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GEOGRAPHICAL INFORMATION SYSTEMS FOR PLANNING IN ECOLOGY

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R G H Bunce & D C Howard

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Institute of Terrestrial Ecology
Merlewood Research Station
Grange-over-Sands
Cumbria LA11 6JU

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INTRODUCTION

This document comprises papers presented at a Workshop held in March 1988. The programme was initiated within the ITE project sponsored by the Department of the Environment on the *Ecological consequences of land use change* (ECOLUC). A major component of this project has been to link research groups and individuals working on particular applications within the general field covered by the programme, who may not necessarily be aware of each other's work.

The use of Geographical Information Systems (GIS) is central to many projects on land use, and different approaches have been adopted. GIS is a tool which may have an intrinsic attraction for computer scientists and some geographers, but it must be carefully considered and evaluated when applied to practical problems. Many of the techniques described have been available in comparable forms for several years, although not specifically termed GIS, eg computer-aided design (CAD) and image analysis. The value of efficient data handling and intricate analysis has been recognised by the Government, as evidenced in the report of the Chorley Committee and the subsequent discussions it provoked. However, problems still remain in GIS, notably the lack of census information at relevant scales, the subjective assessment and identification of areas, and the degree of commitment required for large data sets.

It was not originally intended to produce a publication from the Workshop, but the range of subjects covered provided such a useful impression of the variation in approaches that it seemed sensible to gather them together. Although the papers were collected immediately after the Workshop, pressure of other work has regrettably delayed publication until now, but, in spite of rapid developments in the field since the meeting was held, we believe that the papers represent a useful summary of the application of GIS in ecology at the present time.

One of the consequences of the Workshop in our own work has been the recent acquisition of an ARC/INFO system for use in ECOLUC. The information currently being used in ITE is derived from the two national surveys of Great Britain (1978 and1984). The data were analysed prior to the acquisition of ARC/INFO. However, future analyses using ARC/INFO will progressively lead to major benefits. The system can be used to describe a variety of measures of pattern, ranging from the description of populations of features within the landscape through to assessments of scale. We are identifying methods of improving the capability for making more precise predictions of the consequences of land use change by including their spatial differentation.

Although Laserscan has been adopted for general use in NERC, ARC/INFO is particularly suited to the type of modelling work we are now undertaking. It is also being used by many of the groups with whom we are collaborating, eg the NERC ESRC Land Use Programme at Newcastle, the National Remote Sensing Centre at Farnborough, the Agricultural University at Wageningen, and Lancashire County Council in Preston. Other systems in use are Intergraph (Nature Conservancy Council), Laserscan (University of Nottingham), AIMS (Ministry of Agriculture, Fisheries and Food), and SPANS (Soil Survey and Land Research Centre).

We have now been working with ARC/INFO for about four months, and, already, we can identify new areas of research, many involving modelling to produce a more dynamic description of the effects of land management. We hope that such new initiatives will provide an insight into ecological theories, and that the present document may serve as a stimulus to such developments.

R G H BUNCE and D C HOWARD
February 1990

A SPECULATIVE VIEW OF THE USEFULNESS OF GIS

J C PETERS
Department of the Environment, Tollgate House, Houlton Street, Bristol BS2 9DJ

INTRODUCTION

Lord Chorley defined the Geographical Information System as 'Information which can be related to specific locations on the earth'. This definition includes such data as the distribution of natural resources, the incidence of pollution, descriptions of infrastructure, such as buildings, utility and transport services, patterns of land use, and the health, wealth, employment, housing and voting habits of people.

We need to ask ourselves whether we consider GIS to be a computer-aided system for producing maps as overlays - a special case of digital cartography - or whether there is something rather special about the concept.

On a conventional map, it is possible to demonstrate the distribution of similar areas by the use of individual colours or shading. A map is a simple visual presentation, but it rapidly becomes confused if too much information is demonstrated.

The Department of Environment (DoE) used to publish a planning handbook of maps, indicating the location of different geographical features and resources. A recent map has been published in the DoE *Digest of environmental statistics*,indicating protected areas in the UK. All of these maps demonstrate themes which may be of interest to some particular user, and therefore familiar to them, but no map can possibly accommodate all interests. GIS enables the user to obtain rapid access to what he requires and, at the same time, to check that his requirements will not impinge unduly on the interests of others. At present, the main emphasis appears to be concentrated upon information retrieval for a particular site in order to facilitate the planning of services in urban areas. This requirement is the main driving force for the development of GIS, and is supported by the utilities.

THE GOVERNMENT RESPONSE TO THE CHORLEY COMMITTEE

The UK government has responded to the report of the Chorley Committee with the following basic statements.

- GIS needs to be cost-effective to the user.

- A national data set should not require government funding because of the large user demand.

- The Ordnance Survey (OS) has agreed with the utilities to provide a new specification for digital mapping which will allow joint investment without unnecessary mapped detail. The utilities and Ordnance Survey will explore methods of quality assurance for such maps. Responsibility for the preparation and updating of conventional OS maps will, however, remain with the Ordnance Survey.

- Spatially referenced data which have been collected by Government will be examined by a subcommittee working within the tradeable information initiative.

- A proposed centre for GIS has been rejected on the grounds that the interests are too diverse and multiple. Instead, Automated Mapping Facilities Management (AMFM) organised a conference on 29 March 1988, which resulted in a UK Division of AMFM with responsibility to incorporate local authority and academic interests and to build upon the Economic and Social Research Council (ESRC) Regional Research Laboratory (RRL) initiative. ESRC has allocated £1.4 million between 1988 and 1992 to set up a core of up to 7 RRLs. There are also encouraging signs that ESRC and NERC are beginning to work closely together in this area, particularly through the Rural Areas Data Base.

ECOLOGICAL EFFECTS OF LAND USE CHANGE (ECOLUC)

This project was set up by DoE, following a joint project with the Countryside Commission which monitored land use change. Its aim was to determine the significance of the changes observed in terms of national and local decision-making. In particular, the project is trying to determine the minimum expenditure of resources which will meet the data collection requirements of the user to enable him to take decisions.

The following questions need to be answered before the basic data requirements for GIS can be established. A decision-maker seeking action on landscape change in terms of its effect on ecology may need to know the following.

- Who believes that such change matters?

- At what point do we perceive ecological change to have occurred?

- How can the decision-maker be given early warning of significant changes?

- Can early warning help in managing the effects?

- Is the cost of providing such warning acceptable?

- Could an ecological statement help the decision-maker, even though no amelioration of effects may seem immediately possible?

- What alternative regime could be developed to compensate for the changes?

- Are the changes permanent, temporary or responsive to manipulation?

- How can the costs/benefits be optimised?

- What weighting can therefore be given to ecology?

The ECOLUC project is attempting to build an Expert System to help clarify such problems.

GIS

What is so special about a Geographic Information System? It needs spatially oriented data and should be capable of listing what data are available on different features at any chosen location. Is it more than an easily accessible locational dictionary? To what extent should a GIS be able to tell us something about the relationship between data at any one location and those of neighbouring locations, even far away in the spatial distribution?

GIS must surely be important in demonstrating to a user whether a spatially similar or extreme situation exists at any location, in order to determine the tolerance range, distribution, or habitat requirements, thus making the needs of species and communities explicit and rapidly available. We have already seen that the GIS can store more information for a particular location than can possibly be mapped. Is a GIS the correct vehicle to inform on the significance of effects? Can we demonstrate that all the environmental requirements for the occurrence of a particular species can be satisfied through data storage in a GIS? Will such a system help to detect the reasons why a species occurs, and, conversely, can it provide evidence for the lack of occurrence of a species in a situation where all the requirements appear to be satisfied? Can we even store data on the ephemeral nature of some species' presence on the basis of their life histories and distribution?

Perhaps these requirements are more appropriate to the role of an Expert System. What is the difference? Is GIS the vehicle to test hypotheses proposed by an Expert System?

GIS AS A RESEARCH TOOL

Will the average GIS be powerful enough to test assumptions about relationships and to assess the extent to which they hold true?

For years, the geologist has been able to visit a site and date the strata by referring back to the stratigraphy worked out in great detail at a particular location, and thereby to shortcircuit the amount of data collection required. There is certainly potential for a portable GIS which could be used at the time of such a survey.

For the ecologist, however, the sheer quantity of data and the incompatibility of data bases which have been developed because of the piecemeal nature of ecological survey have prevented a similar approach. The geologist is lucky that his systems are comparatively stable dynamically, whereas the ecologist is looking at a snapshot in time, and, as a result, spatial referencing may miss similarities between sites because cycles of time are out of phase. It is, therefore, important that GIS should include time series information and that these data provide increasing linkages between the snapshots in time.

For a Department like DoE, a GIS is obviously of great value in rapidly informing the policy-maker where resources are becoming exhausted or inaccessible to different users, either through pollution, a shift in market location, or the effects of such catastrophes as Chernobyl and the recent storms. It also has the potential to examine the significance of change, particularly the synergistic effects of multiple pressures, as in agriculture, upon the suitability of land for different uses.

GIS should improve the decision-taking process, provided it can also indicate the significance of the information being made available. What are the implications for standards of data quality and presentation? Is there a danger that GIS can provide much information which may be of questionable quality? Is there also a danger of too much information being collected, so that the true significance of a situation will be missed because the trend is buried within too much 'noise'? This is a real problem which has been a continual worry to those involved with ECOLUC, where we need to match the questions being posed at the top with the information coming up, and to determine whether there is a meeting point. Without such linkages, the decision-taker will continue to say: 'So what'!

THE CO-ORDINATION AND SPATIAL INTEGRATION OF ' RURAL ' DATA - SOME ISSUES

M LANE, H NEWBY, J SHEARMAN and N WALFORD
ESRC Data Archive, University of Essex, Wivenhoe Park, Colchester, Essex CO4 3SQ

INTRODUCTION

There has been increasing demand amongst those agencies concerned with rural research and planning for access to information across a wide range of subject areas in order to analyse and monitor the complex processes which govern rural change. Associated with this increased demand is a growing need for co-ordination and co-operation between agencies, from the data gathering stage though to policy-making. The growth in demand for such information stems from a number of factors - not only the degree of concern about the complexity and speed of rural change, but also the technological developments which have vastly improved capabilities for data access and manipulation. Of particular importance in this context are the advances in techniques and software tools for handling the spatial aspect of the information, and the availability of digital data sets.

Although many agencies are now taking significant steps to interrelate data sets and analysis techniques, there is still much fundamental effort required for co-ordination at the earlier stages, and for the further development of techniques and available software. The spatial integration of 'rural' data sets in the UK is a central function of the Rural Areas Database Unit (RAD), based at the ESRC Data Archive at the University of Essex, which is concerned with both environmental and socio-economic data relating to rural areas and issues.

SPATIAL UNITS AND GEOGRAPHICAL REFERENCING

Even within disciplines, data sets relate to a wide variety of spatial bases which often do not nest within one another and for which the 'common aggregation unit' is at national level, if it exists at all. Grid squares are a common spatial unit, particularly in environmental research where regular, arbitrary boundaries are suitable for gathering and analysing information relating to such factors as land use, vegetation cover, and soil type. Socio-economic applications tend to use political and administrative boundaries, although the use of one km grid squares has increased significantly in recent years. The advantages of using grid squares lie in their regularity, scale flexibility, independence and ease of manipulation, but there are also disadvantages in that they bear little resemblance to ground features and do not nest within other spatial unit boundaries. One km grid squares are being favoured as a standard 'basic spatial unit' (BSU) for many national data sets, because finer resolutions are unrealistic for any ground data collection on a national scale (apart from remote sensing applications and resolutions). Localised studies will normally require finer resolutions, but the use of grid squares enables aggregation to higher spatial levels. It is important to recognise, however, that one km grid squares may not be the correct choice for a standard BSU for national data. Their resolution is usually considered too coarse to use as building blocks for defining area designations. There has already been significant historical investment in irregular polygon networks, and grid square boundaries can be unsuitable for some applications which require accurate matching to 'real-world' features. Other commonly used BSUs are unit postcodes, parishes, wards and enumeration districts, which may be aggregated up to local authority district, county and region level. Postcodes are becoming increasingly important for property and population-based data sets.

As well as using established administrative boundaries, rural policy matters are frequently concerned with identifying area designations - placing irregular boundaries around areas of particular need or areas which merit special attention - eg National Parks, Areas of Outstanding Natural Beauty, Sites of Special Scientific Interest, Rural Development Areas, etc. It is important to continue to monitor changes and developments within the area in order to adapt policy and/or make boundary changes where necessary. Given the current conflicts in some rural areas, many organisations require data 'profiles' - consisting of ecological, agricultural and socio-economic data - for such spatial units, at regular time periods. It is also important to be able to locate, identify and derive information for overlapping area designations for considering combined effects, such as needs and constraints.

Another issue is the requirement for building national pictures from localised data sets. Many authorities undertake ecological surveys and rural settlement surveys, but each may use different spatial bases, different geo-coding systems, different classifications, and may structure the data in different ways.

Clearly, in order to approximate one spatial unit and its associated attributes to another spatial unit using GIS facilities, data sets must be geo-coded, and features must be defined digitally in some form. The methods used also vary widely - a few examples of the spatial data sets which the Rural Areas Database handles are given below.

1. A data set having simply a code or name for an irregular area with no associated digital co-ordinate reference. Until recently, the parish-based agricultural census data were of this type. Crude boundary files and centroid references do now exist.

2 Data sets relating to irregular areas for which there is only a point co-ordinate reference, for example a centroid, and an area measurement, eg SSSI data, Forestry Commission sub-compartments.

3 Data sets for which there exists a full boundary description, eg ward-based population census data.

4. Gridded data sets relating to squares of a certain resolution, with a point co- ordin ate reference for the south-west corner of the square, eg ITE land characteristics and land classification data sets. Some other gridded data sets alternatively reference the centre of the square.

5. Data sets relating to network and tree structures, such as roadways and rivers.

6. Rasterised data sets, where the spatial reference is implicit in the structure of the data set, with associated information about registration, pixel size, etc. Satellite images are one example.

The finer the resolution of the spatial reference or spatial unit, the greater the flexibility for aggregating or approximating to other spatial units. For this reason, the RAD tries to aquire data at the finest spatial detail possible, even if the data cannot be released for general access at this level for sensitivity reasons. Agreements can be reached for spatial levels at which the data can be released, usually in association with attribute subsets, so that there can be different 'acceptable' spatial levels, in terms of access, for different aspects of a data base.

Most of the spatial data sets aquired by the RAD relate to England, Scotland and Wales, for which the National Grid co-ordinate system is commonly used. Otherwise, we try to convert the data to the National Grid where possible. Irish data normally use the Irish Grid system, which can be linked with the National Grid. When considering European-wide data at any reasonably detailed spatial level, there are further problems not only of different co-ordinate systems, but of different projection systems. A number of problems were recently experienced when trying to collate data and digital outlines for administrative areas at the equivalent of county level for the whole of Europe. It was difficult simply to acquire maps with latitude and longitude reference points, scales and projections.

In addition to the above issues, there are other properties of digital data sets which must be included, ie level of generalisation, digitising scale, accuracy, resolution, data structure, and method and degree to which topological relationships have been incorporated. Also, feature coding and classification used, date reference, and pointers to appropriate attribute data sets should be included within the system. Standards are beginning to emerge in the UK, particularly for the transfer of spatial data. However, issues like topology, feature coding, data quality, generalisation, etc, have yet to be fully discussed and clarified.

TECHNIQUES AND SYSTEMS

There are several algorithms for approximating spatial units to one another. The term 'polygon overlay' is freely used these days, but can mean a whole variety of operations from simply plotting boundaries over one another on a map to fairly sophisticated facilities which merge and combine polygon boundaries and derive statistics for different attribute data types relating to the spatial units concerned. When evaluating a GIS system, it is important to discover the nature and capabilities of such procedures as polygon overlay, and to be aware of the implications of the methods used. Routines such as point-in-polygon are generally more straightforward - there are some well established algorithms available. Other aspects to check are capabilities for explicit definition of topological relationships, such as coincidence and enclosure.

Available GIS systems either tend to be appropriate for rasterised and grid-based data structures or for vectorised data structures, or are designed specifically for satellite image processing, although more recent system developments are beginning to close this gap. For environmental applications, there is a need to handle all these data structures, eg relating grid square data and raster satellite data to irregular area designations, deriving vector boundaries from gridded or rasterised data, and looking at the path and extent of a linear feature across a gridded area. Although raster-based GIS systems have some advantages in terms of data manipulation, efficient storage strategies, etc, there are still difficulties, eg with topological referencing, feature coding, and resolution for detailed features.

RAD MANAGEMENT AND SOFTWARE

The scope and variety of data sets which the RAD handles and the range of its application areas necessitates a broad approach to the development of a GIS. The definition includes hardware and software, which will in a sense be tailored to RAD needs, but which will also be open and sufficiently adaptable to enable the Unit to provide spatial data structured in formats suitable for most users. Core spatial manipulation functions must be surrounded by extensive peripheral software (not normally provided by most GISs). For example, a sophisticated indexing and information retrieval system, defining spatial and other relationships between objects, incorporates pointers to associated digital data sets, and allows keyword searching and cross-referencing. It must incorporate facilities for data quality assessment, and also various administrative aspects, eg ownership, documentation referencing, and access indicators relating to spatial levels and data subsets. The RAD is enhancing the existing information retrieval system at the data archive to handle spatial data. This system is available to users over the JANET or PSS network.

Linked in with the information retrieval system is the development of a spatial indexing system to define spatial relationships between commonly used spatial units in the UK - really a topological 'enclosure' index of units contained within other units, and aggregation hierarchies. This system is an important accompaniment to the data base, because it will reduce the need to perform digital searches for this purpose (eg finding one km grid squares within National Park boundaries), will interrelate spatial units which have no digital definition, and will increase capabilities for users having no direct access to GIS software.

