THE APPLICATION OF GIS TO WEED SURVEY

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Summary An assessment of weed survey techniques and an investigation of the factors affecting weed distribution was carried out in the area covered by the Yendon (7622-1-2 Zone 54) 1:25 000 map sheet, near Ballarat in Victoria. A selective sampling strategy was devised to map the location of woody weed species problematic in the Ballarat area. A digital database comprising spatial and attribute information was constructed in a vector-based geographic information system (GIS). The application of GIS to the development of a weed database and the analysis of these data is discussed. Chi-squared goodness-of-fit tests were utilized to statistically analyse the presence of weed patches within classes of attributes categorized in the spatial layers. The results will be utilized in the development of a model for predicting weed distribution based on geographic, edaphic and cultural attributes.

INTRODUCTION

Weed control methods currently employed are expensive, time consuming, and rarely provide long-term eradication of pest species. It is recognised that further research into control methods is necessary (Combellack 1990, Australian Weeds Committee 1992). A greater understanding of the influence of ecological and cultural factors on the distribution and spread of weeds would lead to a prediction and prevention approach to weed control, rather than a cure (Australian Weeds Committee 1992).

Database weed information is scattered and incomplete, and the monitoring of weed infestation and spread is *ad hoc* (Johnston 1993). The Department of Natural Resources and Environment (DNRE) currently uses a computer database system (PMIS) to record the location of pest plants and animal infestations, however the system in its present form does not incorporate mapping components (Lane *et al.* 1989). The climatic prediction system BIOCLIM® (CSIRO) has been widely used to predict the spread of species throughout climatic regions (Busby 1991). The importance of soil type and other environmental factors cannot be ignored when investigating species distribution (Holzner 1982, Swincer 1986) and the role of cultural elements of the landscape and land management practices have generally been overlooked in the design of weed database systems and previous studies into weed species distribution.

A nationally consistent recording and analysis system has been recommended to amalgamate existing scattered knowledge and to provide a basis for future data collection (Humphries *et al*. 1991, Australian Weeds Committee 1992). GIS are designed for storing, manipulating and analysing spatial data (Zhou 1989). The power of a GIS resides in its ability to associate locations and characteristics, and to cross-reference different types of spatial information (Smith *et al.* 1992).

This study was undertaken to assess the utilization of a GIS (MapInfo®, MapInfo Corporation New York) for giving a better understanding of factors affecting weed distribution and the extent to which it could lead to prediction of future sites of infestation and more efficient and effective control programs.

The objectives of the study were to:

- Provide a map of the sites currently infested by weeds in the area covered by the Yendon (7622-1-2 Zone 54) 1:25 000 topographic map sheet.
- Assess the utility of reporting and recording weed distribution data.
- Create a database in a GIS to investigate correlations between weed species and environmental/cultural factors.
- Develop a model for weed invasion and occurrence that can be used for predicting areas likely to be invaded by certain weed species.

MATERIALS AND METHODS

Study area The study area was delineated by the Yendon 1:25 000 topographic map sheet (7622-1-2 Zone 54), south east of Ballarat in Victoria. The area encompasses a range of land uses, including pastoral properties, softwood plantations, small 'hobby' farms and urban blocks. Remnant patches of native vegetation remain, the larger areas being *Eucalyptus obliqua*/*E. radiata*/*E. dives* open forest. There was adequate access to most of the 15 390 hectare area via the public road network. The townships of Buninyong, Mount Helen, Clarendon, Durham Lead, Garibaldi, Scotsburn and Yendon lie within the study area.

The study species were *Ulex europaeus* L., *Rosa rubiginosa* L., *Rubus fruticosus* spp. agg. L., *Crataegus monogyna* Jacq., *Conium maculatum* L., *Pinus radiata* D. Don, *Erica lusitanica* Rudolph, *Juncus acutus* L. and *Genista monspessulana* (L.) L. Johnson. All are large perennial plants which are highly visible in the field, particularly during flowering season.

