	3030							
Dist. veg.	3040	5	48	397	2400	3322	165	755
Aquatic/sw.	3050	7328	229	2376	5633	1168	121	7093
All MGs (except MG7)		**161553**	**68983**	**316187**	**1481110**	**575043**	**171160**	**130425**
CG1	4100	21	121		1175	9651	1606	20130
CG2	4200	150	637	1310	27519	46831	20107	47566
CG2a	4210	12938	911	2686	54807	104431	19600	58244
CG2c	4230	95	130	854	16234	29187	6619	8814
CG3	4300		1098	260	15475	40997	1667	621
CG3a	4310	6843	468	3934	92633	210580	11558	24916
CG3b	4320		142		8416	24522	1580	11972
CG3c	4330		573	6671	33027	14907	1296	3225
CG3d	4340	6360	6703	55271	404017	547603	77177	33242
CG3di	4345		76	792	5954	13125	337	5117
CG4	4400							
CG5	4500							
CG6	4600	25735	1245	19648	114013	61453	24751	3046
CG7	4700		4		630	2143	1345	2194
CG mosaic	4010	8155	765	5219	60679	91355	18081	17325
CG unclass	4020		76	493	16268	17740	10591	3079
Ch. heath	4030							
All CGs		**60297**	**12949**	**97138**	**850847**	**1214525**	**196315**	**239491**
CG/MG mosaic	**5000**	**6910**	**4669**	**43693**	**342107**	**187846**	**43234**	**35682**
Decid. wd.	6100	7550	2086	15768	26872	36049	8947	179977
Decid. pl.	6200	143210	2256	21023	43738	36191	8891	258249
Conif. pl.	6300	11814	2843	6316	13689	24756	4880	253702
Mixed pl.	6400	34352	2971	29087	37739	48258	10137	452101
Woodland (conif & b.l.)		**196926**	**10156**	**72194**	**122038**	**145254**	**32855**	**1144029**
Burnt gslnd.	**7000**							
Bare/quarry	9100	1014	125	2171	11974	15337	4725	5476
Urban etc	9200	8045	630	2635	11905	4234	947	17136
Bare soil or built-up		**9059**	**755**	**4806**	**23879**	**19571**	**5672**	**22612**
Air to ground	Common	**165484**	**378391**	**608314**	**1481110**	**1214525**	**43234**	**1144029**
Correspondence	Total	**847116**	**1049478**	**1336346**	**4545312**	**2512730**	**552732**	**1932694**
	Percentage	**19.53**	**36.06**	**45.52**	**32.59**	**48.33**	**7.82**	**59.19**

Ground survey classes in normal type are summed to common classes in bold type.
Items 8, 10, 11 and 12 in the air survey classification (in italics) have no equivalent in the ground survey classification and are omitted from the calculations of correspondence.

East study area: original air survey data

Burnt or shaded 7	*Grassland regen 8*	Bare soil or built-up 9	*Cloud 10*	*Cloud shadow 11*	*Water 12*	**Ground to air correspondence** Common	Total	Percentage
974		**379355**	*602*	*11727*		**165484**	**1990073**	**8.32**
		373189	*9112*	*1066*		**378391**	**1376211**	**27.5**
4		**110949**	*21866*	*1034*		**608314**	**2224625**	**27.34**
74		126962	*19930*	*1031*			1757074	
		5842	*2204*	*115*			188092	
		312	*7*				4548	
							0	
							8162	
		15614	*17160*	*307*			531666	
4		25797	*1365*	*307*			558484	
							0	
		3374					10466	
		4625	*28*				28573	
78	*0*	**182526**	*40694*	*1760*	*0*	**1481110**	**3087065**	**47.98**
9		1419	*1*				34132	
51		19731	*182*	*2*			163902	
189		30322	*196*	*50*			284128	
		33003	*35*	*4*	*2*		94936	
		9636	*15*				69754	
4		35803	*17423*	*111*	*5*		386739	
17		3411		*1*			50060	
		1782	*5477*	*1378*			61481	
		81213	*32024*	*657*			1211586	
		2725		*54*			28126	
							0	
							0	
		6069	*9499*	*228*			255960	
		1795					8111	
89		37343	*1002*	*20*			239011	
		1498					49745	
							0	
359	*0*	**265750**	*65854*	*2505*	*7*	**1214525**	**2937671**	**41.34**
		56127	*58959*	*339*	*9*	**43234**	**720268**	**6**
4		22541	*6726*	*54*			299794	
21		54508	*205*	*163*			568087	
233		16799	*1281*	*138*			335032	
132		60721	*2945*	*417*			675498	
390	*0*	**154569**	*11157*	*772*	*0*	**1144029**	**1878411**	**60.9**
						0	**0**	
		61155	*201*	*19*			101977	
		19401	*299*	*27*			64933	
0	*0*	**80556**	*500*	*46*	*0*	**80556**	**166910**	**48.26**
0	*n/a*	**80556**	*n/a*	*n/a*	*n/a*	**5115643**	**14381234**	
1805	*0*	**1603021**	*208744*	*19249*	*16*	**5115643**	**14381234**	
0		**5.03**						35.57