A sufficiently versatile GIS may be found and acquired in the future to reside at the centre of the RAD software, but in the meantime the Unit has been making good use of some very low-cost packages and routines. During the early development of RAD, a GIS 'toolkit' has been assembled by bringing in selected, commonly available, packages and writing programs to interface them with existing general-purpose software. Although the more complex spatial procedures, such as network analysis for example, tend not to be available in this modular form, a surprisingly good set of basic spatial data handling facilities has been provided on a mainframe or microcomputer at very little cost. These facilities include spatial searching (circular, linear, point-in-polygon), overlaying polygon networks to compare one with another, to generate new networks, or to derive approximate attribute values for alternative spatial units, translating between co-ordinate systems and projections, transforming between vector and raster structures, manipulating raster data, and some spatial analysis techniques. Currently, there is a large price differential between buying low-cost software modules and purchasing a complete GIS, which does not reflect the difference in use between the two approaches.

The former may cost less than £5,000 for a broad spectrum of spatial data and general-purpose mainframe-based software tools, the latter £30,000-£50,000 and more (academic prices).

In summary, low-cost modules with some programming time and resources have considerable potential, and this route can lead to a more flexible and versatile system in the long term. The particular software currently used by RAD is mainly MAPICS, GIMMS, Odyssey and Harwell routines for spatial searching. Whilst many of these techniques provide overlapping facilities, each includes procedures not available within any of the others.

Some examples of recent work within the RAD Unit given at the Workshop included deriving total productive and unproductive woodland within local authority districts on behalf of the Forestry Commission, and converting ward-based population census data to a grid base from ward digital boundaries using MAPICS.

REMOTE SENSING AND GIS: AN ACADEMIC VIEW

R H HAINES-YOUNG
Department of Geography, University of Nottingham, University Park, Nottingham NG 7 2RD

The practical issues arising from the integration of remote sensing and Geographic Information Systems are not simply related to hardware and software. To some extent, difficulties arise out of our attitudes towards the two technologies. This point was illustrated by reference to recent attempts to monitor countryside change in the UK.

Recent experience seems to show that the current generation of earth observation satellites still cannot meet all of our requirements for such a monitoring system. Part of the difficulty has arisen from the attempt to find a single-technology solution to the problem of monitoring. Perhaps we should focus more on the design of solutions to the problems of monitoring rather than the application of any one technology. An example of an integrated approach to landscape monitoring was described.

The need to base our efforts in the fields of remote sensing and GIS on the search for solutions leads on to a number of methodological issues. Both technologies tend to be data driven, despite the fact that the classical, inductive model of science has largely been refuted. Two recent reviews of some methodological issues in remote sensing and GIS were discussed. It was argued that we should approach the design of solutions using remote sensing and GIS technologies in a more deductive and critical way than currently seems to be the case.

If it is accepted that GIS and remote sensing technologies should be used to design and test solutions rather than merely handle data, then one is conflicted by the attempt to create a general-purpose spatial information system. To illustrate this point, some of the political and organisational issues which arose out of the desire to create a rural information system for Wales (WALTER) were described.

In seeking to establish a spatial information system, the political and organisational problems which it creates are amongst the most difficult to solve. Success often depends on the political agenda rather than on technical adequacy. It was argued that, as we enter an era in which emphasis will increasingly be placed on monitoring the effectiveness of policies, the successful implementation of spatial information systems is more likely to be assisted if they are viewed primarily as problem-solving tools. What does a policy represent, if it is not a solution to some problem? The effectiveness of a policy, like any proposed solution to a problem in science, needs to be tested critically.

GIS, ECOLOGICAL MODELLING AND LANDSCAPE PLANNING

P A BURROUGH
Department of Physical Geography, University of Utrecht, Postbus 80115, 3508TC Utrecht, The Netherlands

Good landscape planning depends on a balanced mix of good ideas, adequate data, appropriate tools and timely actions. Although the understanding of ecological processes and the interactions with human activities has greatly improved in recent years, the availability of appropriate data and the tools with which to process them have only recently begun to match the demands of planners, as distinct from those of the research workers. This paper presents a brief review of the current state-of-the-art of geographical information systems (GIS) and ecological modelling as useful tools for landscape planners, and illustrates the ways in which developments are proceeding.

The development of cheap, fast computers and mathematical methods has made two kinds of 'super tool' possible for landscape planners. GIS are tools for storing and manipulating data about the spatial distribution and pattern of objects on, and of, properties of the earth's surface. Using map overlay techniques, remote sensing and interpolation methods, data on geographical objects, be they point observations, linear features or thematic map polygons representing land use classes, can be stored, combined and analysed (Burrough 1986). Currently, data from existing sources, such as maps of soil, geology, vegetation and land use, are being converted to digital form and stored in various kinds of GIS. Many forms of GIS are available, from simple lists of objects such as plant species or soil profiles together with their geographical location and attributes, to fully fledged systems capable of making highly accurate maps and performing sophisticated data retrieval and analysis.

The development of quantitative models of how materials, plants and animals move through a landscape, describing how changes occur, has also reached considerable levels of sophistication. Many quantitative models have been developed for processes such as groundwater and surface water movement, nitrate leaching, crop growth and plant production, air pollution, and soil erosion. These models can be grouped roughly into three classes: empirical models that reflect a correlative understanding of a process; deterministic models that attempt to model the physical process directly; and stochastic models that apply methods of randomisation (eg Markov chains). In practice, a given model may well combine elements of all three classes. Some models have been developed from the standpoint of localised case studies, while other models that claim to be of general application also exist.

For a landscape planner it would be attractive to be able to combine the power of models with the facilities of a GIS. Then the models could be applied to selected landscapes by feeding them with the appropriate data from the spatial data base. The results of the models could be displayed together with other spatial data, thereby permitting visual appreciation of the results of change. By varying the input parameters of the models to reflect different land use scenarios, the possible effects of land use policies on the ecology of the area in question could be examined. Decision-makers could then be presented with a range of studies that would not only give an idea of what changes might be expected, but also where they would be most likely to occur. A recent example of this kind of approach for soil erosion has recently been completed in the Netherlands (de Roo, Burrough & Hazelhoff 1988).

Although this approach is certainly attractive, it is not without its pitfalls and problems. Many scientists feel that models should not be used indiscriminantly by lay persons who do not have a proper understanding of the processes involved. Also, there is no certainty that data already resident in a GIS will be of sufficient quality or quantity to allow modelling to proceed without serious (and often unknown) propagation of errors (eg Burrough 1986). Clearly, users of a GIS that is equipped for ecological modelling will need expert guidance both in the assembly of data for a model (an analysis of the information flow) and about the quality of the results that can be expected. Both these aspects are being studied in a research project just started at the University of Utrecht.

The current state-of-the-art of GIS allows most kinds of basic, statistical spatial analysis to be carried out with relative ease. What we face now is not so much a hardware/software technology crisis of how to handle spatial data, or a conceptual problem of how to model dynamic processes, such as soil erosion or groundwater movement, but the real possibility of a data crisis. This dilemma is not because we do not have sufficient data, but rather because the data may not be appropriate for running models because they are too general or have already been classified. In order to obtain the correct data at the most economic cost, it will be necessary to consider methods of sampling that can optimise data gathering and ensure that spatial data are collected at a scale appropriate for the application in hand. In certain situations, such as subsoil studies of groundwater movement, it may be appropriate to supplement actual field data with simulations based on known physical processes in order to create spatial units with a fine enough resolution so that the transport models perform well.

REFERENCES

Burrough, P.A. 1986. *Principles of Geographical Information Systems for land resources assessment.* Oxford: Oxford University Press.

de Roo, A.P.J., Burrough, P.A. &Hazelhoff, L. 1988. Modelling soil erosion using geographical information systems. *Proceedings of the 1988 Benelux Geomorphological Congress, Amsterdam.*

DEVELOPING AND TESTING A GIS FOR PREDICTING REGIONAL CHANGES IN LAND USE

R J ASPINALL
Macaulay Land Use Research Institute, Land Use Division, Craigiebuckler, Aberdeen AB9 2QJ

The aim of this project is to develop and test a methodology for using a geographical data base to predict the likely consequences of changes in policy decisions or economic circumstances on the regional distribution of major land uses. The particular concern of the present study is in the area of land used for agriculture, forestry and nature conservation in the Grampian Region.

The project has four additional applications: first, in providing a means of **assessing** land according to a variety of criteria and for different purposes; second, as a means of **identifying** the most appropriate land use in an area, given its resource base and current pattern of land use; third, as an aid to **planning** integrated land use strategies and assisting in the design of land use policy; and fourth, in providing a means of **monitoring** land use and the effects of policy implementation.

The research is being carried out in relation to three main objectives:

- the development of a geographical data base and information system as a basis for analysis
- investigation of past land use changes and development of models relating land use changes to land resources and land use policy
- testing the results of these models.

These objectives form the bases for three main phases of the work. First, the form and operation of systems which already exist, their advantages and disadvantages, and their application and relevance to the geographical analysis of regional land allocation are being evaluated. Second, following this evaluation, geographical sampling procedures and data requirements are being established. Data are being collected using a variety of methods and sources (eg field survey, land user survey, existing maps, data bases, and remote sensing imagery). A comprehensive regional data base is being compiled for the Grampian Region, and this will act as an information system for the GIS and a data source for analyses of land use change. The data base is a detailed inventory of physical resources (climatic, edaphic, geological geomorphic, biotic), interpretations of physical resources (land capability), administrative areas (districts, parishes, estates, nature reserves, SSSIs), and assessments of land use and land use changes. Third, the data will be analysed to examine past patterns of land use change defined according to a variety of criteria relating to physical and administrative factors (eg topography, altitude, land capability class, land tenure). The causes of land use change are being sought both from past and present land management practices and from the pattern of physical resources and administrative factors used in the classification. A pilot analysis of land use around Elgin has shown there to be a close relationship between land use and land capability and altitude, and the analysis of land use change in relation to physical and administrative criteria will be used to develop probability statistics as the basis of model development. Subsequently, the development, application, testing and refinement of models of land allocation derived from data investigation will take place, and alternative methods of interpreting policy in a regional context will be developed using the GIS.

GIS APPLICATIONS FOR REGIONAL STUDIES: THE ANTRIM COAST EROSION SURVEY

D BARTLETT
Department of Environmental Studies, University of Ulster at Coleraine, Cromore Road, Coleraine, Co Londonderry BT52 1SA, Northern Ireland

INTRODUCTION

The coastal zone represents an extremely complex, yet crucially important, region of the earth's surface. It is here that marine, terrestrial and atmospheric processes all interact uniquely. It is here, too, that many of man's activities have been, and continue to be, focused. As the human pressures on the coast increase, the natural coastal environment is becoming more and more threatened with pollution, instability in the sediment budget, and overexploitation of the coastal resources. Thus, there emerges a corresponding need for integrated and rational coastal management strategies.

Historically, the complexity of the coastal system has required that only small 'chunks' of coast could be considered at any one time. However, this reductionist approach has frequently resulted in the creation of greater problems than those solved. More recently, the fundamental approach in coastal management has shifted away from this 'site-based' perspective to a more holistic, 'regional', basis.

The success of any coastal management initiative depends on the availability of information, which, in turn, requires data to be processed (Tomlinson 1972). Thus, rational and sustainable coastal management can only be achieved when suitable data handling tools have been developed.

This paper discusses some of the GIS-related issues encountered during the first six months of a survey of erosion on the coast of County Antrim, Northern Ireland. The discussion will focus on the problems of georeferencing coastal features, because it is felt that many of the problems are common to any regional GIS application.

GEOREFERENCING COASTAL FEATURES

In its simplest form, the coast may be treated as a one-dimensional entity (Weyl 1982). However, in any detailed study, this linear form of representation is inadequate, and there is a requirement for more complex forms of data structure for several reasons.

First, the absolute location of the boundary between land and sea (in particular) can only be set within constraints imposed by the scale of the survey. These problems are well known to cartographers, who have traditionally employed a variety of generalisation techniques for portraying different levels of detail at different scales of map (see, eg, Muller 1986, 1987). Second, the coast is the interface between two highly dynamic environments - the marine and the atmospheric - and a third, generally more stable, one - the terrestrial sphere. The position of this boundary is, therefore, subject to changes over a variety of timescales and directions. Third, and closely related to the above, there is a high degree of interchange of matter, organisms and energy across the divides between each of the three media. The magnitude and effects of these exchanges diminish with distance, but rarely is there a sharply definable cut-off point. Fourth, many of the critical parameters of a coastal system have planar or bulk qualities (eg the area and orientation of a beach; the volume of sand available for dune/nearshore exchange). Other parameters may be represented by point data (eg records (Erwin *et al.* 1986)) or as vectors (eg energy fluxes driven by waves, river outflow or the wind).

The ideal GIS for regional coastal applications, therefore, will need to handle data variously represented in no, one, two, three and (where time is considered as a dimension) four dimensions. There should also be the facility to increase or decrease the resolution of the data, to accord with the scale of the study area.

A number of techniques are emerging as possible answers to some of these questions, and include the use of knowledge-based systems and advanced spatial data models such as quadtrees, Morton ordering, fractal geometry, etc (Waugh & Healey 1987; Muller 1986, 1987). However, on a pragmatic level, it must be remembered that even the uptake of existing GIS within society at large has been slow (HMSO 1987), and it will probably be some time before these state-of-the-art techniques can be used routinely for solving real-world problems.

THE ANTRIM COAST EROSION SURVEY

This study is being undertaken under a fixed-term research contract, on behalf of the Department of the Environment for Northern Ireland, as an adjunct to the scheduled renotification of the Antrim Coast and Glens and the Causeway Coast Areas of Outstanding Natural Beauty. In the 12 months available for the survey, the entire GIS has to be assembled (largely from scratch) and brought on-stream; the required data have to be captured (often through direct field observations), entered into the system and analysed; and the final reports have to be written. Given these constraints, it was clear that use should be made of existing techniques, even if the methods occasionally lacked the sophistication found in more state-of-the-art systems.

For the sake of expediency, and because financial constraints made the purchase of ARC/INFO impractical, we adopted a comparatively simple and unsophisticated relational data base approach, based on the ORACLE system. The relational approach to GIS is well documented (eg van Roessel & Fosnight 1984; Waugh & Healey 1987), while ORACLE is itself becoming increasingly used as a tool for GIS applications (see Collins & Sanderson 1987). In the present application, Professional ORACLE, the PC-based version of the software, is being used on an Olivetti M380 machine fitted with 4 Mb RAM and a 40 Mb hard disc. So far, both the hardware and the software have satisfied all expectations of cost and performance.

At present, any graphical output required is achieved by downloading the data (over a Kermit link) to a VAX mini-mainframe, where they are incorporated into GIMMS files for plotting. This process is by no means ideal, and we are starting to investigate the suitability of PC-based mapping packages, including ATLAS and PC-MAPICS. We also learn that a PC version of GIMMS is shortly to be available (T Waugh, pers. comm.).

LOCATIONAL DATA

For the purposes of the survey, all locational data are held in ORACLE as Irish Grid co-ordinates, stored in a 'long thin' co-ordinates table. Each record consists of a unique sequence number, an easting and a northing, captured from the 1:50 000 scale maps of the Ordnance Survey for Northern Ireland. When the records are selected and ordered by sequence number, the co-ordinates may be used to define the whole or, where appropriate, part of the Antrim Coast.

DATA ON ENTITIES, ATTRIBUTES AND PROCESSES

In addition to the locational data, a GIS must also enable the handling of data on entities, attributes and processes. In a coastal context, these variables include the physical properties of the coastal zone (wave climate and dynamics, coastal topography, sedimentology, estuary conditions, beach morphology,etc); cultural parameters (beach access, coastal land use); engineering factors (eg the occurrence and design of coastal defence structures); and biological factors (dune vegetation, in-shore fisheries protection/management, waterfowl conservation, etc). The relational data model, again, greatly facilitates this task.

In the Antrim Coast erosion survey, these data are being stored in the form of nested tables within a form-based ORACLE application. The entry point to the data base is a features table, that permits the operator to specify the coastal entity (cliff line, dune system, harbour development, beach, etc) required. Depending on the selection made at this point, a series of case-driven behind-the-scenes triggers display the form or forms relevant to the chosen variable. The features table also provides links to the co-ordinates table, so that individual entities may be georeferenced.

CONCLUSION

The survey is now well under way. As mentioned above, in real-world applications, the ability to perform the required tasks within the allotted time and budget is probably the ultimate test of any GIS. Our methods may not be elegant, and there is certainly scope for refinement of the data base architecture, but we are hopeful that they will comfortably meet this crucial basic criterion.

REFERENCES

Collins, D.S. & Sanderson, R.H. 1987. _ORACLE as a data management tool in a scientific environment. In: *Proceedings of the 5th European ORACLE Users Group Conference, Munich, 1987.*

Erwin, D.G., Picton, B.E., Connor, D.W., Howson, C.M., Gilleece, P. & Bogues, M.J. 1986. *The Northern Ireland sublittoral survey.* Belfast: Ulster Museum.

HMSO. 1987. *Handling geographic information.* Report of the Committee of Enquiry chaired by Lord Chorley. London: HMSO.

Muller, J. C. 1986. Fractal dimensions and inconsistencies in cartographic line representations. *Cartographic Journal*, **23**, 123-130.

Muller, J. C. 1987. Fractal and automated line generalization. *Cartographic Journal*, **24**, 27 -34.

Tomlinson, R.F. 1972. *Geographical Data Handling, symposium edition, Volume 1: Environmental Information Systems.* Ottawa: IGU Commission on Geographical Data Sensing and Processing.

Van Roessel, J.W. & Fosnight, E.A. 1984. A relational approach to vector data structure conversion. In: *Proceedings of International Symposium on Spatial Data Handling, Zurich.*, edited by D. Marble.

Waugh, T.C. & Healey, R.G. 1987. The GEOVIEW design. A relational data base approach to geographical data handling. *Int. J. Geographical Information Systems*, **1**, 101-118.