Survey methodology An intensive selective sampling strategy was devised to cover the largest possible proportion of the study area. All roads, tracks and accessible boundaries were traversed and the weed species within view were identified, mapped and categorized in terms of site and patch characteristics. A 500 metre grid was drawn over the Yendon map sheet and used as a locater for transects when these were required. Transect walks were performed over areas that were not visible from access routes, principally the large forested areas and land with steep terrain. A 'site' for the purpose of this study constitutes a land-feature based classification for the area in which the weed patches or clumps were defined. No site data were collected for locations without weeds.

Each site was delineated by natural or cultural boundaries, therefore not having uniform size or shape, but containing homogenous intrinsic features. A change in land-use, vegetation, fence condition etc. was deemed a new site. For each site the location and a number of site characteristics including land use, proximity to main distribution routes and the presence of running or standing waters were recorded. These data overlap with the digital information collected and were not used for analysis, however they provided ground truthing for the vegetation and land use layers, and formed the foundation for the attribute database. A list of these variables include vegetation community, condition of vegetation, evidence of fire, past and current disturbance, fence condition, grazing level, presence of dwelling and the total width of the road reserve. All weed patches within the site were recorded. Age classes of the weed patches were estimated and recorded using a three point scale: seedling, young growth and fully-formed adult. The foliage cover was estimated for each species over the site area, and evidence of control measures were noted. A representation of the size and shape of the weed patch was sketched onto a topographic map at the field site. Simple point locations for each patch were deemed to be unsuitable as linear patches, for example roadside infestations of *Ulex europaeus* or *Rubus fruticosus*, may extend for several hundred metres.

The selection of field sampling sites for this type of project has in some previous studies been determined by identifying 'environmental land classes' and employing a stratified sampling method within these classes (Chicoine *et al.* 1985, Davis and Dozier 1990, Cocks and Baird 1991). The classes were generated by overlaying and grouping all spatial factors prior to commencement of field survey. This method was not used as it involves assumptions that some factors, either singly or in combination, contribute to plant distribution.

GIS analysis A digital database was compiled incorporating environmental and cultural factors of the landscape. The data were provided by various government departments and required manipulation before they could be usefully applied to the survey data. The development of a robust database is necessary before analysis and modelling can be achieved with accurate, meaningful results.

The choice of factors used in the GIS analysis was made with consideration of the availability of digital data and evidence in relevant literature of the importance of the factor in weed distribution. Factors in the GIS database of digital information that was compiled together with the source are given in Table 1.

All spatial layers in the digital database were either imported from ARCInfo or INTERGRAPH or digitized directly into MapInfo. The advantage of MapInfo over the more powerful systems is that it is relatively simple to use, the user can become competent with concepts and functions in a short time and it does not require expert knowledge of computer programming language.

Some layers were combined to produce composite coverages. Buffers of five metres were placed around all

Table 1. Layers in GIS database and source of data.

Layer	Source
Geology	Geological Survey Victoria
Soil type	Department of Agriculture
Land systems	Jefferey (1980)
Aspect	State Data Centre
Slope	State Data Centre
Vegetation	Smithyman (unpubl.) (mod.)
Canopy cover	Smithyman (unpubl.) (mod.)
Rainfall isohyets	Land Conservation Council (1980)
Land use	State Data Centre (mod.)
Management unit area	State Data Centre
Tenure	State Data Centre and DCNR (modified)
Location of boreholes	Department of Minerals and Energy
Altitude	State Data Centre
Rivers, streams and channels	State Data Centre
Dams	State Data Centre
Natural lakes	State Data Centre
Fence lines	State Data Centre
Railway	State Data Centre
Sealed roads, unsealed roads and tracks	State Data Centre
Location of fire events	DCNR, Ballarat
Quarries and excavation sites	State Data Centre

road boundary objects in the road layer to examine the association between weed infestation and the location of roads. Waterways from the river, stream, and channel layers were also buffered (10 metres) and combined with the road layer to form a composite layer for linear distribution routes. The correlation of infestations to roadways is well documented (Amor and Stevens 1976). A composite layer of disturbance factors was compiled using boreholes, fire events, quarries, excavation sites and fence lines.

