Agricultural land capability assessment using an expert system

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Summary. An expert system was developed to simulate the assessment of agricultural land capability as used in NSW. A single expert's knowledge was used to formulate the rule base used in the expert system. The most limiting factor approach was used to determine agricultural land capability from land unit soil. climate and geomorphic attributes. The expert system solution quality was verified against other experts of varying experience in land capability assessment. A Spearman's ranked correlation 'rho' showed that the expert system was closely associated with the high skilled experts. The practical use of the expert system extends to land resource assessment for agricultural purposes and education of land managers.

Introduction

Agricultural land capability assessment may take two forms, either a quantitative assessment for specific purposes, or a qualitative assessment for agriculture, in general. Quantitative agricultural land assessment is based on crop specific models describing crop production potential under various environmental and management conditions. In practice agricultural land is examined by qualitative general assessment which attempts to estimate the overall plant production potential in relation to the environmental hazards of agricultural use. Precise mathematical models require significant expense in their development, data input and equipment. Generally, these models offer no gain in regional agricultural planning terms when compared with rapid expert judgement (l).

General agricultural land capability assessment considers a wider set of land use options than the crop-specific models which may be difficult to assess in a quantitative manner. There are many facets of land assessment which are totally dependent upon the assessor's intuitive judgements, e.g. integration of social, environmental and economic criteria. The main approach used to gain a broad overview of the agricultural potential of land is land capability assessment which is best incorporated early in the strategy planning phase for an agricultural enterprise (2). Agricultural land capability identifies the appropriate management package to achieve sustainable productivity without land degradation and is used successfully at both the regional and farm scale (3).

There arc three main problems in determining agricultural land capability. First, experts have difficulty in collating and interpreting the large sets of bio-physical and socio-economic data used in capability assessment in a consistent and reliable manner. Secondly, heuristic judgements by the expert are used to assess some of the criteria applied in land capability assessment. For instance, permanent limitations to agricultural production are identified by the poor cost-effectiveness of removing that limitation, i.e. an implicit goal of balancing inputs against outputs (4). However, there are no explicit rules to determine economic viability other than an expert's heuristic judgement. Thirdly, aggregation of land attributes using non-commensurate units into one grand index has no hard and fast rules (5). The most common aggregation method adopted is to use a constraint satisfaction approach, where the most limiting factor determines the ultimate land capability. The expert makes a judgement on the interactions of the criteria used in land capability assessment.

The Soil Conservation Service (SCS) of NSW as with many other related agencies in Australia uses a similar system of capability assessment to the United States Department of Agriculture (6). The procedures used in this as well as the other systems offers many problems. Subjectivity, a shortage of experts and significant potential conflicts between competing land uses means that a capability assessment needs to be formalised. Several attempts have been made to do just that. For example, land capability assessment for the Hunter Valley of NSW was formalised with a description of the land attributes used by the experts (7). However, the method of interpreting the role of each of the land attributes and their interaction was not described. An example driven description of land capability assessment was published by the SCS of NSW (8). A llow chart was developed to guide capability assessment that was subsequently extended to include more explicit criteria for farm planning purposes (9). These examples provide the opportunity to dissect the experts' judgements into the individual components of their decision making. Consequently. land capability assessment may be formalised.

Experts are able to express their methods or reasoning and generally agree on a solution. These two factors are essential requirements for developing a computer based expert system of land capability assessment. Explicit computer representation of land capability overcomes the problems associated with individual operators' interpretations of the subjective components of land capability. In addition. information processing and modelling requires strict mathematical representations of land capability assessment, which do not exist. The heuristic nature of land capability assessment. its complexity and narrow knowledge domain, suggest that an expert system is a viable alternative for quantification.

Methods

The expert system was developed for use in the northern tablelands and north-west slopes and plains of NSW. The knowledge of a single technical expert was used to develop the rule bases. A hybrid structured rule base software tool (VP EXPERT) was used as the framework for the expert system.

The expert system used a structured rule base implemented by backward chaining. The system employed a hierarchy of rule bases to address each component of land capability namely: soil erodibility; site erosion hazard; plant production potential; and other geomorphic factors. The rules took the form of "IF constraints THEN solution" with a maximum of ten constraints in each rule. The constraints were described in terms of the natural language description of the soil. climate and geomorphic attributes used by soil conservationists. The system was designed as a user interactive expert system. The output of the expert system was a series of text statements to describe the land attributes, identifying the land use inferences from the land attributes and provide the resultant agricultural land capability.