Weyl, P.K. 1982. Simple information systems for coastal zone management. *Coastal Zone Management Journal*, **9**, 155-182.

REQUIREMENTS AND APPLICATIONS OF GIS BY THE FORESTRY COMMISSION

A BETTS
Forestry Commission, Alice Holt Lodge, Wrecclesham, Farnham, Surrey GU10 4LH

The Forestry Commission (FC) manages 1.3 million hectares of land throughout Great Britain. Apart from the production of timber, which continues to be the most important objective, there are a number of other management aims, such as the encouragement of rural employment and provision for public access. In addition to its 'enterprise' role, the FC also acts as the forest authority in matters concerning private forestry (eg grant payment, tree health, research).

Map and crop data for the forest estate are prepared by a specialist survey branch ,and each forest is revisited on a 15-year cycle. In between surveys, local forest staff update maps and data to take account of major changes (eg new planting, disposals). Interest in crop data is usually very high at local forest district level (of which there are 65 in Great Britain), because both short-term working and long-term planning are dependent on a good knowledge of such data as species, age, growth rate and stocking. The FC has had a computer-held subcompartment data base since the late 1960s and within the last two years, local staff have had access to it via their local microcomputers. Whereas crop data are accepted as an essential component of management, maps within the FC do not always seem to generate the same interest. Once the location of an area to be worked is identified, there is often little further use for a map - indeed, many foresters know their areas so well that maps may almost be unnecessary for day-to-day management. Maps do, of course, assume great importance in showing ownership and wayleave information and in longer-term planning for landscaping, production planning and road maintenance.

Once prepared, stock maps are reproduced and updated by the seven regional offices. Cartographic effort is thus rather diluted throughout the FC and, after surveys, map data and crop data go their separate ways (the maintenance of crop data is centralised). Any proposals to introduce computerised mapping facilities would have to face the organisational problems encountered in the FC. As each regional drawing office will have varying work priorities (eg timber sale maps, private woodland grant records, display material) and perhaps a range of technical abilities among its staff, the introduction of new technology is not easy. Perhaps it is a feature of many Government ventures that the risks of failure can be great and the rewards of success negligible for the individuals faced with that risk.

The FC did embark on an ambitious map digitising programme in the early 1980s, employing a suite of computer programs developed jointly with a private company. This programme was ended in 1985 for a number of reasons, including cost. The central idea of the system depended on digitising boundary information direct from aerial photographs. However, considerable editing was required following checks by field staff. Since that time, involvement with geographically referenced data has been more basic. Some very straightforward work combining crop data with small-scale regional maps was carried out using GIMMS at Edinburgh University. Within the last two years, the National Grid reference for some 50 000 compartments has been added to the crop data base. This development has enabled the plotting of maps illustrating any number of relationships derived from the data base. More importantly, the grid reference has given the FC the ability to link its data with information similarly referenced.

The Rural Areas Data Base is of considerable interest to the FC, who has acted as a contributing sponsor for the past two years. One recent task carried out on behalf of the FC has been to allocate all FC crops in England to the District Council areas in which they lay - only county-level information is at present held on the crop data base.

REQUIREMENTS FROM GIS FOR CATCHMENT CLASSIFICATION

K R BULL and J R HALL
ITE, Monks Wood Experimental Station, Abbots Ripton, Huntingdon, Cambs PE17 2LS

INTRODUCTION

Catchments are hydrologically convenient working units. Their boundaries are readily defined from maps, and much of the chemistry and hydrology of the water within them reflects the topography, soil, geology and land use characteristics of the catchment.

When small numbers of catchments are studied, it is relatively simple to compare them and to explain differences in surface and ground waters. For larger numbers, it is more difficult: many parameters need comparing in an objective way. Multivariate classification methods can, however, reduce the number of comparisons by generating classes of catchments with similar characteristics. These methods have provided a framework for studying land use in Britain, both regionally and nationally. We are now using them to compare 600 British catchment areas. These areas drain into streams or lakes which are the subject of several ongoing acidification studies.

ACIDIFIED CATCHMENT STUDIES

The aims of our current study are to identify similarities between study areas in different parts of Britain, and to draw attention to areas which merit further investigation.

To classify catchment areas, several data bases are used, drawn from a number of maps. These maps must give consistent cover of the study areas whilst being of sufficient resolution to provide the necessary degree of detail. This requirement usually results in a compromise, between large-scale maps of great detail covering only part of Britain and small-scale maps with their inherent spatial errors and simplified data.

Much time may be involved in deriving the necessary parameters from the maps. Micro-computers aid the task of measuring areas and lines, but the information for these calculations must be in digital form, which usually requires a digitising tablet for its abstraction. Additional information, such as the presence of certain map features (eg waterfalls, springs, rock outcrops, farm buildings), and the measurement of basin characteristics (eg length, aspect) are taken directly from the maps.

THE USE OF GIS

A GIS, with the relevant data bases in store, could derive the required information for a classsification model much more quickly and easily than at present. For example, a GIS with access to a topographical data base, such as the British terrain model, could not only define the catchment boundaries from a specified grid reference, but also measure basin parameters, such as size and slope. By overlaying catchment boundaries on other map data bases (eg soils, geology), parameters from these could be summarised within the system.

The boundaries and shape parameters describing a catchment are essential basic measurements. They may, however, vary, with differences in map scales and operator subjectivity. A GIS system is probably limited to a small range of map scales by the data bases available, but would have the advantage of calculating in an objective, reproducible manner.

At present, map-derived data are stored on an ORACLE data base system, from where they are retrieved for analysis. Systems like ORACLE provide great flexibility. Transformations and combinations of different parameters are easily made, and the parameters selected can be varied *ad infinitum*. Although it is possible to select different data within the range of catchments in the data base, additional catchments require further map measurements, even if classification indicators identified by the analysis are used.

If a GIS can collect information from suitable data bases and derive specified parameters quickly, the options for selecting catchments for classification are greatly increased. In particular, those catchments which are large, complex and difficult to digitise will be more easily included in future studies, and whole sets of catchments from chosen areas may be compared and classified. It is possible to envisage an interactive classification system whereby sets of grid references and parameters are chosen, and a GIS creates a classification dendrogram from the corresponding catchment areas. Classifications could then be set up for specific purposes, and modified or extended as required.

ELEMENTS OF GIS FOR A NATIONAL PARK

M J DANNATT

Peak District National Park, Peak Park Joint Planning Board, Aldern House, Baslow Road, Bakewell, Derbyshire DE4 1AE

INTRODUCTION

The Peak Park Joint Planning Board is one of ten authorities charged with responsibility for the National Parks in England and Wales. The Board has specific responsibility for development control - planning functions - in an area which extends over parts of six counties. In addition, it is charged with conserving the Park's resources and for controlling the development of recreational opportunities. It also has a special responsibility for the socio-economic well-being of the resident population.

Information concerning topics as varied as ecologically valuable sites, ancient monuments, car parks and local industries is held on a variety of paper-based files, and much of it is marked on Ordnance Survey base maps at various scales. Practically all the data are essentially 'snapshots' - a record of a situation which existed at the time it was recorded. Only with improved storage and retrieval facilities can time series data be recorded properly. Nevertheless, it is using this type of information that the day-to-day 'tactical' planning decisions and responses must be made.

An important part of the Board's work is concerned with longer-term - or strategic - planning. Realistic policies must be based on an understanding of processes within the Park, which, in turn, needs to be based on an understanding of the spatial relationships between various sets of data.

A suitable GIS would be a welcome addition to the Board's modest computer resources. Before describing the elements of such a system, it is as well to consider the phrase 'a suitable GIS'. Insofar as the Peak Park is concerned, a GIS may be defined as a system to provide the means for linking sets of data whose only common relationship is their location with respect to the National Grid. The various sets of data would be an integral part of the GIS, which may be used to extract suitable subsets of data for input to a separate statistical analysis and mathematical modelling system. The word 'suitable' is important, and must necessarily imply satisfactory cost-effectiveness.

BASIC SYSTEM

'The first requirement for a GIS is a full set of digitised Ordnance Survey (OS) data for the area.' This statement has frequently appeared in print, but, if we accept it for the Peak District, then any GIS must necessarily be a long way off. Certainly, the work of the Board requires that an acceptable cartographic standard is maintained. For this purpose, accurately digitised Park records can be readily plotted on licensed dye-line copies of OS maps. Insofar as normal data handling is concerned, an OS map base is not required for most purposes. Indeed, it is principally for presentation purposes that a conventional base map is required. There are clearly instances where representation of the map base on a visual display unit is practically indispensible. For this purpose, we see no reason why a system based on video-discs, similar to the BBC Domesday system, should not be used. The immediate reaction of Board officers has been that a video-disc system is very user-friendly. The identification of a precise geographical location is virtually identical to a similar process on a paper-based map. Presentation of a base map of this type using the Board's own digitised data, with the ability to fade the image away, is an attractive option, which we perceive to be viable with the 50 000, 10 000 and 2500 series maps, subject to satisfactory arrangements with the OS.

Digitised data for Park records need to be related to information which is best held in a conventional data base. Indeed, it would seem logical to maintain the vector data as part of a relational data base, so that records can be readily selected by enquiry criteria based upon other non-spatial factors.

Therefore, in order to meet its statutory duties insofar as **tactical** planning is concerned, the Board would require a system with the following three elements:

- a qood-quality cartographic facility, providing output scaled to the plotting medium;
- an on-screen presentation to allow users to 'browse' and identify areas of interest;
- the capability for linking digitised data into a relational data base, which must therefore be able to handle records of variable length.

FUTURE REQUIREMENTS

The **strategic** planning role of the Board requires that the vector data, which can be used for the basic system outlined above, should also be capable of being converted to raster or quadtree format. Functions which lend themselves to such a representation include:

- presentation of species distribution in conventional format;
- analysis of the overlap of sets of complex polygons;
- ability to import remotely sensed data to assist in monitoring landscape change.

Strategic planning within the context of a National Park requires the establishment and review of published policies. To this end, the work of the planner is assisted by effective mathematical modelling and statistical analysis techniques, but the officers at Peak Park believe that these techniques should be interfaced to the GIS, rather than forming an integral part of it.

PROJECT METHODOLOGY USING A GIS FOR LAND EVALUATION IN GREECE

D A DAVIDSON[1] and S P THEOCHAROPOULOS[2]

[1]*Department of Environmental Science, University of Stirling, Stirling , FK9 4LA*

[2]*Soil Science Institute of Athens, Athens, Greece*

Staff at the Soil Science Institute of Athens are currently mapping the soils of Viotia in Greece, to the immediate north and north-west of Athens. Much of the area of 321 000 ha is agricultural land in the Kopias basin, which is floored with Holocene alluvial, lacustrine and aeolian deposits. The basin is fringed with a coalescing series of alluvial fans. The surrounding hills are of Cretaceous to Tertiary age, and consist of a wide range of carbonate-rich rocks, from limestones to conglomerates. Entisols and vertisols predominate on the basin floor, with inceptisols and alfisols on the older fluvial landforms. Entisols occur again on the steep hillslopes. Viotia has a prosperous agriculture, based on maize, wheat, alfalfa, potatoes, cotton, tomatoes and vegetables. The need for a land resource assessment has been identified because of increasing non-agricultural land use pressures, farm amalgamation schemes, and the need to provide advice to farmers and co-operatives about crop suitability.

The Soil Science Institute is currently mapping Viotia at the 1:50 000 scale, with the final map to be produced at 1:100 000. Land mapping units are defined through aerial photointerpretation and subsequent field checks. A fractional code is given to each unit in order to summarise information on drainage, texture, slope, erosion, presence of $CaCO_3$ and soil type. Standard profile and analytical data are provided for each sample point (at least one per mapping unit). Additional information on geology, land use, agroclimate and irrigation water availability is being collected.

The aim of using a GIS in this project is to store, process and present the data in forms suitable for particular land planning and management issues. Use will be made of Laserscan software, which has modules for digitising and editing vector files, plotting, non-graphical manipulation of vector files, tidying and structuring vector data, creating polygons, switching from vector to raster formats, and creating digital terrain models. The Laserscan software operates on a microVAX II in the Department of Environmental Science at the University of Stirling, and is integrated with a Diad image analysis system.

The objectives of using a GIS in this project are to produce:

- high-quality maps for any of the input variables
- land suitability maps for a range of different crops
- maps of land capability and erosion hazard.

The application of GIS is driven by land use planning and management needs. Through the experience gained in this project, it is hoped to demonstrate further applications of GIS technology to land resource issues in Greece.

LAKE DISTRICT NATIONAL PARK CONTRIBUTION ON USER NEEDS - LANGDALE SITE VISIT

A FISHWICK
Lake District Special Planning Board, Busher Walk, Kendal, Cumbria LA 9 4RH

The National Park Authority (NPA) has a statutory duty to preserve and enhance the natural beauty of the area and to promote its enjoyment by the public. It is the unitary planning authority, with responsibilities for the social and economic well-being of the Park. It has to prepare and keep under review a National Park plan and maps of mountain, moor, heath, woodlands and coastal features, the natural beauty of which it considers particularly important to conserve.

Its specific powers and responsibilities include the determination of planning applications (c1400 a year), related appeals (80), land charge searches (2000) and enforcement work; consultations on agricultural grant aid and forestry matters (c500 a year); maintenance and improvement of public rights-of-way (estimated 2900 km); management of properties - car parks, toilets, access areas, woodlands, common land; provision of information about the Park to the general public; and the award of grants for conservation work (c70 involving listed buildings, tree planting, woodland management, and pond creation).

A wide range of information needs flow from these functions:

- information about the environment and the way it is changing, eg visitor numbers, population census data, agricultural statistics, land available for development, landscape components, etc;

- information to aid decision-taking - special considerations such as statutory designations, eg Sites of Special Scientific Interest, policy constraints, relevant records of previous decisions, habitat surveys, and site records of plants and animals;

- information to monitor the effectiveness of the Authority's policies and actions, and to maintain public accountability.

Virtually all the information has a spatial component, but our ability to deal with and utilise that component on our existing computer systems is severely limited The spatial resolution required for many applications is very high, eg precise boundaries are needed for statutory maps, planning applications, etc, and these usually have to be produced on Ordnance Survey base maps (1:2500 - 1:25 000 scales). Most survey data are held on paper or microfiche, and map production is still basically a manual process. Although ITE pioneered its land classification system in Cumbria (one km square resolution), analytical work by the NPA on spatial relationships between existing data sets has been minimal.

CURRENT REQUIREMENTS

1. Improved management of existing and proposed data bases, particularly to enable the linking of spatially contiguous information from different data bases.

2. Creation of digitised files of key information, eg Section 3 Map boundaries, public rights of way, SSSIs, land with planning permission for development, and the capability to link between map files and data bases, and *vice versa*.

3. Spatial analysis, eg local handling of data produced by the Countryside Commission's National Parks landscape monitoring project (comparison of air photointerpretation 1972-present (land cover types)) and exploration of relationships between this and other information, eg agricultural statistics, records of local flora, etc.

RELATED ISSUES

Other issues involved in meeting these requirements include the following: committed budgets already constrained by financial stringencies; justifying 'untried' methodologies against established administrative systems with a more easily assessed return on investment; staff resources/training to maintain and develop systems; choice of systems, particularly to enable cost-effective development for new applications.

EXAMPLES OF INFORMATION AVAILABLE

1. Parish statistics: MAFF June returns, population census
   NB Langdale is only a small part
2. Habitat survey by the Nature Conservancy Council: maps and site notes held on microfiche
3. Sites of Special Scientific Interest - meadow
4. Tree preservation orders
5. Tree planting grant
6. Ancient semi-natural woodland
7. Section 3 Map woodland
8. Detailed site records, eg species in hay
9. Verbal agreement with MAFF
10. Areas of archaeological interest
11. Listed building
12. Recreation survey information, eg car parking counts, some questionnaire data

ECOLOGICAL INFRASTRUCTURE AND THE AFFORESTATION OF THE RANDSTAD URBAN AREA OF THE NETHERLANDS

W B HARMS
De Dorschkamp, PO Box 23, 6700 AA Wageningen, The Netherlands

The Randstad green structure plan is an outline project for the urban afforestation of the Randstad, which will create about 10 000 ha of forest and recreation areas within the next 15 years. The forests are planned to be in or near the four biggest cities in The Netherlands: Amsterdam, The Hague, Rotterdam and Utrecht.

These future forests could be an important network for the dispersal and persistence of forest fauna, and these two aspects of ecological infrastructure are being investigated In addition to studying the sites marked for development, six alternative forest distributions have been investigated, based on the assumptions that the ecological infrastructure of the Randstad can be improved, but that the improvement will affect different ecological groups of species in different ways. The MAP2 Geographical Information System has been used to develop a computer model (DISPERS) to predict the probability of colonisation and persistence of species in suitable habitats (eg deciduous woodlands). The model simulates the dispersal from the source area to unpopulated areas of suitable habitat, the dispersal rate being dependent on the 'resistance values' of the landscape. The results of the simulation are expressed in zones of relative accessibility, and, by superimposing the proposed forest areas, the relative probability of colonisation can be obtained. The probability of persistence was assumed to be proportional to the total area of the proposed forest and the nearby existing forests, and to be related to the specific population dynamics of the species in each ecological group.

Seven ecological groups of forest species were considered: three groups of bird species associated with different stages in forest stand development, three mammals associated with the same stages, and a group of butterfly species typical of forests and forest edges.

GIS - A TOOL FOR RECONCILING CONSERVATION AND DEVELOPMENT IN LAND USE STRATEGIES

J HOLBROOK
Nature Conservancy Council, Rural Development Unit, 12 Hope Terrace, Edinburgh EH9 2AS

EARLIER PILOT PROJECT

During 1986-87, a short pilot project was carried out by the Nature Conservancy Council (NCC) to explore the interactions between nature conservation and other rural land use interests. Islay was used as a case study area because research had shown that its nature conservation resource was of both national and international significance. Also, numerous development proposals had come into conflict with the need to protect the conservation interest. Thus, NCC began the process of formulating a working approach which other agencies and interests would agree upon and have regard to in the implementation of their duties and activities. Only once the interactions between the various interests have been ascertained, can the nature conservation resource be given appropriate weighting in policy development and subsequent programme implementation.