Visual analysis was used to assess the relationship between individual weed species and the layers previously outlined. Polygon overlays were also used to determine relationships between weed species and overlay factors. Chi-squared tests were employed to test for significant variation between the number of weed patches of each individual weed species and the expected number of patches for the categories and classes in all layers containing complete polygon coverages (geology, soils, land systems, aspect, slope, height, canopy cover, road buffers, land use, tenure, size of management unit and vegetation). Command-line (Structured Query Language) queries were used to produce counts of the patch polygons for each weed and the relative area of each category in the overlays.

RESULTS AND DISCUSSION

Maps of the distribution of the nine study species in the area of the Yendon 1:25 000 map sheet were constructed. Factors which are significantly correlated to weed distribution were identified. The factors associated with the distribution of all or most of the weed species are: proximity to roads, land use, size of management unit, soil type, vegetation, land system and geology.

Evaluation of GIS analysis MapInfo was successful in identifying significant relationships between the study species and the environmental and cultural factors. An attribute database was compiled which was only partially used for the analysis but which provided ground truthing for the digital maps. The construction of the non-spatial attribute database and the evaluation of its structure was an objective of this project. The display product consisted of single or composite factor layers overlayed with locations of the polygonized weed patches. The maps produced gave a strong indication of the spatial distribution of each of the weed species, and in some cases, a clear view of the relationship between weed distribution and the underlying factor.

Evaluation of methodology The intensive survey method was devised to cover the largest possible proportion of the study area. The survey method was compatible with the nature of the landscape in the agricultural and settled areas as most of these blocks are cleared and woody weeds are highly visible. Several of the study species were also highly visible in forested areas due to their bright yellow flowers and dense growth. Analysis of the dimensions of land parcel size over the map sheet identified that the average distance to the midpoint of any land parcel from a road or accessible boundary was approximately 500 metres. The transects across larger parcels and vegetated areas were 500 metres apart, therefore providing an even coverage of the study area. A slight bias toward roadsides is evident in the survey methodology, as the patches adjoining roads are more easily visible and readily accessed.

Analysis The analysis showed relationships between the weed species and the factors for which digital information was obtained. Visual representation of the relationships was also successful. The univariate analysis (χ^2 test) was informative and effectively demonstrated the role of the individual variables, however it could not be completed directly through MapInfo.

MapInfo was successful in creating new layers from non-spatial and spatial databases by allowing the joining and manipulation of tables and then displaying the results. The visual representation and analysis of two factors overlayed was successful, however, the overlay of more than two coverages for analysis was not attempted. Multiple polygon overlay to create new polygons (modelling) with MapInfo is not recommended (R. Pope personal communication). Incorrect results may be obtained due to the limitations of the system and it is recommended that a more powerful raster-based GIS be used.

CONCLUSIONS AND ONGOING RESEARCH

GIS provides opportunities for exploring spatial relationships between plant species and environmental/cultural factors that would be otherwise extremely expensive or impossible (Smith *et al*. 1995). These systems should be utilized in the construction of a weed database.

MapInfo was found to be an effective system for entering, storing and displaying weed distribution data. MapInfo was utilized for basic input and analysis of the data, however it was not successful in performing complex modelling operations. Although the results given are not predictive, the basic components of a predictive model have been provided.

A further extension of the analysis is currently being undertaken at the University of Ballarat involving modelling the environmental/cultural factors in relation to weed distribution to predict future infestations. The datasets are being developed and manipulated in ArcInfo, a more powerful raster-based GIS. Further investigation in collaboration with organizations requiring weed locality information is required before a standardized weed data collection, storage and analysis system can be created.

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