(O.C.C.)

(O.C.C. = Overall Classification Correspondence)

Comparison matrix between ground and original air survey vegetation data
West/Central study area

Ground survey Classes	Air survey Classes Codes	Unclass 0	Arable 1	MG7 2	All MGs :xcept MG 3	All CGs 4	Mosaic (cg/mg) 5	Woodland (con & b.l.) 6
Unclass.	**0**	**289104**	**466844**	**90487**	**192114**	**195484**	**17723**	**31858**
Arable	**1000**	**291452**	**924592**	**171788**	**250317**	**181777**	**17119**	**20291**
MG7	**2000**	**652425**	**446593**	**1458672**	**1709657**	**620676**	**222565**	**37104**
MG1	3100	257196	104878	173587	952215	1992304	247694	73872
MG11	3110	28202	1100	21899	100378	20384	6706	519
MG12	3120	10168	113	940	2785	1455	172	75
MG5	3500		236	1500	54514	65767	2148	1223
MG6	3600	21960	456	27089	248020	94999	31898	2360
MG mosaic	3010	88728	15008	91586	386353	227316	27747	12997
MG unclass.	3020	236812	33289	161892	378476	402413	77669	16396
Cleared wd.	3030							
Dist. veg.	3040		327	37311	15897	21055	604	640
Aquatic/sw.	3050	9712	1	17	2469	2424	24	2382
All MGs (except MG7)		**652778**	**155408**	**515821**	**2141107**	**2828117**	**394662**	**110464**
CG1	4100				103	718	7	
CG2	4200	862	291	1417	29500	81976	15173	1171
CG2a	4210	9800	1077	13196	36658	99491	9006	10542
CG2c	4230	2266	1248	7347	17595	33267	11731	710
CG3	4300	7961	303	7191	9317	130168	3701	5659
CG3a	4310	17744	1774	27032	203784	822677	95258	26133
CG3b	4320		1	33	11264	16630	126	55
CG3c	4330	36192	62	3665	30490	90664	18743	361
CG3d	4340	214168	13783	137627	1088100	6103552	754137	99802
CG3di	4345	37	34	2639	33604	473052	47551	13817
CG4	4400	13			5	2791	1418	
CG5	4500	2683						
CG6	4600	12554	114	2861	67846	67879	8083	1760
CG7	4700	2407	52	19	1384	15238	1644	143
CG mosaic	4010	14029	872	2886	96775	633638	29799	10496
CG unclass	4020		122	3592	31943	29315	1137	340
Ch. heath	4030					16005	312	6632
All CGs		**320716**	**19733**	**209505**	**1658368**	**8617061**	**997826**	**177621**
CG/MG mosaic	**5000**	**133985**	**22239**	**145520**	**961970**	**2724728**	**394151**	**92405**
Decid. wd.	6100	2165	776	4120	17421	95259	8256	69855
Decid. pl.	6200	72697	2532	13490	105621	227380	23157	113886
Conif. pl.	6300	1976	234	557	13614	41048	6893	66477
Mixed pl.	6400	126543	5780	15975	66125	278224	24524	342608
Woodland (conif & b.l.)		**203381**	**9322**	**34142**	**202781**	**641911**	**62830**	**592826**
Burnt gslnd.	**7000**	**15**			**207**	**19458**	**966**	**491**
Bare/quarry	9100	3969	2505	1405	6945	22027	1321	2864
Urban etc	9200	25597	1406	2340	17651	13885	1705	7988
Bare soil or built-up		**29566**	**3911**	**3745**	**24596**	**35912**	**3026**	**10852**
Raster	Common	**289104**	**924592**	**1458672**	**2141107**	**8617061**	**394151**	**592826**
Correspondence	Total	**2573422**	**2048642**	**2629680**	**7141117**	**15865124**	**2110868**	**1073912**
	Percentage	**11.23**	**45.13**	**55.47**	**29.98**	**54.31**	**18.67**	**55.2**

Ground survey classes in normal type are summed to common classes in bold type.
Items 8, 10, 11 and 12 in the air survey classification (in italics) have no equivalent in the ground survey classification and are omitted from the calculations of correspondence.