The pilot project used an in-house microcomputer digital mapping system, which was designed for the NCC's National Countryside Monitoring Scheme. This system enabled the capture of spatial data, such as topography, soils, land capability for agriculture and forestry, designated conservation site boundaries and various other conservation information. However, because it had been specially designed for other purposes, its limitations for use with more extensive and complex data sets became apparent as work progressed. These limitations were important when it came to integrating, manipulating and examining spatial and non-spatial data. The results from this initial project were encouraging, but indicated the potential of a more powerful computer-based information system if applied to this field of research by the NCC.

RURAL STRATEGIES PROJECT

In February 1988, a three-year research project was initiated to follow on from the earlier pilot study. The aim of the current project is to examine the feasibility and methodology required to establish local indicative strategies for nature conservation, based on the use of a GIS. The earlier pilot study had highlighted the need for an appropriately designed system, which was sufficiently powerful and flexible to handle large volumes of both spatial and non-spatial data. An efficient relational data base management system was required which could cross-reference both types of data input.

The ARC/INFO GIS and expertise at the University of Edinburgh's Department of Geography is central to this project. Emphasis is being placed on the quality and technical accuracy of both data input and the establishment of map layers.

Much of the initial effort has concentrated on the creation of a good 1:10 000 base for the study area. This base layer contains the high and low water marks, as well as the Sites of Special Scientific Interest (SSSI) boundaries. Such a base is important for the successful integration of other data layers. The coastline was generalised to a 1:50 000 scale of detail to provide a common template for data layers, such as those of soils and topography which do not have a common coastline in their currently available form.

Figure 1 provides a simple example of one operation that can be attempted. It shows the overlay of the boundary of the Gruinart Flats Site of Special Scientific Interest on land capability for forestry, and Table 1 lists the summary statistics. Such information can be quickly and easily extracted from the INFO data base and converted into a report format. As the analysis proceeds, such operations will form a greater part of the project activity.

The project will develop techniques for handling information relevant to resolving land use conflicts between conservation and development. To do so, it will look at many issues pertaining to the collecting, recording, collating, analysing, interpretation, display and presentation of information.

Work is progressing on two broad levels, described below.

i. **First level**

The project is looking at the potential uses of GIS in relation to available information, and is identifying modifications that are perhaps required to current methods of data collection and handling, as well as pinpointing areas where existing information could be improved by additional or new forms of data. New uses for current information may become apparent, as well as new methods of processing and analysing data, thus increasing the cost-effectiveness of investment in data acquisition.

ii. **Second level**

The progress made and results obtained in developing the use of GIS in this area of work are integral to the overall objectives of the project, which are to build up an approach that will characterise the nature conservation interest and to examine its context in two case study areas - the island of Islay and the Breadalbane Environmentally Sensitive Area. This work will necessitate the assessment and quantification of the nature, location and extent of existing and potential interactions of major land uses with the nature conservation interest. It will consider the local social and economic implications that may arise from the protection of the conservation resources.

The GIS will enable a comparative analysis of the dynamics of different land use interests, and its flexible data handling capabilities are of central importance in helping to produce the overall assessment of environmental quality which is required as input to the strategy being explored by the Islay Land Use Working Group. The Working Group has been convened by the local District Council and is currently addressing the collation of the large amount of information that has been collected, so as to resolve conflicts and to provide an integrated framework for development and conservation.

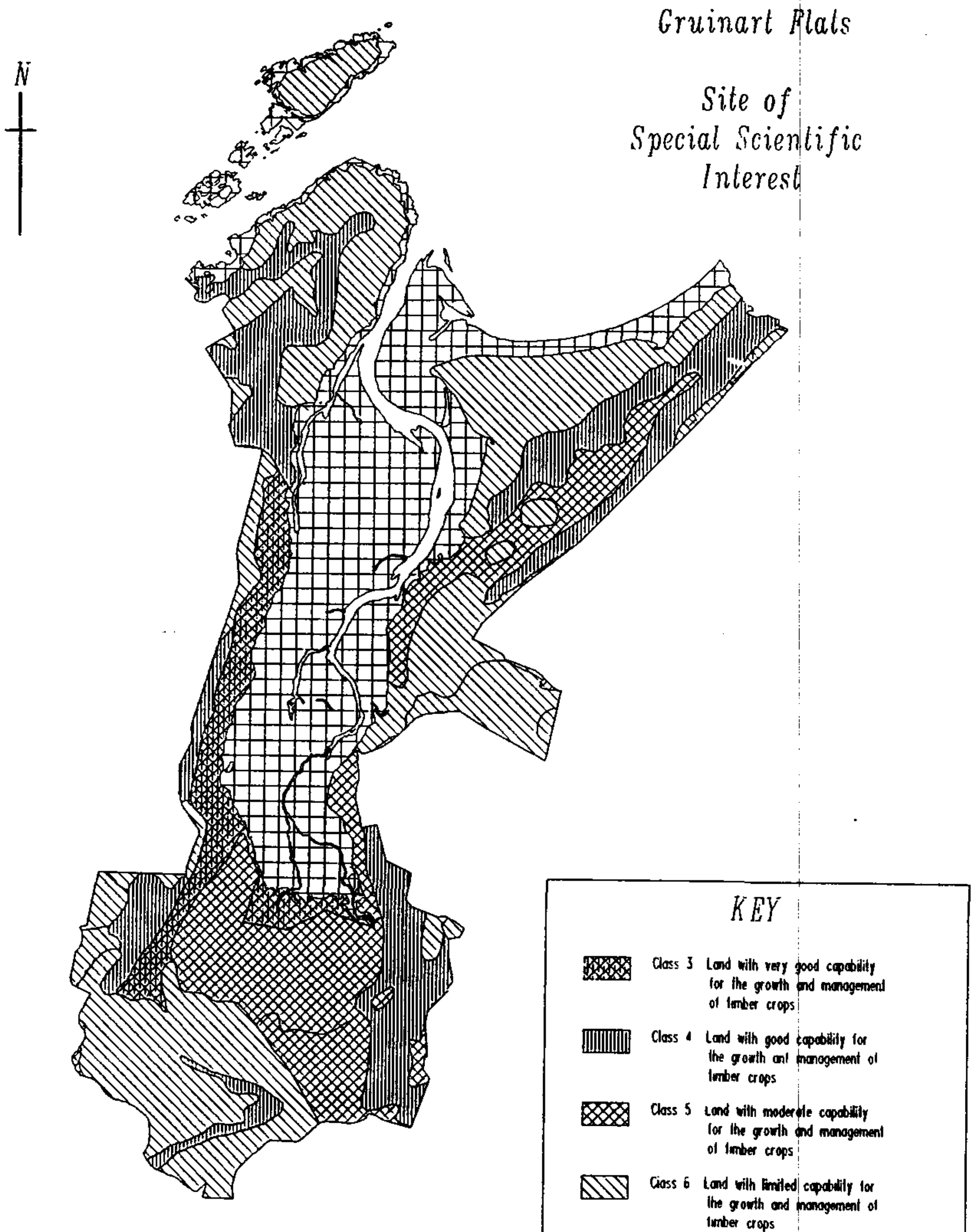
NCC is interested in the development of such initiatives as the Working Group's effort to produce a locally based, integrated, strategic approach to rural land use, especially where these present the opportunity to incorporate strategic statements of nature conservation interest. This interest stems from NCC's obligation under Section 37 of the Countryside Act to have due regard to the needs of agriculture and forestry and the social and economic interests of rural areas. It is also reflected in NCC's *13th Annual Report:*

'In recent years NCC has become increasingly concerned about the need to integrate the various sectoral strands of rural policy, of which the NCC's work is a part. NCC believe that many of the conflicts with nature conservation could be reconciled at a local level within an agreed strategic framework.'

This project is thus part of NCC's continuing efforts to aid in the development of a working environment, based on communication and co-operation, which will promote ways of placing nature conservation needs into a local as well as national context.

Example Overlay of Data Layers

Overlay of SSSI boundaries on Land Capability for Forestry



Source : Macaulay Institute for Soil Research, Sheet 60. **Scale : 1:60000**

TABLE 1

CAPABILITY CLASS	AREA-ha
0 *	900.768
3	184.677
4	560.330
5	493.855
6	1018.872
TOTAL	3158.502

* INTER-TIDAL

ESTABLISHMENT AND APPLICATION OF A TERRITORIAL RESOURCES INFORMATION SYSTEM USING A MICROCOMPUTER

SUN JIULIN and NI JIANHUA
Commission for Integrated Survey of Natural Resources, Chinese Academy of Sciences, Beijing, People's Republic of China

The project to establish a Territorial Resources Information System for Louyang Economic Region, in Henan Province, was initiated by the Bureau of Territorial, State Planning Committee. There are ten counties and one city in Louyang Economic Region; its area covers 17 000 km^2, and the population numbers 5.8 million. A data base has been created, and a model designed for use in territorial development management planning. The system was completed in 1986, and some valuable experience has been gained.

CONTENT OF DATA BASE

Basic territorial information, such as roads, rivers, administrative boundaries
Natural resource nformation, such as water, soil, climate, biology, mineral, etc
Socio-economic information, such as industry, agriculture, transportation, commerce, and architecture
Utility information, such as city and town, traffic, communication, culture, and health
Catastrophy and administrative information, such as environmental incidents, and environmental pollution
Decision data, such as timescales, planning objectives, and control data
Population and labour, such as population quality, and manpower
Related data for areas outside the Region for comparative purposes

There are more than 1100 data items for each county stored in the data base, and over 80 000 items of information in total.

COMPOSITION OF THE SYSTEM

1. **Territorial resources data base subsystem**
About 50 000 items of data are stored under DBASE2.

2. **Decision model subsystem**
planning and decision-making, and a methods base enables the user to choose between seven different types of calculation. The model data base includes resource data for decision modelling and the ability to create a new data file for the development of new models.

3. **Graphic display subsystem**
A base map data file provides geographical location data, and a thematic map base stores over 30 maps on file. The user can edit and update the software to update old map data and to create new maps. The subsystem uses a common CAD system.

4. **Data conversion subsystem**
This subsystem converts the basic data within the resources data base to a new format for use in modelling and plotting.

SYSTEM CHARACTERISTICS

The system comprises the data base, model subsystem and graphic subsystem, and is held on a microcomputer. It can be used for the statistical analysis of resources data, for compiling various maps, and in decision-making. The conceptual design of the model is based on the requirements of the user, and can be adapted for new applications.The system is menu-driven, using the Chinese characters, and is user-friendly. The information could be adapted for use in other large systems, such as a Resources and Environmental Information system. The software can run on any IBM-PC computer.

APPLICATION DEVELOPMENT

The system was established during regional planning in Louyang Economic Region, and it has provided useful information for the scientific management of territorial resources. It has also been used to compile an atlas of territorial resources. The system is designed for planning purposes, and includes several comparative models, eg population prediction, water resources, integrated energy development, location of cities and towns, and coal resources. The results from these models are available for regional planning applications.

CONCLUSIONS

It is possible to establish a regional/territorial resources information system on a microcomputer for each county in China, and to maintain an interface between the different systems to form a network. Such systems should satisfy the needs of territorial development planners, by making available a resources data base, an associated decision model, and a graphic display subsystem. It is important to maintain close contact with the users during the development phase, to ensure that the system is as user-friendly as possible.

GIS FOR INSTRUMENTAL DATA-BASED CLIMATE: SCENARIOS IN FLUVIAL SYSTEMS

R H G JONGMAN
Agricultural University, Dept of Physical Planning, Gen. Foulkesweg 13, 6703 BJ Wageningen, The Netherlands

INTRODUCTION

Future climatic change will result from the warming up of the atmosphere by increasing concentrations of trace gases (CO_2, N_2O, CH_4 and CFCs). This warming up will influence many aspects of human life and the persistence of ecosystems, not least by changing hydrological processes in fluvial systems.

Fluvial systems can be defined as the drainage basin characterised by hydrological phenomena (precipitation, evapotranspiration, and transport) and related ecological processes (biomass production, buffering, etc). Hydrological consequences of climate change are hard to estimate, because of the many feedback mechanisms involved in the hydrological system, each of which might react in different ways to the possible changes in temperature and precipitation. Hydrological changes may, on the one hand, have serious consequences for ecosystems, but, on the other hand, be minimised by certain ecosystems (eg bogs, lakes).

Human impact on fluvial systems is considerable in Europe. Rivers are used for shipping, drinking water, the discharge of industrial and agricultural wastewater, and for agricultural drainage and water supply. Man is always trying to prevent a shortage or surplus of water by altering the river system, but alteration will also occur in reaction to climate-induced hydrological changes. Fluvial ecosystems, therefore, will not only be influenced directly by climate-induced hydrological changes, but also by indirect changes, caused by man's reaction to those changes.

Changes in the fluvial system can be studied in different ways. Research can be done by studying historical changes in fluvial systems that are relatively well documented, as proposed by Wigley, Jones and Kelly (1986), by constructing instrumental data-based scenarios. Such research includes estimating the system's sensibility to possible changes and the likely effects.

Gleick (1986) proposed linking regional water balance models to general circulation models (GCMs). The advantages over other methods include greater accuracy, particularly if data are available in only limited form, less sensitivity to model calibration by the use of actual data, the availability of historical data (over 25 years), and compatibility with existing general circulation models. Effects can be measured directly by changes in variability and magnitude of runoff, and indirectly through the consequences for ecosystems.

However, measuring effects will not be easy because of the problems of 'noise' in real-world systems. Effects of small historical changes in ecosystems are hard to detect and interpret, because of the buffering capacity of ecosystems and possible groundwater availability. Partial effects on ecosystems might be assessed as possible changes because of the sensitivity of ecosystems and land use to changes in hydrological regime. In effect, it is nearly impossible to predict the real-world factors that may cause a sudden collapse of an ecosystem or fluvial system.

There are three kinds of research that resolve the above-mentioned problems:

- studying historical geomorphological processes in river systems;
- assessing the sensitivity of riverine ecosystems and land use to changes in hydrological regime in small-scale model basins that are already well documented;
- constructing regional data bases and linking them to hydrological models.

CLIMATIC MODELS

Several types of numerical climate models have been developed to estimate the impact of a CO_2 increase on the atmosphere, as part of the search for a better understanding of our future climate. A hierarchy of climatic models has been developed, ranging from simple zero-dimensional (O-D) energy balance models to more sophisticated 3-D general atmosphere and ocean-coupled circulation models (Eybergen & van Huis 1988):

- Energy balance models (O-D, 1-D, 2-D)
- Radiative/convective models (1-D)
- Statistical/dynamic models (2-D)
- General circulation models (3-D)

The general circulation models have been developed from numerical weather prediction models, which are based on computations of atmospheric winds (equation of motion), radiative transfer and heating (thermodynamic equation), water vapour (hydrological cycle), and cloud formation. More advanced models incorporate the ice albedo/temperature feedback and are linked to oceanic models.

Although there has recently been a rapid improvement in climatic modelling, such models still suffer from many deficiencies. Most GCMs have a low spatial resolution, insufficient recognition of the effects of orography, wrong seasonal cycles, and inadequate incorporation of detailed oceanic data and cloud feedback. The models perform poorly in tests with field data, and represent steady-state systems rather than dynamic ones (Wigley 1987).

In spite of all these problems, one thing is certain: climate will change and temperature will rise in the next century. The questions to be resolved concern the extent of the changes and their related effects. Linking regional data to such a general circulation model might provide some answers to these questions.

CLIMATIC CHANGE IN THE RHINE CATCHMENT

In all European countries, climatic change will lead to a rise in temperature, an increase in evapotranspiration, and an intensified hydrological cycle. These effects may cause an increase in precipitation over the whole year, or an increase during winter and a decrease in summer. The winter period will be shorter, and later, because of the warming of the earth in summer and autumn. Glaciers in the Alps will diminish and partly disappear.

The catchment of the River Rhine stretches from the Alps and the northern part of Bayern to the Netherlands. If climatic change in the whole of Europe follows the same direction, the effects will be increased in the discharge of this river; if there are differential effects, the consequences will be reduced (Jongman 1987). The effects on discharge are important, because of the many functions of this river. Its water is important for shipping, drinking water, waste disposal, agriculture and riverine ecosystems.

To explore climatic change and its possible effects on land and water use, two research strategies can be combined: improving the climatic model, and developing water balance models in relation to land and water use. For both strategies, a GIS might be useful.

USE OF A GEOGRAPHICAL INFORMATION SYSTEM

A GIS might be used to develop a climatic model. The Rhine catchment covers 185 000 km^2, and comprehensive data are available on temperature, precipitation, geomorphology and land use. It is, therefore, possible to construct a data base that contains detailed information, including both time series and spatial patterns. However, in the initial model, the GCMs are rather coarse. The signal-noise is influenced by man-made changes to the hydrological system, caused by draining, channelling watercourses, building water reserves, etc. The choice of the correct size of grid cell is determined by the underlying model, the character and the magnitude of the signal-noise relationship, and the precision of the available data. To provide a regional interpretation of the effects of climatic change, a high resolution is preferable, and, to avoid additional effort in collecting and analysing data, the size of the grid cell should be as large as possible.

The choice of data collection is determined by processes in the underlying model, the possibility of stratifying the research area, and the methods of data analysis to be used. It is better to use a stratified sampling method that fits the real landscape than to use either a random sampling technique that does not take all landscape ecological differentiation into account, or a sampling technique involving unnecessary effort.

The choice of data analysis is determined by the data that are used and the questions that need to be resolved to validate the underlying model. Canonical correspondence analysis (Ter Braak 1987) has been used successfully for palynological modelling of historical climatic change.

Some of the data used in the model are easy to determine, for instance geomorphology, which might be expected to remain stable in the next century. On the other hand, man's influence on a river system is hard to predict, and data related to such influence on land and water use are difficult to assess. Man's impact can be an important noise factor in the model, and, therefore, human activities should be integrated into the model. However, it will not be easy to provide reliable trends in land use for the next century.

REFERENCES

Eybergen, F.A. & van Huis, J.C. 1988. *Landscape-ecological impact of climatic change. Agricultural* University of Wageningen, University of Utrecht and University of Amsterdam.

Gleick, P.H. 1986. Methods for evaluating the regional hydrological impacts of global climatic changes. *J. Hydrology*, **88**, 97-116.

Jongman, R.H.G. 1987. *The Rhine-Maas megalopolis and its water-resources: consequences of climate induced hydrological changes.* European workshop on interrelated bioclimatic and landuse changes, Noordwijkerhout.

Ter Braak, C.J.F. 1987. Ordination. In: *Data analysis in community and landscape ecology*, edited by R.H.G. Jongman, C.J.F. Ter Braak & O.F.R. van Tongeren, 91-173.

Wigley, T.M.L., Jones, P.D. & Kelly, P.M. 1986. Empirical climate studies. Warm world scenarios and the detection of climatic change induced by adiatively active gases. In: *The greenhouse effect, climatic change and ecosystems.* edited by B. Bolin et al. (SCOPE 29.) Chichester: Wiley.

Wigley, T.M.L. 1987. Climate scenarios. In: *Climate Scenarios, European workshop on interrelated bioclimatic and landuse changes*, 10-23. Noordwijkerhout.

GIS-RELATED RESEARCH AT THE NERC UNIT FOR THEMATIC INFORMATION SYSTEMS

D C MASON and J R G TOWNSHEND
NERC Unit for Thematic Information Systems, Department of Geography, University of Reading, Whiteknights, PO Box 227, Reading, Berkshire RG6 2AB

INTRODUCTION

The role of the Natural Environment Research Council's Unit for Thematic Information Systems (NUTIS) is to carry out research into techniques of spatial data processing, to support investigations of the natural environment. As such, its research includes topics from digital cartography, geographic information systems, and remote sensing. Remotely sensed data, especially from satellite platforms, are available in increasingly diverse forms and have considerable potential to assist our understanding of the complex behaviour of natural systems. The extraction of information from such data is, however, often a difficult process, requiring much expertise and ingenuity in the development of algorithms. Many environmental data are alternatively provided as line maps or, increasingly, as digital representations of them. Their manipulation, storage and display also require a substantial research effort if their full potential is to be realised. The best use of such data is realised by integrating all these various forms in integrated geographic information systems. Even with the power of today's computers, the efficient processing of the many types of environmental data requires the development of new techniques.

This note outlines the various GIS-related projects either currently under way at NUTIS or recently completed. They cover a number of topics related to GIS, including spatial data structures, knowledge-based image segmentation, automated map cataloguing, colour display, and GIS modelling.

SPATIAL DATA ADDRESSING AND ARITHMETICS

Spatial data models lie at the core of GIS, and NUTIS has investigated various aspects within the context of integrated GIS. Integration of the two dominant data forms, raster and vector data, is generally achieved either by converting the vector data to raster and working with the combined raster data sets, or *vice versa*. An alternative which has received attention is the identification of a common intermediate data model suitable for holding both forms of spatial data in a compact form which allows efficient retrieval and processing. Hierarchical data models involving a regular recursive decomposition of the plane have been proposed.

In conjunction with collaborators at Liverpool and The Open Universities, NUTIS has been developing tesseral addressing and arithmetics, capable of allowing spatial operations (such as translation, rotation, etc) to be performed on hierarchical data structures (Bell *et al.* 1983; Diaz & Bell 1986). This study has also considered the various isohedral regular tessellations of the plane (in particular the square and hexagonal tessellations) from the viewpoint of the optimum processing of geographical spatial data, and ways of amalgamating the basic 'atomic' tiles into hierarchies of larger composite 'molecular' tiles. Tesseral addressing systems using bit-interleaved x and y addresses and covering the whole plane have been developed for a number of hierarchical data models, including the quadtree. Tesseral arithmetics have been developed associated with these addressing schemes, which enable spatial operations to be mapped directly into arithmetic operations on the tile addresses. Such operations on the tile addresses induce efficient transformations in the image, such as translation, rotation, and scaling. There is no need to convert the tesseral address to its x and y components prior to performing the transformation, and then to reconvert the result afterwards, as would be necessary using ordinary (linear) arithmetic. Tesseral addressing systems and arithmetics have also been developed for higher three- and four-dimensional spaces; in particular, the linear quadtree has been treated using the quaternions. New forms of hierarchical data model have also been discovered, in particular the hexagon or rhombus quadtree, in which four hexagons are amalgamated to form a first-level molecular tile.

HIERARCHICAL DATA MODELS WITHIN AN INTEGRATED GIS

The use of hierarchical data models within an integrated GIS (ie one designed to handle all data types in a consistent fashion) have also been investigated, in an implementation study running in parallel with the more theoretical tesserals project (Callen *et al.* 1986).

The particular hierarchical data model investigated so far has been the linear quadtree. System development has been aimed at producing a test bed for use in experiments on hierarchical data models, rather than the implementation of an integrated GIS based on quadtrees *per se*, and the work has concentrated on handling the spatial data themselves rather than their attributes. The system is implemented in 'C' on a VAX-8200 computer.

Several processing modules exist for handling raster data in region quadtree form. Region quadtrees may be generated from a raster image and *vice versa*. A quadtree display option illustrates the quadtree's power-of-two generalisation capability. The overlay of two images to produce a third image which is a logical function of them is also possible. A fast region quadtree dilation algorithm has been developed to allow buffering operations (Mason 1987). This algorithm requires two passes through the ordered leaf set, the second pass being in the opposite direction to the first. The two-pass algorithm has been compared to existing one-pass algorithms, and found to be faster. Other facilities include a connected component finder for region quadtrees. Region property computations include region area and perimeter.

Linear quadtrees are also used to hold vector data, though a different form of quadtree is necessary. The linear quadtree chosen is a modified form of the PM3 quadtree. The decomposition rule for the PM3 quadtree is that not more than one vertex may be present in a leaf, though an unlimited number of line segments not passing through that vertex are possible. Software exists to generate a PM3 quadtree from a vector map, and to display the result. It is also possible to overlay a PM3 quadtree with a binary region quadtree to produce a new PM3 quadtree for the vector data in the black areas of the region quadtree. Having similar data structures for raster and vector data facilitates operations which involve both data types.

KNOWLEDGE-BASED APPROACHES

There are opportunities for using artificial intelligence (AI) techniques in a number of the subsystems of a GIS. One area of GIS in which NUTIS is using AI techniques is data input, for image segmentation. Remotely sensed data are a major potential source of input to a GIS. One impediment, however, which detracts from their more widespread use in GIS is that they are often only relatively poorly classified prior to input, compared with the vector data with which they often need to be combined in GIS analyses. Current automatic classification of remotely sensed data is generally based upon independent classification of individual pixels on the basis of their spectral signatures, using a per-pixel classifier. A basic difficulty with this approach is that it attempts simply to associate a class label with each pixel. It fails to incorporate the concept of an object into the processing, and thus to exploit knowledge of the various properties of the object, such as size, shape, texture and relationships with other objects. This is the type of information which would be used by a human interpreter.

However, much of this knowledge may already be contained within the data sets resident within a GIS. Therefore, the possibility exists of using data within the GIS as input to the remote sensing classification process, in order to improve classification accuracy. This is the main objective of an Alvey Information Technology project, which has developed a system for the knowledge-based segmentation and interpretation of remotely sensed terrain images (Tailor *et al.* 1988; Mason *et al.* 1988). NUTIS has collaborated in this project with Systems Designers Scientific, the University of Sussex, and the Institute of Terrestrial Ecology.

The system is characterised by a number of features. One basic feature is its exploitation of other data sets, such as digital maps and previous classifications. Classification errors for the two test sites are 8-9%, while the per-pixel classification errors are 24-29%, so the reduction is about a factor of three.

AUTOMATED MAP CATALOGUING

Another area of development is that of automated map cataloguing. NUTIS is involved through the NERC marine atlas project (Ramster *et al.* 1987), which aims to produce an electronic graphical catalogue of digital marine data covering the seas around the British Isles. The digital data include those held by NERC and related organisations, and the atlas is seen as a mechanism for advertising the digital data sets held by these organisations. The catalogue will comprise summary maps of each data set, together with ancillary diagrams, descriptive text, and index information.

Users will include the general public, commerce, and Government departments, and access will be indirect, via two types of output product. The first type will include a series of digitally produced high-quality atlases ranging from those of general interest to more specialised editions, and catalogue listings. The second type will be medium-quality digital atlas products for display on personal computers.

The design study for this project has begun with the digitisation of the latest edition of the MAFF *Atlas of the seas around the British Isles*. This test set is being used to investigate the technical aspects of producing a demonstrator system.

DEVELOPMENTS IN COLOUR DISPLAY

Another important area of development is GIS output. An easy-to-use tool for selecting colours for classified remotely sensed images and maps displayed on VDUs has been developed at NUTIS. This tool, known as CANVAS, has been implemented on an I^2S image processing system (Gill & Trigg 1988).

Major difficulties are often encountered in interpreting classified imagery because of an inappropriate use of colours. They are often not clearly distinguishable or are poorly suited to the information they are intended to convey. Whilst many users of image processing systems are doubtless aware of these problems, difficulties are often experienced in selecting appropriate colours on VDUs, partly because of the awkwardness for most users of using R, G, B values for colour specification. One of the reasons is that the RGB system does not constitute an 'information' space, in that its dimensions have no intuitive significance to the interpreter. Instead, the CANVAS system employs a uniform colour space in which Euclidean distances reflect as closely as possible the colour-discriminating ability of the eye. The co-ordinates in this space are obtained from RGB values using several mathematical transformations, which involve knowledge of the display device, including its gamma corrections, and the chromaticity co-ordinates of the red, green, and blue phosphors used.

The dual aim of CANVAS is to help users in the interactive selection of particular colours for particular classes, and automatically to choose maximally distinct colours for any remaining classes. In a classified image,there may be a number of classes for which a specific colour is meaningful or conventional. These can be selected interactively from a range of colour palettes which may be displayed to the user. The colour palettes are obtained by taking 2-D slices at regular intervals through the colour space, along planes of uniform brightness. Colours for any classes which remain uncoloured after the interactive stage may be selected automatically. Each successive colour is chosen by searching through the quantised colour samples for the colour with the largest minimum distance in colour space from every previously chosen colour.

This procedure minimises the risk of misinterpretation because of similarly coloured classes.

GIS MODELLING

A growing trend in GIS is the movement away from its use for simple map overlay to more complex spatial analyses. Two NUTIS projects fall into this category.

i. Use of a digital elevation model for interpretingsatellite imagerv

The first example is the use of a digital elevation model (DEM) for topographic correction and classification of SPOT HRV data in the ecological mapping of upland areas (Jones, Settle & Wyatt 1988). This work was carried out as part of the SPOT PEPS evaluation programme by ITE staff and NUTIS. A DEM was generated from 1:25 000 map contours for a 10 km x 10 km study area in the Coed-y-Brenin forest of southern Snowdonia, north Wales. Data from the model were used to generate slope and aspect images in co-registration with the satellite image, and models were developed to describe the effects of changes in radiance due to topography using the slope and aspect data. An improved classification accuracy was achieved, compared with that obtained using uncorrected radiances.

These two data sets have also been used to produce perspective views, by 'draping' the SPOT data over the co-registered DEM, and viewing from a particular direction. The multispectral imagery often contains information more representative of the human's visual perception of the ground surface, and therefore has great potential for modelling topography in applications such as landscape assessment and land use planning.

ii. Volcanic hazard zone mapping by computer

The second example of GIS modelling concerns the evaluation of hazards from volcanoes (Wadge & Isaacs 1988). Government authorities in regions likely to be affected by future eruptions of active volcanoes are increasingly aware of the need for accurate assessments of the potential hazards which their communities face. These assessments are usually presented in zone maps of different types and degrees of hazard. This project's goal was to prepare such an assessment for the Soufriere Hills Volcano on Montserrat in the West Indies. In the event of an eruption (there have been none in historical times), the island's capital, Plymouth, which is only 5 km from the volcano's summit, would be under threat.

The modelling process involves producing computer simulations of eruption models on an image processor. The basic empirical data set used is a digital elevation model of the island. Algorithms simulate the collapse of eruption columns on to the digital topography, producing ground-hugging gravity flows that settle as pyroclastic flow deposits. The eruption model parameters are vent position, height of collapsing eruption column, and the angle that the collapse makes with the horizontal. The validity of the deposit model can be tested by comparing it to deposits of earlier radiocarbon-dated eruptions mapped in the field. Valid models can then be superimposed on cultural information - houses, roads, bridges, and utilities - to show those zones at risk. The value of this type of map lies in short-term planning of evacuation priorities and routes. The hazard maps produced in this study have been supplied to the Montserrat Government and the Pan-Caribbean Disaster Preparedness and Prevention Project.

REFERENCES

Bell, S.B.M., Diaz, B.M., Holroyd, F.C. &Jackson, M.J. 1983. Spatially referenced methods of processing raster and vector data. *Image and Vision Computing*, **1**, 4, 211-220.

Callen, M., James, I., Mason, D.C. & Quarmby, N.A. 1986.
A test-bed for experiments on hierarchical data models in integrated geographic information systems. *Proceedings of 2nd Tesseral Workshop, Reading*, 193-212.

Corr, D.G., Tailor, A.M., Cross, A., Hogg, D.C., Lawrence, D.H., Mason, D.C. & Petrou, M. 1989. Progress in automatic analysis of multitemporal remotely sensed data. *Int. J. Remote Sensing*,**10**, 1175-1195.

Diaz, B.M. & Bell, S.B.M., eds. 1986. Spatial data processing using tesseral methods. (Copies available from NUTIS at £25.00 each.)

Gill, G.A. &Trigg, A.D. 1988. An intelligent system for colour selection on CRT displays. *Int. J. Remote Sensing.*, **9**, 1423-1432.

Jones, A.R., Settle, J.J. & Wyatt, B.K. 1988. Use of digital terrain data in the interpretation of SPOT-1 HRV multispectral imagery. *Int. J. Remote Sensing.*, **9**, 669-692.

Mason, D.C. 1987. Dilation algorithm for a linear quadtree. *Image and Vision Computing*,**5**, 1, 11-20.

Mason, D.C., Corr, D.G., Cross, A., Hogg, D.C., Lawrence, D.H., Petrou, M. & Tailor, A.M. 1988. The use of digital map data in the segmentation and classification of remotely sensed images. *Int. J. Geographical Information Systems.*

Ramster, J., Robinson, G.J. & Fannin, N. 1987. Presenting oceanographic data spatially: dilemma or opportunity? In: *Ocean 87: The Ocean - An International Workplace*, Vol. *II*, 720-723.

Wadge, G. & Isaacs, M.I. 1988. Mapping the volcanic hazards from Soufriere Hills Volcano, Montserrat, West Indies using an image processor. *J. Geological Society of London*, **145**, 541-551.

INTERFACING SYSTEM DYNAMIC MODELS WITH GIS

I MOFFAT
Department of Environmental Science, University of Stirling, Stirling FK9 4LA

For the past year, the Scottish Environmental Modelling Research Unit has been developing a series of dynamic models for exploring sustainable development options in national and regional planning. The term 'sustainable development' implies that both ecological and economic components are interconnected within the one model. The ecological components of these models consist of various land use classes, whilst the economic indicators permit evaluation of different scenarios of resource use. To date, this research has developed several dynamic models for exploring medium- to long-term scenarios of sustainable development in countries such as Kenya and China, as well as a pilot study of regional development in Scotland.

As a result of a series of workshops held in 1987, the Unit is currently disaggregating one of their models to give a coarse spatial representation of land use classes in the River Forth valley. The model consists of five land use zones, namely forests, upland agriculture, lowland farming, urban/industrial use, and the Forth estuary. Each of the major land use classes is subdivided into a series of three-dimensional blocks representing land uses, including vegetation, underlying topography, and economic activities such as housing. Within each of these dimensional blocks, flows of water, nutrients and energy use are represented to trace causal processes acting within the system. Current research includes the collation of various data sets for calibrating and independently verifying the model.

It is clear that the coarse approach to spatial disaggregation used in the Scottish pilot study could be improved by integration with a GIS. Several problems, however, need to be resolved. First, in order to keep the model mathematically tractable, the pilot study is examining only several three-dimensional blocks per land use class. This problem concerning the size of the matrix for the simulation can be resolved by using matrix algebra in an advanced simulation language. Second, given the block-like nature of the dynamic model, it is clear that a raster approach to GIS can be used, but the problem of interfacing the dynamic causal model with a GIS has yet to be resolved. It is hoped that co-operation with Dr D A Davidson using the Laserscan system at the Department of Environmental Science at the University of Stirling will resolve this technical problem. Third, the problem remains of implementing this approach for use by enlightened people in economic and ecological planning.

HYDROLOGICAL APPLICATIONS OF GIS

R MOORE, D MORRIS and N BONVOISIN
Institute of Hydrology, Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

Maps are a prime source of data in hydrological studies, yet until recently it has only been possible to extract a tiny fraction of the potential information they contain. Consequently, although great progress has been made in the analysis of time series data, the spatial dimension of hydrological problems is still treated in an extremely simplistic way. However, this situation is being transformed by the ability to convert maps to digital form.