West/Central study area: original air survey data

Burnt or shaded 7	*Grassland regen 8*	Bare soil or built-up 9	*Cloud 10*	*Cloud shadow 11*	*Water 12*	**Ground to air correspondence** Common	Total	Percentage
411	5089	**203934**	3994	5331		**289104**	**1487959**	**19.43**
45	1192	**608501**	4515	5959		**924592**	**2465882**	**37.5**
746	2552	**210369**	157834	25190		**1458672**	**5358807**	**27.22**
13929	66246	337044	142311	42748			4152719	
50	1	7163	67	2222			186401	
	48	412	2				16120	
7	7754	4543	12	1277			129938	
	32	18668	1524	14274			445450	
533	8568	47083	27069	6443			897351	
5	6532	80163	35130	13033			1387115	
							0	
5	1	9813					85652	
		5336	4904	2269			22365	
14529	89182	**510225**	211019	82266	0	**2141107**	**7323111**	**29.24**
		17					845	
92	1846	7497	70				137979	
3165	20877	11111	8	69			194046	
		4310	1516				78474	
39	16928	11713	22	3329			176052	
847	4724	103864	628	5189			1299113	
	3	4749	7				32858	
3	35	6295					186475	
22183	140892	581338	389942	101199			9014690	
675	34637	45240	13211				616649	
							4227	
							2683	
373	9194	5132	3157	1018			166602	
		1763					22650	
1679	5225	61524	549	4871			851698	
	77	5582					72031	
8	132						22957	
29064	234570	**850135**	409110	115675	0	**8617061**	**12880029**	**66.9**
2271	61274	**345339**	45136	51052		**394151**	**4822608**	**8.17**
98	1513	16452	18346	3670			214402	
1503	1667	67167	20324	20924	16		627433	
58	235	12318	11007				143175	
2519	3027	79625	9193	6055			941923	
4178	6442	**175562**	58870	30649	16	**592826**	**1926933**	**30.77**
203	3684	**18**				**203**	**21358**	**0.95**
35	58	86703	912	357			127774	
12	41	39179	678	1223			109763	
47	99	**125882**	1590	1580	0	**125882**	**237537**	**52.99**
203	n/a	**125882**	n/a	n/a	n/a	**14543598**	**36524224**	
51494	404084	**3029965**	892068	317702	16	**14543598**	**36524224**	
0.39		**4.15**						**39.82**

(O.C.C.)

(O.C.C. = Overall Classification Correspondence)

Comparison matrix between ground and air survey (modal class per land parcel) vegetation data
East study area

Ground survey Classes	Air survey Classes Codes	Unclass 0	Arable 1	MG7 2	All MGs (except MG7) 3	All CGs 4	Mosaic (cg/mg) 5	Woodland (con & b.l.) 6
Unclass.	**0**	**34580**			**1933773**	**659**	**4158**	**14252**
Arable	**1000**	**86834**			**843544**	**62041**	**9736**	**1**
MG7	**2000**	**156887**			**1967249**	**31763**	**2027**	**23746**
MG1	3100	66863			1422842	177540	28509	34992
MG11	3110				154827	26703		8167
MG12	3120	4236						
MG5	3500							
MG6	3600				8481			
MG mosaic	3010	30743			502512	11379		4032
MG unclass.	3020	33516			434642	35146	39811	3156
Cleared wd.	3030							
Dist. veg.	3040				2922	5005		826
Aquatic/sw.	3050	8455			7381			7536
All MGs (except MG7)		**143813**	**0**	**0**	**2533607**	**255773**	**68320**	**58709**
CG1	4100				757	16841		16535
CG2	4200				19971	56217	21754	51958
CG2a	4210	15310			63511	132008	4898	43178
CG2c	4230	292			26080	20515		
CG3	4300				8714	56678	3487	723
CG3a	4310	4000			73925	276917	8736	23588
CG3b	4320				1458	45017		
CG3c	4330				40673	12123		
CG3d	4340	5081			432780	729898	19984	9741
CG3di	4345				6312	11258		10610
CG4	4400							
CG5	4500							
CG6	4600	37041			210782	17864		
CG7	4700				80	1017		3658
CG mosaic	4010	9911			54539	132824	7698	9252
CG unclass	4020				14144	12804	22797	
Ch. heath	4030							
All CGs		**71635**	**0**	**0**	**953726**	**1521981**	**89354**	**169243**
CG/MG mosaic	**5000**	**1691**			**451565**	**170764**	**53025**	**23834**
Decid. wd.	6100	5728			20599	19291		246097
Decid. pl.	6200	148455			54856	19340	277	305614
Conif. pl.	6300	11125			5911	773	4	316003
Mixed pl.	6400	31484			67340	21137	951	539549
Woodland (conif & b.l.)		**196792**	**0**	**0**	**148706**	**60541**	**1232**	**1407263**
Burnt gslnd.	**7000**							
Bare/quarry	9100	1618			17345	7223		171
Urban etc	9200	8587			9194		247	28415
Bare soil or built-up		**10205**	**0**	**0**	**26539**	**7223**	**247**	**28586**
Air to ground	Common	**34580**	**0**	**0**	**2533607**	**1521981**	**53025**	**1407263**
Correspondence	Total	**702437**	**0**	**0**	**8858709**	**2110745**	**228099**	**1725634**
	Percentage	**4.92**			**28.6**	**72.11**	**23.25**	**81.55**

Ground survey classes in normal type are summed to common classes in bold type.
Items 8, 10, 11 and 12 in the air survey classification (in italics) have no equivalent in the ground survey classification and are omitted from the calculations of correspondence.

East study area: air survey data as modal class per land parcel

Burnt or shaded 7	*Grassland regen 8*	Bare soil or built-up 9	*Cloud 10*	*Cloud shadow 11*	*Water 12*	Ground to air correspondence Common	Total	Percentage
		14980				**34580**	**2002402**	**1.73**
		374472	*9760*			**0**	**1376628**	**0**
		56162	*9691*			**0**	**2237834**	**0**
		25792	*21496*				1756538	
		714					190411	
							4236	
							0	
							8481	
		339	*128*				549005	
		13612	*273*				559883	
							0	
		1713					10466	
		5229					28601	
0	*0*	**47399**	*21897*	*0*	*0*	**2533607**	**3107621**	**81.53**
							34133	
		14186					164086	
		25469					284374	
		48090					94977	
		167					69769	
		7149	*9963*				394315	
		3586					50061	
			15540				52796	
		8684	*38099*				1206168	
							28180	
							0	
							0	
							265687	
		3356					8111	
		25809					240033	
							49745	
							0	
0	*0*	**136496**	*63602*	*0*	*0*	**1521981**	**2942435**	**51.73**
		13877	*64819*			**53025**	**714756**	**7.42**
		9191	*5667*				300906	
		39913					568455	
		2635					336451	
		18354					678815	
0	*0*	**70093**	*5667*	*0*	*0*	**1407263**	**1884627**	**74.67**
						0	**0**	
		75804	*36*				102161	
		18816					65259	
0	*0*	**94620**	*36*	*0*	*0*	**94620**	**167420**	**56.52**
0	*n/a*	**94620**	*n/a*	*n/a*	*n/a*	**5645076**	**14433723**	
0	*0*	**808099**	*175472*	*0*	*0*	**5645076**	**14433723**	
		11.71						**39.11**

(O.C.C.)

(O.C.C. = Overall Classification Correspondence)

Comparison matrix between ground and air survey (modal classes per land parcel) vegetation data
West/Central study area