The major objectives of digital cartography are two-fold: (i) to allow the user to produce maps showing only the area and detail required at a scale and in a style appropriate to a particular application, and (ii) to allow the numerical analysis of all the information within the map, whether it be shown implicitly or explicitly. Digital cartography has the potential to improve dramatically not only the way in which design procedures are made available, but also the techniques they involve. An objective approach to data capturing overcomes the problem of the subjectivity of users extracting information manually from identical maps. Central to many of the proposed changes is the availability of a UK-wide digital terrain model (DTM), a 50 m x 50 m grid of heights over the entire land surface. For the first time, there will be access to a complete three-dimensional description of the land surface in a form amenable to analysis. An initial application of boundary will then provide the basis for extracting other data types in digital form, such as soil, rainfall and lakes. In the future, a computer graphics package may well replace the written manual and printed maps in the design engineer's office.

Digital data offer far more than automation of existing procedures. Implicit in the digital terrain data, for example, is information on the slope, and hence drainage direction, at all points on the ground. Access to this information should allow new catchment characteristics to be developed. In particular, detailed slope, aspect and elevation data can be used to improve the estimation of snow melt rates. The analysis of climate, land use, soil, terrain and river network should identify areas most at risk from acid rain. The combination of water quality data, flow data and the digitised river network makes possible the automatic production of river maps - both exisiting types such as those of the river quality survey and new types. The digitised river is also the key to data base access systems that require data to be sorted in order along a watercourse.

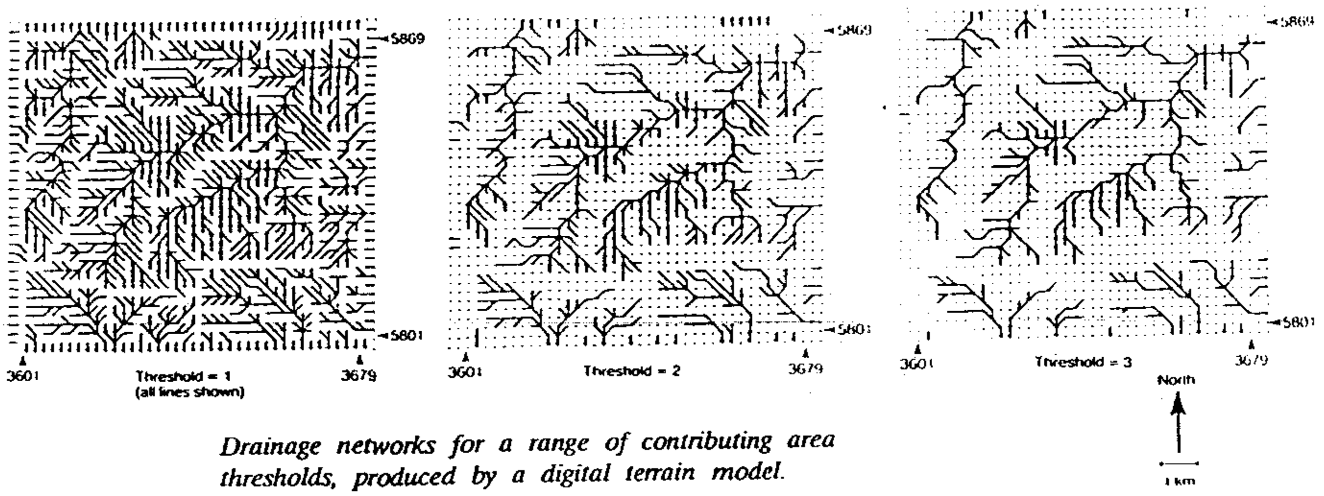
To focus work in this highly exciting field, a new project has been created out of the current river network digitising project and from aspects of work on floods and low flows.

In co-operation with the water authorities, the river networks of seven of the ten authorities have been digitised from the Ordnance Survey 1:50 000 series maps, and work in other areas, including southern Scotland, is planned. The data record not only the position of the lakes and rivers, but also their interconnections and flow direction. A wide range of spatial data, including all the Flood Studies Report maps, climatic variables and terrain, is also being captured or acquired.

Exploitation of spatial data is critically dependent on the way in which they are stored. The data volumes are vast, and data bases require good indexing systems to achieve the very fast access times necessary. A range of data base designs have been explored, and work is about to start on a purpose-written system to handle both vector (line) and raster (gridded) data. The maintenance of digital data requires a variety of tools for detecting errors, editing, and basic manipulations. Work to date has been dominated by the problems of data collection, but attention is now turning to applications. Digital techniques have been used for some time in the European Flood Studies Report to estimate catchment characteristics. This work has been taken a step further in a project for the Department of the Environment for Northern Ireland, where mean and low flow (discharge exceeded for 95% of the time) values are being computed at some 10 000 points on the river network and digitised contour data. The Institute of Hydrology is structuring the river network and generating a ten million point digital terrain model. Additionally, rainfall and sand and gravel map data are being digitised. One objective is to demonstrate the integration of all the different new techniques. The points for which flows are to be computed are determined by the digitised river network. For each reach, the catchment is computed from the DTM and then superimposed on the rainfall and sand and gravel data. Evaporation is assumed to be a function of height. Whenever a gauging station is passed, estimated and observed flows are compared and a correction function is applied. The practical application of the results lies in the production of river quality and fish maps, and in determining consent conditions for effluent discharges.

In another application, where terrain data are not available, the relationship between low flows and lengths of river across various classes of soil in the catchment is being explored.

A Hydrologically Appropriate Geographical Information System (HAGIS) is being developed to integrate the work into a versatile system. HAGIS will comprise a number of components. At its core will be a vector/raster data base which also provides for time series data. Around this core, a variety of systems will be developed for the capture and analysis of data. Although initially developed for hydrological applications, the system could be extended to any environmental problem involving space and time dimensions.



Drainage networks for a range of contributing area thresholds, produced by a digital terrain model.

Figure 1

LANDSCAPE ECOLOGY OF AREAS OF OUTSTANDING NATURAL BEAUTY AND ENVIRONMENTALLY SENSITIVE AREAS IN NORTHERN IRELAND

R MURRAY
Department of Environmental Studies, University of Ulster at Coleraine, Cromore Road, Coleraine, Co Londonderry BT52 1SA, Northern Ireland

Following the implementation of the Nature Conservation and Amenity Lands (Northern Ireland) Order (1985), one of the main objectives of the Department of the Environment for Northern Ireland (DoE) has been to redesignate existing Areas of Outstanding Natural Beauty (AONB). At the same time, the Department of Agriculture has been considering farmed land suitable for designation as Environmentally Sensitive Areas (ESA).

The Mourne AONB was redesignated in December 1986, and the Mourne ESA is currently in the process of designation. The ESA has the same boundaries as the AONB, but excludes unenclosed upland. The Causeway Coast AONB and the Antrim Coast and Glens AONB, both in County Antrim, are in the latter stages of consultation, whilst the Sperrins AONB and the North Derry AONB are about to be reviewed.

Alan Cooper and myself at the University of Ulster have been, and are currently, undertaking landscape ecological studies of these areas, funded by the Countryside and Wildlife Branch of the DoE (NI).

The main aims of the studies are:

i. development of an objective methodology for assessing areas for AONB status;
ii. quantification of land use, ecological resources and boundary types, together with information related to management and structure;
iii. identification of environmental problems and prescription of management options;
iv. preparation of a computerised data base for monitoring environmental change.

A multivariate land classification for Northern Ireland has been constructed using the numerical classification technique TWINSPAN (Hill 1979), based on attributes such as climate, physical environment, physiography, settlement patterns, soils and geology. Kilometre grid squares are grouped into 23 land classes to provide a framework for comparing regional differences and further study, using a technique originally developed at ITE's Merlewood Research Station by Bunce, Barr and Whittaker (1983).

Field surveys of the Mourne and Antrim AONBs have been completed. Sample kilometre grid squares were selected for combined Northern Ireland land classes, and a random quarter was identified within each kilometre square. The extent and nature of ecological resources, land use, boundaries and other landscape attributes were recorded on standard field data sheets in a format suitable for transfer to the data base system dBASE III PLUS (Ashton-Tate 1985). The locations were recorded on an enlarged

1:10 000 map of the 25 ha square as a permanent archive for future monitoring.

The distribution of parcels of land or boundaries with specified characteristics can be recalled from the data base, together with raw abundance data for specified areas or land classes. The data have been analysed and tables produced using the spreadsheet programme LOTUS 1-2-3 (Lotus Development Corporation 1985). Raw data for each cell of the spreadsheet were converted to required values by a formula in the cell. The program has the facility for adding labels and headings, thus producing instant tables. Both dBASE III PLUS and LOTUS 1-2-3 programs are menu-driven, easy to use, and can be learned in a minimal amount of time.

A similar study is under way in The Sperrins and North Derry. Because of the region's size and its diffuse nature, the use of land classification has been extended to subdivide the area into smaller units. Boundaries were drawn on the basis of similar land class composition, specified juxtapositions of land classes and landform discontinuities. Following a pilot field survey of specified landscape criteria carried out during the winter, these units were modified by the DoE (NI) using administrative and local criteria, and then assessed for potential AONB status. Units of obvious low landscape quality, mainly comprising agricultural grassland, have been excluded at this stage from further consideration and full field survey.

The study areas in Northern Ireland generally show a transition from low-elevation land classes comprising improved grassland and semi-natural coastal vegetation, through to less productive grassland at higher elevation, and heath/bog vegetation at high altitude. General dereliction is a major problem, whether it be ruined buildings, abandoned vehicles, rubbish dumping, deterioration of heath, invasion by gorse or bracken, or non-functional boundaries. Boundary dereliction is a common problem. Hedges are not generally stockproof, unless accompanied by a post and wire fence; complete hedges account for less than 10% of hedge length. Dry stone walls have suffered a similar fate, although in some localities they are a managed feature and generally intact.

Semi-natural deciduous woodland is poorly represented (<5% cover), although the landscape often has a wooded appearance due to the structure of overgrown hedges. Coniferous plantations, often poorly landscaped monocultures, are a feature of the uplands and comprise up to 20% cover in some locations.

The Mourne AONB has particular problems related to its function as a prime tourist location. There is a major land use conflict in the Antrim Coast and Glens AONB between the conservation of attractive blanket and upland raised bog or the use of peat as a fuel resource. Gold deposits have recently been found in The Sperrins and a pilot mining operation is currently in operation. County Tyrone could be the new Klondyke.

REFERENCES

Ashton Tate. 1985. *dBASE III PLUS.*

Bunce, R.G.H., Barr, C.J. & Whittaker, H. 1983. A stratification system for ecological sampling. In: *Ecological mapping from ground, air and space*, edited by R.M. Fuller. Abbots Ripton: Institute of Terrestrial Ecology.

Cooper, A. 1986. *The Northern Ireland land classification.* Report to the Countryside and Wildlife Branch, DoE (NI). Coleraine: University of Ulster.

Cooper, A. & Murray, R. 1987. *A landscape ecological study of the Mourne AONB.* Report to the Countryside and Wildlife Branch, DoE (NI). Coleraine: University of Ulster.

Cooper, A. & Murray, R. 1987. *A landscape ecological study of the Antrim Coast & Glens and Causeway Coast Areas of Outstanding Natural Beauty.* Report to the Countryside and Wildlife Branch, DoE (NI). Coleraine: University of Ulster.

Cooper, A. & Murray, R. 1988. The management of semi-natural vegetation in an Environmentally Sensitive Area. In: *The pactice of weed control and vegetation management in forestry, amenity and conservation areas.* Aspects of Applied Biology 16.

Hill, M. O. 1979 *TWINSPAN.* New York: Cornell University.

Lotus Development Corporation. 1985. Lotus 1-2-3.

SMALL STEPS TOWARDS A GIS FOR THE SNOWDONIA NATIONAL PARK

P A OGDEN
Swyddfa'r Parc Cenedlaethol, Gwynedd County Council, National Park Office, Penrhyndeudraeth, Gwynedd LL48 6LS

The Snowdonia National Park Authority has a statutory responsibility not only to conserve and enhance the natural beauty of the National Park area, but also to promote public enjoyment of the area. As part of its statutory function, the Park Authority is obliged to prepare and periodically review a policy blueprint for the Park's future planning and management: the *National Park plan*.

In order for policy decisions to be made about land use, conservation, social and recreation issues, it is important that varying data sets, often chronologically based, are maintained and compared. Most of this information has traditionally been stored on maps, but such systems tend to be clumsy to cross-relate and difficult to update. The development of GIS within the National Park would, therefore, have numerous advantages over traditional methods of data storage.

It was with this long-term objective in mind that the Snowdonia National Park Authority (SNPA) embarked upon a small experimental project with the University College of North Wales (UCNW), to explore the possibilities of developing a small raster-based data storage and retrieval system which would improve data handling. The project focused on a small, 10 km x 5 km, area north-west of Dolgellau, encompassing varied landscapes, with coniferous forest merging into traditional hill farming upland. A prerequisite of the experiment was to establish the feasibility and practicality of transposing this methodology to the whole of the Park area, a total of 2175 km^2.

Of particular importance was the desire to establish whether it was possible to use inexpensive desk-top microcomputers to store and manipulate the data, and to develop a programming system which enabled individuals with little or no computing skills not only to use the system confidently, but to amend it in order to keep the information up-to-date. This requirement was seen as being particularly crucial as the individuals most likely to use the systems had little experience or training in computing, apart from word-processing skills.

The data base would ultimately be held on an IBM-compatible Victor VPC 2E hard-disk microcomputer, using dBASEII as the data storage system (at the time of the project dBASE III was not widely available).

The development of a vector-based system was impractical, as no digitising facilities or sophisticated plotting equipment were available or likely to be made available within the Snowdonia National Park Authority offices.

Whilst there were, therefore, limitations on the systems available, there was a clear understanding of why the data base was needed. A system which provided a means of accessing up-to-date information was important, if informed decisions about land use matters in the National Park were to be made.

APPLICATIONS OF AN INTEGRATED INFORMATION SYSTEM WITHIN THE NATIONAL PARK

Three levels of value of a GIS can be recognised: *quantitative, correlative,* and *predictive,* each of which either individually or in combination is important in the decision-making process of resource management in Snowdonia. Although not exhaustive, the following examples describe the ways in which such an information system could be utilised by the Park Authority.

Quantitative value

As a basis for the physical description of Snowdonia at any particular point in time, in terms of the quantity and quality of the Park's natural resources.

Example

To establish or confirm the location and condition of various types of semi-natural or man-made habitats, eg heather moorland, broadleaved woodlands, wetlands or forest.

Application

i. To assist in the Park's statutory responsibility to determine those areas of the Park which are particularly important to conserve.
ii. To determine priorities for management initiatives or action by the Park Authority to conserve the landscape, thereby influencing the preparation of the Park's annual functional strategy/budgetary programme.

Correlative value

i. To monitor and quantify causal relationships brought about naturally or by human influence.
ii. To assess the effects of national land use policy and grant systems as they affect the environment of Snowdonia.

Examples

i. To monitor management activities aimed at improving the quality of such habitats as moorlands or broadleaved woods.
ii. To assess the effects of a different grazing regime on the ecology of upland acidic grasslands.
iii. To establish the effect of increased recreational use of the natural resources of the area, eg by monitoring erosion of the landscape.

Application

i. To review the success of policy decision and specific management initiatives.
ii. To influence and encourage the types of management practices and/or activities

most sympathetic to the environment as a whole or to parts of the National Park.

Predictive value

To assess the possible effect or implications of altering or manipulating a series of physical variables on the landscape of the Park.

Examples

i. To assess those areas of Snowdonia with potential for differing land uses, eg forestry, improved agricultural pasture, water supply, etc.
ii. To illustrate and quantify the displacement effect of such land use change.
iii. To predict those natural habitats most susceptible to change as a result of natural encroachment or reversion, eg from bracken or rhododendron invasion.

Application

i. To extend the appreciation of land use options in formulating policy decision concerning resource management.
ii. To assess priorities for habitat conservation or site management action. An important generalised advantage of a comprehensive GIS is its value in developing a multidisciplinary approach toward resource planning and, in particular, the optimum use of the limited financial resources available for positive management.

THE PILOT PROJECT

The experimental project considered an area of 50 km^2, ie 4% of the surface area of the Park. Because of the need for a localised level of detail, it was decided to make the unit area 0.5 km^2. If a more generalised overview of the area was needed, it was considered that this detailed information could be reaggregated.

Because of the limitations of dBASE II, only 32 fields were available. Therefore, a series of 'compound' fields were necessary to accommodate the 120 individual attributes to be recorded for each 0.5 km^2 In some cases, up to 17 different variables had to be accommodated within one field.

Information was collected and stored either as a percentage area or a linear measurement, thus allowing summations. Both physical resource information, eg soils, vegetation cover, lengths of footpaths, etc, and 'synthetic' information, ie the existence of a designation, eg SSSI, LFA, Conservation Area Status, etc, were included.

The limitations and inexperience of using dBASE II certainly proved a problem in assembling the data base and creating adequate interrogation programs. To overcome this deficiency, secondary computing advice and skills were needed from the Computing Department of the University College of North Wales.

EXAMPLE OF A STRUCTURED DATA BASE

Structure for file: A:SNOWCOED.DBF Number of records: 00200
Date of last update: 02/01/80
Primary use database

Fld	Name	Type	Width	Dec
001	GRIDREF	C	012	
002	SLOPE	C	009	
003	SOILS	C	054	
004	WATERWAYS	C	020	
005	WATERBODY	N	003	
006	ROADS	C	020	
007	RAILWAYS	C	020	
008	BOUNDARIES	C	020	
009	SHELTBELTS	C	020	
010	DRAINAGE	C	020	
011	FOOTPATHS	C	020	
012	POWERLINES	N	004	
013	PIPELINES	N	004	
014	DUMPS	N	003	
015	LANDCOVER	C	054	
016	LANDSURVEY	C	060	
017	NATPARK	N	003	
018	RESERVES	C	020	
019	SSSI	N	003	
020	MOORLAND	C	012	
021	COMMONLAND	C	012	
022	AGREEMENTS	C	030	
023	ORDERS	C	065	
024	GRANTS	C	050	
025	PROPOSALS	C	030	
026	PLANS	C	025	
027	STATUS	C	040	
028	DESIGNATON	C	050	
029	TOURISM	C	016	
030	HILLUPLAND	C	048	
031	OWNERSHIP	C	050	
032	MANAGEMENT	C	050	
Total			00848	

LESSONS LEARNT

1. In compiling the data base, the 200 records required over 170 000 bytes of storage. Immediate problems would inevitably be encountered in transposing this system to a microcomputer-based data base covering the whole Park, as this would require 7.4 million bytes of storage., which is well beyond the storage capacity of the microcomputer. Given that a time series of data bases is needed to monitor change, the present system is totally inadequate.