Ground survey Classes	Air survey Classes Codes	Unclass 0	Arable 1	MG7 2	All MGs (except MG7) 3	All CGs 4	Mosaic (cg/mg) 5	Woodland (con & b.l.) 6
Unclass.	**0**	**363541**			**1044799**	**86921**	**2947**	
Arable	**1000**	**272672**			**1475789**	**73225**	**1414**	
MG7	**2000**	**708936**			**4321715**	**247026**	**47356**	**804**
MG1	3100	259331			1280101	2499359	9845	24624
MG11	3110	28205			135930	21115		
MG12	3120	14473			624	1073		
MG5	3500				48061	90775	145	
MG6	3600	22808			330304	73856	9175	
MG mosaic	3010	79742			618356	189069	16	
MG unclass.	3020	236424			682956	407369	20146	
Cleared wd.	3030							
Dist. veg.	3040				63692	5353	89	953
Aquatic/sw.	3050	11539			675	837		174
All MGs (except MG7)		**652522**	**0**	**0**	**3160699**	**3288806**	**39416**	**25751**
CG1	4100					845		
CG2	4200	907			9049	126192	3598	149
CG2a	4210	5132			61373	145184	2203	
CG2c	4230				16893	46698	16399	
CG3	4300	7942			20980	162150		
CG3a	4310	19164			169991	1059983	35550	2237
CG3b	4320				6490	26377		
CG3c	4330	37282			49679	99548		
CG3d	4340	219523			971893	7879536	24001	7547
CG3di	4345				21662	599096	7949	
CG4	4400					2674	1553	
CG5	4500	2683						
CG6	4600	14147			92005	67871	4365	
CG7	4700	2386				20264		
CG mosaic	4010	14016			121102	691677	6552	
CG unclass	4020				33249	38859		
Ch. heath	4030					23089		
All CGs		**323182**	**0**	**0**	**1574366**	**10990043**	**102170**	**9933**
CG/MG mosaic	**5000**	**151632**			**1058970**	**3548060**	**71944**	**20335**
Decid. wd.	6100	3146			18223	108346		71538
Decid. pl.	6200	74754			121011	229065	15741	144183
Conif. pl.	6300	1838			1676	32129		85054
Mixed pl.	6400	134551			74338	260962	2735	439507
Woodland (conif & b.l.)		**214289**	**0**	**0**	**215248**	**630502**	**18476**	**740282**
Burnt gslnd.	**7000**					**25042**		
Bare/quarry	9100	4011			7120	13017		1499
Urban etc	9200	24955			16930	11710		4890
Bare soil or built-up		**28966**	**0**	**0**	**24050**	**24727**	**0**	**6389**
Air to ground	Common	**363541**	**0**	**0**	**3160699**	**10990043**	**71944**	**740282**
Correspondence	Total	**2715740**	**0**	**0**	**12875636**	**18914352**	**283723**	**803494**
	Percentage	**13.39**			**24.55**	**58.1**	**25.36**	**92.13**

Ground survey classes in normal type are summed to common classes in bold type.
Items 8, 10, 11 and 12 in the air survey classification (in italics) have no equivalent in the ground survey classification and are omitted from the calculations of correspondence.

West/Central area: air survey data as modal classes per land parcel

Burnt or shaded 7	*Grassland regen 8*	Bare soil or built-up 9	*Cloud 10*	*Cloud shadow 11*	*Water 12*	Ground to air correspondence Common	Total	Percentage
		4165				**363541**	**1502373**	**24.2**
		651967	*2481*			**0**	**2475067**	**0**
		47158	*171388*			**0**	**5372995**	**0**
		137412	*193352*				4210672	
			3441				185250	
							16170	
							138981	
		2106	*23031*				438249	
		21561	*30687*				908744	
		41353	*53562*				1388248	
							0	
		15566					85653	
		7717	*8596*				20942	
0	*0*	**225715**	*312669*	*0*	*0*	**3160699**	**7392909**	**42.75**
							845	
							139895	
		1108					215000	
							79990	
			5259				191072	
		10602	*12127*				1297527	
		1					32868	
							186509	
		80415	*463808*				9182915	
		19784	*16006*				648491	
							4227	
							2683	
			1583				178388	
							22650	
		21839	*7157*				855186	
							72108	
							23089	
0	*0*	**133749**	*505940*	*0*	*0*	**10990043**	**13133443**	**83.68**
		41057	*88069*			**71944**	**4891998**	**1.47**
		1687	*34991*				202940	
		34675	*50935*				619429	
		427	*33293*				121124	
		36138	*11967*				948231	
0	*0*	**72927**	*131186*	*0*	*0*	**740282**	**1891724**	**39.13**
						0	**25042**	**0**
		103246	*209*				128893	
		51992	*1228*				110477	
0	*0*	**155238**	*1437*	*0*	*0*	**155238**	**239370**	**64.85**
0	*n/a*	**155238**	*n/a*	*n/a*	*n/a*	**15481747**	**36924921**	
0	*0*	**1331976**	*1213170*	*0*	*0*	**15481747**	**36924921**	
		11.65						**41.93**

(O.C.C.)

(O.C.C. = Overall Classification Correspondence)

Comparison matrix between merged classes of ground and original air - surveyed data

East study area

Ground Survey Class	**Air Survey** Class Code/Value	*Unclass* *0*	**Arable/MG** **3**	**CG** **4**	**Mosaic (cg/mg)** **5**	**Woodland** **6**	**Bare soil or built-up** **9**	*Cloud/ shadow* *11*	*Water* *12*	**Ground to air correspondence** Common	Total	**Percentage**
Unclass.	*0*	*165484*	*1014669*	*105567*	*32697*	*291327*	*379355*	*13303*		*165484*		
Arable/MG	**3000**	*408440*	4331236	839967	241959	199553	666664	*75614*		4331236	6279379	**68.98**
All CGs	**4000**	*60297*	960934	1214525	196315	239491	265750	*68718*	7	1214525	2877015	**42.21**
CG/MG mosaic	**5000**	*6910*	390469	187846	43234	35682	56127	*59298*	9	43234	713358	**6.06**
Woodland	**6000**	*196926*	204388	145254	32855	1144029	154569	*11929*		1144029	1681095	**68.05**
Bare soil or built-up	**9000**	*9059*	29440	19571	5672	22612	80559	*227993*		80559	157854	**51.03**
Air to ground	Common	*165484*	4331236	1214525	43234	1144029	80559			6813583		
Correspondence	Total		5916467	2407163	520035	1641367	1223669				11708701	
	Percentage		**73.21**	**50.45**	**8.31**	**69.7**	**6.58**					**58.19**

Comparison matrix between merged classes of ground and air surveyed (modal class per land parcel) data

East study area

Ground Survey Class	**Air Survey** Class Code/Value	*Unclass* *0*	**Arable/MG** **3**	**CG** **4**	**Mosaic (cg/mg)** **5**	**Woodland** **6**	**Bare soil or built-up** **9**	*Cloud/ shadow* *11*	*Water* *12*	**Ground to air correspondence** Common	Total	**Percentage**
Unclass.	*0*	*34580*	*1933773*	*659*	*4158*	*14252*	*14980*			*34580*		
Arable/MG	**3000**	*387534*	5344400	349577	80083	82456	478033	*41348*		5344400	6334549	**84.37**
All CGs	**4000**	*71635*	953726	1521981	89354	169243	136496	*63602*		1521981	2870800	**53.02**
CG/MG mosaic	**5000**	*1691*	451565	170764	53025	23834	13877	*64819*		53025	713065	**7.44**
Woodland	**6000**	*196792*	148706	60541	1232	1407308	70093	*5667*		1407308	1687880	**83.38**
Bare soil or built-up	**9000**	*10205*	26539	7223	247	28586	94620	*36*		94620	157215	**60.19**
Air to ground	Common	*34580*	5344400	1521981	53025	1407308	94620			8421334		
Correspondence	Total		6924936	2110086	223941	1711427	793119				11763509	
	Percentage		**77.18**	**72.13**	**23.68**	**82.23**	**11.93**					**71.59**

Comparison matrix between combined classes of ground and air surveyed (as modal class per land parcel) data

West/Central study area

Ground Survey Class	Air Survey Class Code/Value	*Unclass* *0*	**Arable/MG** **3**	**CG** **4**	**Mosaic (cg/mg)** **5**	**Woodland** **6**	**Bare soil or built-up** **9**	*Cloud/ shadow* *11*	*Water* *12*	Ground to air correspondence: Common	Total	Percentage
Unclass.	*0*	*363541*	*1044799*	*86921*	*2947*		*4165*			*363541*		
Arable/MG	**3000**	*1634130*	8958203	3609057	88186	26555	924840	*486538*		8958203	13606841	**65.84**
All CGs	**4000**	*323182*	1574366	11015085	102170	9933	133749	*505940*		11015085	12835303	**85.82**
CG/MG mosaic	**5000**	*151632*	1058970	3548060	71944	20335	41057	*88069*		71944	4740366	**1.52**
Woodland	**6000**	*214289*	215248	630502	18476	740282	72927	*131186*		740282	1677435	**44.13**
Bare soil or built-up	**9000**	*28966*	24050	24727		6389	155238	*1437*		155238	210404	**73.78**
Air to ground	Common	*363541*	8958203	11015085	71944	740282	155238			20940752		
correspondence	Total		11830837	18827431	280776	803494	1327811				33070349	
	Percentage		**75.72**	**58.51**	**25.62**	**92.13**	**11.69**					**63.32**