2. The time involved in collecting data should not be underestimated. To compile the data base for 50 km^2 took approximately 28 man-days; to compile the same level of detail for the whole Park would take 3.5 man-years! Outside academic circles, this represents a major financial commitment simply to set up the system, let alone keep the information up-to-date and backed up.

3. The data base is only as good as the information supplied to it. Many practical problems of accuracy occur when information is being logged from map data which vary in original scale from 1:2500 to 1:200 000!

4. DBASE II microsystems with no ancillary hardware have certain limitations as a basis for a low-cost GIS, principally relating to:

- the limitations of using the screen/printer as the only means of visual presentation of information;
- limited graphics facilities;
- a rather slow processing system.

For future development, it is obvious that there must be a commitment to a large system if this work is to proceed. This commitment will, in itself, require a long-term financial investment, not only in hardware but also in labour. Clearly, such investment is not easy at a time when local authorities are under severe financial constraint.

CONCLUSIONS

The project undertaken drew together the skills of the academics and practitioners on a small scale. From that point of view, such collaboration proved to be an effective means whereby each party benefitted from each other's experiences and knowledge. It also highlighted the underlining dependence of each party on the other in producing this small-scale GIS.

Whether a GIS based on present microcomputers and dBASE II is the most effective way of satisfying the SNPA's long-term requirements is debatable. Clearly, it has a role to play as a low-cost data storage system for certain requirements, but its limitations are likely prove its Achilles' heel, if a GIS is to be realised for the whole of the Park.

It is, therefore, with a spirit of optimism and in the light of this experience that the SNPA will be seeking to establish greater collaborative links with UCNW, or others in the academic world who may be able to fill the hardware gap. Such collaboration is clearly essential if the SNPA is to produce a GIS to assist all aspects of long-term decision-making processes within the Snowdonia National Park.

MICROMAPPER: AN END-USER'S VIEW OF A SIMPLE GIS FOR DETAILED LAND USE STUDIES OF A SMALL AREA

D P O'NEILL

Coach House, Torrance, Strathaven Road, East Kilbride G75 0QZ

Considerable time and effort is currently being spent on collecting and recording data in site survey and monitoring schemes by the many professional and voluntary bodies working in the environmental field. This statement is particularly true for sites such as country parks, where staff are involved in these procedures as part of their normal duties.

The usefulness of this type of activity is sometimes questioned, partly because of the difficulties in handling and retrieving the amassed information. For example, if the data are recorded and presented in conventional map form, then the use of overlays can become clumsy and incomprehensible where multivariables are involved. The end result is that full use is not made of the factual information, and management decisions are made on a subjective basis.

With data handling by computer being widely publicised and used successfully in other fields, there is a recognised need for a system to accommodate the problem of handling data for detailed studies of small-area sites.

In a paper presented at the conference on *Rural information for forward planning*, organised by ITE in September 1985, Davidson and Jones described a Land Resource Information System (LRIS), which was a GIS running on the University of Strathclyde's DEC VAX mainframe computer. The system had obvious potential for land managers. However, the drawbacks were the levels of skill required to input and extract data, and the costs and restrictions necessarily imposed by the requirement for access to a mainframe computer. These restrictions resulted in the LRIS package being underutilised in practical applications.

G E Jones and colleagues in the Department of Geography at the University of Strathclyde, therefore, decided to design a user-friendly GIS for use on commonly available, low-cost microcomputers. The package was named 'Micromapper', and the first version ran on an Amstrad CPC6128 with output to a DMP2000 dot matrix printer. Calderglen Country Park was used as a test site, and the outputs were an integral part of the Country Park Management Plan. Further modifications were introduced to make the package more versatile and easy to use by those who were not otherwise computer-literate. A version is now available for IBM-PC compatibles and was demonstrated at the conference.

MICROMAPPER - TECHNICAL DETAILS

Micromapper is a user-friendly, menu-driven program, used for the construction of computer-held data bases. It is particularly suitable for land use management studies, enabling a wide range of physical and biological records to be conveniently stored and analysed.

The data base is of 'raster' format and uses a grid mesh of a size determined by the user. The maximum extent of the grid on the PC version is 100 x 320 cells, although several grids can be physically joined for large geographical areas.

Data values can be obtained from field survey, maps, air photos, laboratory data, questionnaires, or other computer data base packages. Three types of data can be entered: numerical, category, and presence/absence values, using 12 standard data files. These files have been preprogrammed for all the typical environmental variables, such as land use change, soil types, aspect, etc. For non- standard data, the user can easily prepare customised data files. The only limit to the number of files in use is the available disk storage space.

When the data base is completed, it is a simple operation to produce computer-drawn maps for a wide range of user-specified variables. Up to three data files can be used at one time, with up to 30 variable category combinations. Output is obtained in the form of symbol maps produced on an Epson-compatible dot-matrix printer. A total of 37 different map symbols and a graded set of ten shading symbols can be specified. Micromapper also calculates the frequency values of the variable combinations and prints these alongside the key. Data from Micromapper can be used in commercially available graphics packages.

The aim of the Micromapper project was to provide an affordable GIS for use on microcomputer hardware at the lower end of the market, so that managers of country parks and other sites could have their own complete system. From the interest generated so far, it would seem that Micromapper is fulfilling this objective. However, Micromapper has also been shown to be of use in training undergraduates in the principles of GIS. It is currently being used for this purpose at the University of Strathclyde, Liverpool Polytechnic, and the Agricultural University of Norway.

Further information on Micromapper may be obtained from Dr G E Jones, CLMS, Department of Geography, University of Strathclyde, Livingstone Tower, Richmond Street, Glasgow Gl lXH. Tel: 041 552 4400, ext 3794.

MONITORING ENVIRONMENTAL AND SOCIO-ECONOMIC CHANGE IN AN ENVIRONMENTALLY SENSITIVE AREA

T PERKINS
East of Scotland College of Agriculture, Glenbourne, 56 South Oswald Road, Edinburgh EH9 2HH

The East of Scotland College of Agriculture has set up a project to develop and evaluate techniques for monitoring environmental and socio-economic change in Environmentally Sensitive Areas (ESAs), and in particular Breadalbane. The project attempts to use a variety of monitoring techniques, co-ordinated through the use of a GIS, to record, analyse and predict the changes likely to take place as a result of evolving Government policy. It is important to note that the project is not trying to determine whether the scheme is 'good' or 'bad' in environmental terms. To avoid the difficulties of trying to compare and analyse subjective responses, the project is limited to studying the different techniques of monitoring and predicting change, and whether such techniques are able to record what is likely to be very small-scale change.

The project is in its initial stages and progress has therefore been limited. However, as a first step, we are looking at the available monitoring techniques, including conventional aerial photographs, multispectral photography, thermal infra-red imagery, side-looking airborne radar, satellite imagery, aerial video, as well as more traditional field surveys, data bases, paper maps, etc. The ability to record small-scale change is being monitored and analysed.

A Geographical Information System will be used to co-ordinate the different data sets. It is hoped to use the ARC/INFO system at the University of Edinburgh to digitise an initial set of relevant features, including contours, fluvial features, land use, farm boundaries, archaeological remains, infrastructure, etc. Rather than merely recording existing features, we hope to create models which can predict areas liable to experience environmental change, and the nature and extent of that change.

The project is based, in the first instance, in Breadalbane. However, it is expected that, as the project continues, the knowledge gained of the techniques of GIS and computer modelling will be applied to other agricultural and land use projects. There is likely to be considerable land use change as the Common Agriculture Policy structures are modified, and the College believes it is important to be able to predict where these changes will take place and their effects on the landscape.

Therefore, the project involves the use of GIS for broad geographical monitoring purposes, rather than solely for ecological reasons.

THE APPLICATION OF GIS IN MONITORING LANDSCAPE CHANGE IN NATIONAL PARKS

R J ROBERTS
Countryside Commission, Policy Division, John Dower House, Cheltenham, Gloucestershire GL30 3RA

A current project, jointly sponsored by the Countryside Commission and the National Parks Authority, is being carried out by Silsoe College, Cranfield Institute of Technology, to monitor landscape change between the mid-1970s and the present day in the National Parks and Broads Authority areas. The project aims to carry out a mapped and statistical census of the occurrence of, change in, and change between a range of land cover classes at two dates, for each National Park, and for the Parks as a whole, using aerial photography as the main source of information, but also making extensive supplementary use of satellite imagery (Landsat TM and SPOT). Raster-based GIS are being used to manage and manipulate the raw data, and to produce the final analyses.

The project will be an interesting test of the practical usefulness of GIS for data management and presentation under the time and cost constraints of an 'output' rather than a research project, with a wide range of client requirements.

With the Department of the Environment, the Commission is considering a repeat national survey of land cover in 1990. It is hoped that some of the experience of data gathering and handling using GIS in the National Parks project will help determine the approach to this future exercise.

BIOGEOCLIMATIC LAND CLASSIFICATION AND MAPPING OF SPAIN

R ELENA-ROSSELLO
Instituto Nacional de Investigaciones Agrarias, Centro de Investigacion y Tecnologia, 28080 Madrid, Spain

The objectives of this research project are to:

i. set up an appropriate methodology for processing ecological attributes in order to build a biogeoclimatic classification of Spain, at both national and regional scales;

ii. build an ecological data base and a predictive model for use in natural resource research assessment and management.

JUSTIFICATION FOR RESEARCH

At present, there is no land classification of Spain which includes physiographic, biological, climatic and geological information at an appropriate scale. Such a classification would be most useful for natural resources management, especially in forested areas, because it enables the trial results obtained from a reduced number of sample plots to be extended to the whole study area in a statistically controlled way. It will also facilitate the evaluation of natural resources in a reasonably quick and inexpensive manner.

From the management viewpoint, the ecological land classification is a first step towards the characterisation of forest sites for management purposes. Economic models have also been developed from land classificationS in order to assess the ecological and economic impact of the agrarian policies.

RESEARCH METHODOLOGY

The basic method to be used is the ITE land classification system, modified after successful applications in both Spain and other CEC countries. The classification process will be undertaken in two successive phases.

i. **Delineation of ecoregions_**

The land unit will be a 5 km x 5 km square, based on the UTM grid, and 550 squares will be sampled (3% of the total area). The attributes will be selected in accordance with the national scale, based on topographic and geological maps at the 1:400 000 scale, and climatic maps at the 1:1 000 000 scale.

ii. **Ecological land classification of each ecoregion**

The sample size will be 3000 squares (3% of the total area), each 2 km x 2 km, and the topographic and geological map scale will be 1:200 000. TWINSPAN will be used for the multivariate analysis in both first and second phases.

An ecological and land use field survey will be carried out, once the regional land classes are delineated. The land classification obtained from the sample squares will be extended to the whole study area using the indicator attributes, and computer-assisted maps should be designed. A basic ecological data base will be built with the information recorded during the land classification of the sample squares, and will enable future land monitoring and the ecological impact assessment of different human activities.

This type of land classification has already been developed for several CEC countries. Therefore, this new development for the whole of Spain will help to co-ordinate the evaluation of natural resources in the different countries, and facilitate the exchange of information on new applications using existing land classifications.

TIMESCALE OF RESEARCH

1st year
General land classification of Spain and the delineation of ecoregions.

2nd and 3rd years
Land classification of each ecoregion and mapping of the resulting land classes.

4th year
Field survey for the ecological and land use characterisation.

ECOLOGICAL LANDSCAPE MAPPING IN THE NETHERLANDS

A A de VEER
Soil Survey Institute, PO Box 98, NL-6700 AB Wageningen, The Netherlands

From 1988 to 1991, an ecological landscape mapping project is being undertaken by the National Physical Planning Agency (The Hague), the Centre of Environmental Studies of the University of Leiden, and the Soil Survey Institute (Wageningen), based on trial projects in the period 1985-87.

Basic data concerning abiotic and biotic components of the landscape are being stored in a one km square grid system, and the total number of grid ells s approximately 35 000. Maps are being prepared at a scale of 1:250 000, and include the following information:

i. basic data;
ii. sensitivity assessment;
iii. significance from a nature conservation viewpoint;
iv. vulnerability assessment (combination of (ii) and (iii)).

By combining entities, a landscape typology is also being developed.

The data base is held at the Soil Survey Institute (at the Staring Centre). Basic data are derived from different sources, such as provincial authorities (land use and flora/vegetation), national committees, mostly of volunteers, on fauna research (mammals, bird, amphibians and reptiles), and the Soil Survey Institute itself (soil, hydrology, geomorphology). All the data have to be converted into the structure required by the central model.

The data are stored in a data base management system, using ORACLE. To select data, the structural query language (SQL) is used. Maps can be drawn with the help of special grid plotter programs, including ARC/INFO. Maps of types (i), (ii) and (iii) above can be used directly for the solving of planning problems, especially by the National Physical Planning Agency, the principal collaborators in this study. Eventually, the Agency will prepare a complete copy of the ecological landscape data base for use in its own user-friendly information system.

NATIONAL PEATLAND DATA BASE FOR SCOTLAND

S WARD
Macaulay Land Use Research Institute, Craigiebuckler, Aberdeen AB9 2QJ

The data base project forms part of a three-year programme investigating the use of peat as an energy source in the UK, funded jointly by the Department of Energy and the Commission of European Communities. The work is being undertaken by the Macaulay Land Use Research Institute in Aberdeen.

The main aim of the project is to develop a geographical data base for the Scottish peatland resource, in order to:

- assess the potential supply of peat for use as fuel;
- provide objective information on peatlands to a wide range of land use and planning agencies.

CONTENTS

Deposits will be mapped and classified according to:

- the quantity and quality of the peat;
- practical and environmental constraints on extraction (ie access, topography and climate);
- compatibility of existing land uses with peat extraction (ie forestry and conservation).

STRUCTURE

Information will be held as a GIS, allowing both statistical data analysis and map production. It comprises two integrated components:

i. **Geographical data base**

Spatial information is digitised from source maps and integrated with geo-referenced data sets from diverse origins, including satellite imagery, within the framework of the data base. The data base is being developed on the Institute's GEMS image processor, but will ultimately be operated on an ERDAS system.

ii. **Relational data base (ORACLE)**

This data base will contain detailed survey information on individual peat deposits. Site records will include variables indicating peat quality and commercial viability.

TRAINING IN GIS FOR LAND ECOLOGY APPLICATIONS

R VAN DER ZEE

International Institute for Aerospace Survey and Earth Sciences, 75350 Boulevard 1945, PO Box 6, 7500 AA Enschede, The Netherlands

INTRODUCTION

The International Institute for Aerospace Survey and Earth Sciences (ITC) in Enschede, The Netherlands, aims to provide mainly postgraduate education and to carry out research on the application of aerial photography and other remote sensing techniques. The education system is international, and is intended primarily, if not exclusively, for participants from developing countries. ITC is one of the few institutes of higher learning in the world that provides postgraduate studies in GIS covering a wide field of applications. At present, three courses are offered, emphasising cadastral, urban and rural applications, of which the latter is the most interesting for land ecology. The courses are aimed at professionals in senior technical positions who will be involved in the selection and introduction of computer methods and GIS in their organisations. Participants are encouraged to work on their own data, provided that their material is sufficient for a final project. In addition to these regular GIS courses, a number of other courses at ITC include components in which geodata processing occupies a prominent position. The GIS module within the rural and land ecology survey course may be of special interest in this respect.

GENERAL INFORMATION ON THE COURSES

The courses consist of formal lectures, 'hands on' training and practical exercises, literature study, study tours, and the preparation of a project report. The main elements of the curriculum are concluded by examinations. The teaching staff is drawn from a cross-section of all ITC departments, augmented by outside experts.

Applicants should hold a recognised university degree in one of the following disciplines - geography, environmental science, urban and regional planning, agriculture, vegetation science, soil science, forestry. The course duration is 12 months for the rural (and other) GIS course and ten months for the rural and land ecology survey course. All teaching in these courses is conducted in the English language.

EQUIPMENT

The ITC computing facilities include several DEC minicomputers of the PDP and VAX families (VAX 11/750, VAX 11/751, VAX 11/780, MicroVAX II). A classroom with IBM PC/XTs is used for the GIS courses. There is also ample specialised computer hardware and software for geographic data handling, image processing and automated cartography (Intergraph, IGOS, Dipex, Syscan, Contextvision and possibly ERDAS and/or Meridiem). In addition to software designed by ITC (including Masmap, Usemap and special programs for image processing), widely used packages are also available, such as GIMMS, MAP II, ARC/INFO, CRIES and others.

It is ITC's policy to use state-of-the-art hardware and software for education, research and consulting purposes.

THE GIS FOR RURAL APPLICATIONS COURSE

The general objectives of this course are to train people in the selection and use of computer hardware and software for storage, retrieval, transformation, analysis and presentation of spatial survey data, and to decide how these techniques could be developed and used in the management of natural resources (development and/or conservation) by the participants' organisations and countries.

The course is aimed at senior staff from institutions involved in natural resource management or in the provision of training for natural resource management.

The course is organised in five blocks:

i. introduction to GIS and training in basic skills (three months);

ii. techniques for natural resource data collection, analysis and management, ncluding land evaluation, watershed management, development planning (two months);

iii. the use of GIS packages for natural resource management (three months);

iv. establishing and testing a GIS for natural resource management (one month);

v. final project: each participant works on the design and operation of a GIS for his/her own working environment (three months).

THE RURAL AND LAND ECOLOGY SURVEY COURSE

The postgraduate courses in rural and land ecology survey provide instruction in survey methods, and training in the techniques of data collection in the applications of aerospace survey for land resources inventory and the evaluation of rural lands. Emphasis is on the interpretation of aerial photographs and other remote sensing techniques used in these fields of study.

The programme is structured in three phases.

i. A short programme comprising a common core of basic and fundamental subjects and, in addition, offering three lines of specialisation:
agricultural land use survey;
vegetation and rangeland survey; and
human settlement and infrastructure survey (three months).

ii. A choice of several lines of specialisation: land evaluation, remote sensing, watershed management, human geography, agricultural land use, rangeland ecology and evaluation, and GIS. The latter comprises the introduction to and exercises with one or more GIS applied to rural and ecological themes and problems (two months).

iii. The culmination of the course comprises the preparation for and execution of a fieldwork project, processing of the data collected, and preparation of a final report. In this project,those who specialised in GIS in the previous phase may use the methods and techniques also learnt (five months).

It is possible to register for one or two phases only.

Those who complete the whole course with very good results may be admitted to the MSc course in which a GIS specialisation will also be possible.

SUMMARY OF GROUP DISCUSSIONS

D BROWN[1], K R BULL[2] and O BRANDON[3]
[1]*Rural Affairs, Department of the Environment, Tollgate House, Bristol BS2 9DJ*
[2] *Institute of Terrestrial Ecology, Monks Wood Experimental Station, Abbots Ripton, Huntingdon, Herts PE17 2LS*
[3]*Aberdeen Centre for Land Use, University of Aberdeen, Department of Zoology, Tillydrone Avenue, Aberdeen BA9 2TN*

The group discussions developed a number of themes during the Workshop, and these are summarised briefly below.

PRACTICALITY OF APPLICATIONS FOR INEXPERIENCED USERS AND THE POTENTIAL FOR TRAINING

The demands of any system need to be tailored to obtain the required outputs. People currently developing systems do not fully understand the needs of those working at the 'sharp end'. Therefore, this gap must be bridged. A guide to what is available and what can be done would be helpful.

GIS is a useful planning tool for handling data for such purposes as monitoring change and identifying priorities. With regard to training, it was felt that 'crash courses' for practitioners at a lower level than those currently available (MSc) were an immediate requisite.

AVAILABILITY OF INFORMATION ON SYSTEMS AND COST RANGES FOR DIFFERENT USES

A newsletter or gazetteer could usefully disseminate information about current availability and applications. The confidentiality of some data is seen as an impediment to providing a reliable basis for developing a number of systems.

TRAINING

There is a clear need for training, and 'hands on' experience is one of the best methods of teaching inexperienced users, who should be encouraged to take advantage of available facilities.

Demonstration modules provide a useful means of showing the potential of GIS, and are available for a number of systems. However, these particular systems are often expensive, and the modules cannot be applied to the user's own data. Also, modules are usually aimed at the systems expert, rather than the user manager.

Training needs are wider than purely technical skills. It is not just the users who need training - system developers should be educated in user needs. One approach to bridging the gap between users and systems experts would be to employ organisation consultants where systems were to be installed, who could analyse the flow of information and the information requirements. This approach has been used successfully in the USA.

It is necessary to identify people sympathetic to information technology within potential user organisations, so as to help bridge the generation, and other, gaps which may otherwise create resistance to GIS development. A gap exists between geographers and ecologists, and, although neither may be considered inexperienced users, both disciplines need to understand the others' viewpoint.

AVAILABILITY OF INFORMATION OF SYSTEMS AND COST RANGES FOR DIFFERENT USERS

Whilst some universities and manufacturers are developing ever more powerful GIS, cheaper, simpler systems will often meet the immediate needs of a user. If users defined their needs, and suitable systems were available at the right price, then the necessary impetus for purchase and use would be created. This initial step was important because it was felt that only usage will provide the required experience for further development of the system and/or the purchase of subsequent svstems.

Although the price ranges of GIS are wide, the costs of both hardware and software are decreasing. Simple systems are now within the budget of most organisations.

There is generally little need for users to understand how a GIS works as the necessary technical support is usually available. It is questionable, however, whether a systems expert should act as an intermediary between the user and the GIS. Although the presence of an expert is often essential to obtain the maximum benefit from a system, it is important for the user to interact directly with a GIS via the keyboard. Much may depend on the level at which the user is working: for example, a policy-maker may not wish to use the system directly, only to gain information (results) on which to base policy decisions.

The biggest cost of setting up a GIS is often the entering of the data. This cost is frequently overlooked when the price of a system is being estimated. Consequently, data should be transportable between systems, thus preventing their redundancy when the GIS is changed and upgraded.

THE POTENTIAL FOR LINKING DYNAMIC MODELS TO GIS

Caution is required if GIS is to be applied to dynamic models, because of the errors often hidden within the data bases of GIS, which may be compounded when a system is applied to a model. At present, user demands are not for dynamic systems, and more effort was being put into identifying the magnitude of data errors and in ensuring the quality of data for non-dynamic systems. It is recognised, however, that the landscape and the environment are dynamic systems and the use of GIS should ultimately reflect this fact.

Although models themselves are unlikely to be sought by policy-makers, the results generated by such models may be required. At a simple level, this requirement may be met simply by a series of alternative scenarios from which policies can be decided.

DATA QUALITY

The poor quality of input data arises from the need to approximate to common boundaries for data derived from different sources (eg parish boundaries justified to one km grid squares), from the use of incompatible data sets where an assumed relationship has no sound basis, from the use of data sets derived from observations made at different scales, and from limited access to disaggregated data because of confidentiality requirements.

Turning now to the quality of output, it should not be difficult to assess internal inadequacies in generating poor output from GIS. Confidence estimates of the data components should be retained and amended throughout all stages of data manipulation. Alternatively, qualitative estimates of the sensitivity of outputs to changes in input data should be made. Together, such approaches should identify those factors whose potential inaccuracy are likely to cause the most significant effects.

Models are, by definition, relatively simple abstractions of the real world; their output is, therefore, necessarily subject to uncertainty, and it is difficult to assess accuracy. The important criterion should be that they are sufficient for their purpose, which implies that the user has a clear idea of the levels of accuracy required.

Various techniques similar to those used to check the accuracy of output data may be employed to ensure the validity of modelled results. For example, models which produce estimates of livestock populations based on field observations coupled with agricultural management practices may be calibrated by checking against independent estimates. However, it is important to recognise that such estimates may themselves be subject to statistical uncertainty.

DECISION-MAKING

In the absence of a quantitative measure of the statistical uncertainty of input and output data, the user of the GIS should ideally be the decision-maker. If the planner is engaged in the development and improvement of the GIS, judgements of the statistical validity of the system and of the model output are likely to be made with greater authority. There is thus no substitute for the user having 'hands on' experience of the GIS, rather than relying on an external group to provide the material on which decisions are to be based. The full implications of both the advantages and disadvantages of GIS should be available to policy-makers.

PATTERN ANALYSIS

The analysis of patterns apparent in the spatial arrangement of features in the landscape is of increasing relevance for planning in ecology. The aim of regenerating a more diverse population of plants and animals in agricultural environments is a constant theme in much conservation policy, and is related to the promotion of more extensive agricultural production. GIS has a central role in analysing spatial relationships.

However, the spatial pattern of habitats most likely to maximise a conservation benefit remains unclear. Equally, ecologists have not yet fully applied the geographers' pattern analysis techniques to ecological problems. Geographic information systems do not currently include pattern analysis packages, and it is felt that the incorporation of such facilities would serve to improve understanding of the incidence of particular patterns shown to be beneficial to the conservation of wildlife.

FINAL SUMMARY

J T COPPOCK
Department of Geography, University of Edinburgh, Drummond Street, Edinburgh EH8 9XP

Summing up at the end of any workshop or symposium is a difficult task; attempting to do so after hearing the presentations of the findings of discussion groups is even more so. Perhaps I would have been wise to follow the cynic's advice and to write what I have to say before I came; but I did not do so, and these concluding remarks derive from what I have heard and from my own involvment in GIS over more than 20 years, most recently as editor of the *Journal of International Geographical Information Systems.*

One of the features of GIS in this country that strikes me forcibly is how little impact thinking and discussion on GIS has actually had, despite early initiatives, such as the Ordnance Survey's digital programme and the GISP report. In North America, GIS is now a 'buzzword' and involves major federal agencies, state and city governments, the commercial sector, and a new breed of GIS consultants - and, since July 1988, a National Center for Geographic Information and Analysis. In the UK, as the Chorley Committee has shown, there is generally a low level of awareness and, proportionately, a much lower level of activity. Of course, progress must be measured from your starting point, and there is no doubt that there is a rising level of interest, as shown by this Workshop and the NERC Symposium in June 1988. Moreover, the Chorley Committee was, to the best of my knowledge, unique in that this was the first occasion anywhere that there had been an official inquiry into all aspects of handling geographical information, which is a very large part of GIS. It reported in 1987, the Government responded in March 1988, although in typically low key, and we must now await developments.

One need that did emerge in the discussions was for more information about individual systems and what they could offer. North American experience has shown that you cannot rely on providers of commercial hardware and software, and many systems have been oversold or proved unsuitable because there was insufficient in-depth analysis of what was required. It was suggested that there should be a GIS yearbook, giving summary accounts and appraisals of all systems and equipment, on the lines of the successful *Remote Sensing Yearbook.* This idea is certainly worth investigating, although we should first establish whether any comparable initiative is under way in North America, where demand is greatest. Such an initiative also requires a knowledgeable person willing to take on the burden and a willingness of the GIS community to provide, without prompting, a continual flow of information; my experience with the News Section of the Journal has not been very encouraging in this latter respect. A related, and less ambitious, proposal was that everyone attending meetings such as this one should wear badges showing, in addition to their name and affiliation, what system they were contemplating using; talking to existing users of a system is undoubtedly one of the most effective ways of finding out about its strengths and weaknesses.

Another issue raised by several speakers was information about the availability and quality of data. To take the last point first, in my judgement, far too much information, especially that collected by official agencies, is being taken at its face value, with no knowledge of either its reliability or its spatial characteristics. These problems are compounded when such information, whether from maps or from statistical tables, is compared with information from other sources - as it must be if GIS is to serve a useful purpose. There is an urgent need for full and frank evaluation of all major sources of geographical data and a willingness, on the part of users, to recognise that things are not always what they seem. There is an equal need for proper documentation of the technical characteristics of digital data so that they can be readily exchanged. It is ironic that much of the interest in GIS comes from small agencies and from academic researchers who are not themselves primarily collectors of data, whereas many of those who do collect spatially referenced data (or data capable of being so referenced) do not use GIS.

I make only brief comment on the important topics of the compatibility of systems and the exchange of data and software. There are, of course, two broad kinds of systems. Commercial companies seek to market general-purpose systems whieh can be adapted for many purposes; in contrast, many of those attending this workshop have built or are building their own systems, often with very limited budgets and limited functionality. There is no doubt that much can be learnt from building such systems, and they may well be much cheaper and more efficient for these limited purposes; but they do pose considerable problems when attempts are made to expand and diversify and to make the data available to others. Some progress has been made with standardisation with the publication by OS of the *Digital Data Transfer Standards* and, of course, the dominance of a small number of large manufacturers does increasingly impose a standardisation of equipment and operating systems. Many of the small-scale systems we are discussing depend on the increasing power and functionality of the personal computer, and several pleas arose for an Alan Sugar to do for PC-based GIS what he had done at the lower end of the market for PCs generally.

There is clearly a great need for work on the handling and analysis of spatial data, once these have been captured in digital form. Statistical analyses are being undertaken in ignorance not only of the characteristics of the data, but also of the appropriateness for such data of the statistical procedures being used (the requirements of which are often not satisfied by the data available). Stan Openshaw has recently devised what he calls a 'geographical analysis machine', which makes no assumptions about the statistical characteristics of the data and explores all possible hypotheses, something that has become possible only with the rapid growth in, and declining cost of, computer power.

Attention also needs to be paid to the way in which information is actually used in policy-making and decision-making, with particular reference to the speed with which, and the level of aggregation at which, information is required. Fulfilling this objective will also require some understanding of organisational structures, the flow of information in organisations, and decision theory.

Training and education were also fields where discussants felt there was a need for action. As we noted earlier, a prime need in this country is to raise levels of awareness of the scope and potential of GIS, particularly among middle managers. Training also needs to be provided at a number of levels - scientific, technical and user - and that training must not be confined simply to the technical. As far as I know, there is still only one graduate course in GIS, that at Edinburgh, although there are others in digital mapping and remote sensing that provide elements of GIS training. There was felt to be a need for 'hands on' experience at all levels, and some support for the idea of GIS demonstrators, available over the networks, whereby would-be users can acquire some feel for given systems, such as that devised as ARCDEMO and ECODEMO by Nick Green and colleagues at Birkbeck College.

In seeking to meet the education and training needs in GIS, we must not lose sight of the much wider field of information technology generally, not only because there are undoubtedly common elements of training, but also because other fields may generate ideas and developments that may be of great relevance to GIS, as with architecture and computer-aided design.

We could also benefit from information about systems that have been successful, those that have not lived up to expectations, and those that have failed; there are undoubtedly lessons to be learnt. Unfortunately, those who manage such systems do not wish to admit to failure, and official obsessions with secrecy and confidentiality do not help. We do know of one system, at the highest level, that did not fail technically but was withdrawn because it did not appear to serve a useful purpose - the Domestic Information Display System, installed in the White House in the Carter Presidency and then quietly removed in the early years of the Reagan Presidency, apparently without ever having been used operationally. I am sure that a frank appraisal of the first 20 years of the Canada Geographical Information System would have valuable lessons for us all.

There are many other initiatives of which we should be aware, especially now the Government has rejected the Chorley Committee's recommendation that a National Centre for GIS should be established. With this decision, the four Regional Research Laboratories acquire a much greater significance, although GIS are only one of their responsibilities, as do the ESRC Data Archive and, especially for this Workshop, its developing rural data base, and another ESRC initiative, the Programme on Information and Communications Technologies (PICT). We should also look at what is happening in the Computers in Teaching Initiative, particularly in geography, and I believe we can learn something by examining the successes and problems of related initiatives such as Prestel/Minitel, interactive video and electronic publishing. The ideal will be a situation where GIS is as easy to use and as routine as airline booking systems. I will not attempt to guess when that will be, but, given the rate of technical progress and the emergence of a generation reared on computer games, it may be nearer than we are inclined to think.

APPENDIX 1. LIST OF PARTICIPANTS

C. Appleby	Wiltshire Biological Record Centre
R. Aspinall	MLURI, Aberdeen
J. Baker	BNSC/NERC, Swindon
D. Bartlett	University of Ulster, Coleraine
G. Bell	ITE, Bush
A.A. van der Berg	De Dorschkamp, Netherlands
A. Betts	Forestry Commission
R. Birnie	MLURI, Aberdeen
S. Bishop	Hunting Technical Services Ltd
N. Bonvoisin	Institute of Hydrology
K.Bull	ITE, Monks Wood
P. Burrough	Utrecht, Netherlands
R.G.H. Bunce	ITE, Merlewood
R. Butler	Oxford University
O. Brandon	Aberdeen University
D. Brown	DOE,Rural Affairs Directorate
M. Charlton	Newcastle University
H. Clark	Scottish Office
J.T. Coppock	Edinburgh University
G. Cundale	Brecon Beacons National Park
M. J. Dannatt	Peak District National Park
D. Davidson	Stirling University
W. Dias	ITE, Merlewood
P. Dowie	Edinburgh University
C. Dunn	Lancaster University
W. Ely	Rotherham Museum
A. Fishwick	Lake District Special Planning Board
A. Gattrell	Lancaster University
R. Gelinas	Environment Canada
K. Greenhill	North West Water
G. Griffiths	NRSC, Farnborough
R. H.Haines-Young	Nottingham University
J. Hall	ITE, Monks Wood
A. Harrison	Bristol University
P. Hartwell	TYDAC Systems
J Holbrook	NCC, Edinburgh
M. Hornung	ITE, Merlewood
D. Howard	ITE, Merlewood
P. Kelly	Nature Conservancy Council, Cumbria
P. Janssens	Leuven, Belgium
N. R. Jenkins	ITE, Merlewood
R.H.G. Jongman	Wageningen, Netherlands
R. van Lammeren	Wageningen, Netherlands
M. Lane	Rural Areas Database
S.Lawrie	ITE, Merlewood
J. Marsden	Nature Conservancy Council, Cumbria

G. F. Marshall	Computer Services, Surrey
I. Moffat	Stirling University
R. Moore	Institute of Hydrology
A. Mowle	Nature Conservancy Council, Edinburgh
B. Munier	Roskilde, Denmark
R. Murray	University of Ulster, Coleraine
W. Murray	Lake District Special Planning Board
J. Ni	Beijing, China
P. Ogden	Snowdonia National Park
D. O'Neil	Strathclyde University
U. Otto	Munster
A. Payne	North West Water
J. C. Peters	DOE, Rural Affairs Directorate
T. Perkins	East of Scotland College of Agriculture
J. Phillips	AIM Systems
B. Rice	Yorkshire Dales National Park
G. Roberts	Snowdonia National Park
R. Roberts	Countryside Commission
T. Robinson	TYDAC Systems
R. Shannon	Tayside Regional Council
N. Stedman	Yorkshire Dales National Park
R. Stuart	Leeds University
R. Thole	Munster
R Thomas	Peak District National Park
S. Toland	DOE, Rural Affairs Directorate
R. Tomlinson	North Cheshire College
A.A. de Veer	Wageningen, Netherlands
P. Vincent	Lancaster University
S. Ward	MLURI, Aberdeen
D. White	Nature Conservancy Council, Bangor
J. White	Bristol University
M. Wooding	NRSC, Farnborough
R. van der Zee	Enschede, Netherlands