Comparison matrix between combined classes of ground and original air - surveyed data
West/Central study area

	Air Survey				**Mosaic**		**Bare soil or**	*Cloud/*		**Ground to air correspondence**		
Ground Survey	Class	*Unclass*	**Arable/MG**	**CG**	**(cg/mg)**	**Woodland**	**built-up**	*shadow*	*Water*			
Class	Code/Value	*0*	**3**	**4**	**5**	**6**	**9**	*11*	*12*	Common	Total	**Percentage**
Unclass.	*0*	*289104*	*749445*	*200573*	*17723*	*31858*	*203934*	*5742*		*289104*		
Arable/MG	**3000**	*1596655*	7773955	3723496	634346	167859	1329095	*502103*		7773955	13628751	**57.04**
All CGs	**4000**	*320716*	1887813	8663661	998792	178112	850153	554052		8663661	12578531	**68.88**
CG/MG mosaic	**5000**	*133985*	1129729	2786002	394151	92405	345339	*98459*		394151	4747626	**8.3**
Woodland	**6000**	*203381*	246245	648353	62830	592826	175562	*93697*		592826	1725816	**34.35**
Bare soil or built-up	**9000**	*29566*	32252	36011	3026	10852	125882	*3217*		125882	208023	**60.51**
Air to ground	Common	*289104*	7773955	8663661	394151	592826	125882			17550475		
correspondence	Total		11069994	15857523	2093145	1042054	2826031				32888747	
	Percentage		**70.23**	**54.63**	**18.83**	**56.89**	**4.45**					**53.36**

APPENDIX E: Comparison matrices between maximum correspondence values and relating classes

Comparison matrices between maximum correspondence values and relating classes:
From original air survey data

East study area

Value (%) Class	0 - 24	25 - 49	50 - 74	75 - 99	100	Total for row	% of overall total
Arable/MG			4832544		4331236	9163780	66.02
Calcareous		591087	293413		1214525	2099025	15.12
CG/MG mosaic	98914				43234	142148	1.02
Wood			1330588		1144029	2474617	17.83
Total for column	98914	591087	6456545	0	6733024	13879570	
% of overall total	0.71	4.26	46.52	0	48.51	(Overall total)	

West/Central study area

Value (%) Class	0 - 24	25 - 49	50 - 74	75 - 99	100	Total for row	% of overall total
Arable/MG				11999039	7773955	19772994	52.83
Calcareous			6536768		8874773	15411541	41.18
CG/MG mosaic	595506				394151	989657	2.64
Wood		535486	124263		592826	1252575	3.35
Total for column	595506	535486	6661031	11999039	17635705	37426767	
% of overall total	1.59	1.43	17.8	32.06	47.12	(Overall total)	

Comparison matrix between maximum correspondence values and relating classes:
From air survey data as modal classes per land parcel

East study area

Value (%) Class	0 - 24	25 - 49	50 - 74	75 - 99	100	Total for row	% of overall total
Arable/MG				4784634	5344400	10129034	70.14
Calcareous			539733		1521981	2061714	14.28
CG/MG mosaic	70668				53025	123693	0.86
Wood				718946	1407308	2126254	14.72
Total for column	70668	0	539733	5503580	8326714	14440695	
% of overall total	0.49	0	3.74	38.11	57.66	(Overall total)	

West/Central study area

Value (%) Class	0 - 24	25 - 49	50 - 74	75 - 99	100	Total for row	% of overall total
Arable/MG			6742751	2343067	8958203	18044021	48.09
Calcareous			4265483	2639407	11015085	17919975	47.76
CG/MG mosaic	239701	2947			71944	314592	0.84
Wood		436878		63212	740282	1240372	3.31
Total for column	239701	439825	11008234	5045686	20785514	37518960	
% of overall total	0.64	1.17	29.34	13.45	55.4	(Overall total)	

ITE has six Research Stations throughout Britain, which allows the efficient use of resources for regional studies and provides an understanding of local ecological and land use characteristics. The Institute's administrative headquarters is at Monks Wood.

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