The assessments of land capability by three land resource planners, three soil conservationists and three land resource students were compared with solutions from the expert system. Each test subject was given 16 sites from the Tamworth area and asked to indicate the agricultural land capability. A "gold standard" expert also assessed the sites and was asked to rank each subject by a notional score that described the land degradation risk of the wrong response. The associations of the test subjects' rankings to describe the quality of their solutions were examined by a Spearman's ranked correlation co-efficient 'rho'.

Results

The Spearman's analyses found that the performance of the computer expert system was closely associated with the initial single expert used to develop the system (LRP I). The expert system was grouped with the other expert land resource planners but had no close association with any other subjects used in the trial. In addition, LRP3 was associated with the lower skill group of SCI and SC2, while SC3 was associated with ST3 (Table I).

Table I. Associations of the performance ('rho') of the test subjects in assessing land capability (* indicates the association is significant at the 0.05 level).

Test Subjects' Codes [a]										
	COM	LRP1	LRP2	LRP3	SC1	SC2	SC3	ST1	ST2	ST3
COM		.701 *	.536 *	.465 *	.330	.048	.146	.011	.260	.177
LRP1			.843 *	.162	.213	.114	.168	.022	.126	.168
LRP2				.404	.382	.304	.166	-.194	.066	-.051
LRP3					.763 *	.438 *	.271	-.417	.011	.104
SC1						.352	.112	-.417	-.100	.020
SC2							-.194	-.208	.357	.031
SC3								.124	-.179	.452 *
ST1									.344	.032
ST2										.076
ST3										

[a] COM - expert system; LRP - Land resource planner of high skill; SC - Soil conservationist of moderate skill; ST - Land resources university student of low skill.

Discussion

Expert system performance

The results show that the expert system rule base simulates the decisions of an expert. The expert system explicitly identifies the expert's rules that are used during a land capability assessment and provides a check on the subjective assessments of experts. Experts may use incorrect, imprecise or incomplete

information to reach a decision. The system ensures that a complete data set to give a correct capability assessment is collected. The rigidity of the expert system led to a more consistent performance that was not matched by the experts (including the "gold standard" expert). Experts may be inconsistent by using the easily observable land attributes rather than more reliable and detailed data, and may overlook land degradation features such as impervious layers within soil profiles, induced soil acidity or soil structure decline. The expert system will not give an answer unless all the data required for the system to run is entered.

The system was not a perfect simulation of the expert as the rule base was biased by the system developer's own knowledge of land capability. The system at this stage is a hybrid knowledge base which in terms of the simulation of the expert is sub-optimal but never-the-less is grouped with the highest skilled experts (Table 1). The single expert greatly simplifies the knowledge acquisition process as there is no need to aggregate different opinions. Different experts may arrive at the same solution, but their decision paths may be dissimilar (i.e. use different partial data sets). In prototype development. the single expert provides a basis for the construction of the rule bases. However, full operating systems may be better served by incorporating the knowledge of an expert panel who identify when additional rules are needed or when there are errors.

Suitability of the expert system structure to practical land capability assessment

Caution must be exercised in the use of this system in practical land assessment. System representation of knowledge in the rule base format was the easiest to implement as the simple "IF - THEN" structure closely represents the linguistic description of assessment processes used by the expert. However, part of the difficulty in identifying the operation of the rules was the precise description of the levels within each land attribute. A logic programming approach using fuzzy set theory may aid the interpretation of attribute intergrades. The system must be used by land management professionals. The intent of the expert system was not to replace the expert in the field but to be an aid to the processing of large amounts of data and to formalise the heuristic judgements of an expert. Consequently, the system is not suitable for general use by untrained land users (as for all expert systems). The expert system cannot be used outside the test area. Each region has an unique set of environments and management requirements which need another unique. albeit similar, expert system. Software constraints led to the expert system having hidden implicit knowledge which gave a "black box" appearance to the answer provided by the system. There is a risk that the expert system output will be accepted as a matter of faith by the user. It is imperative that the full set of rules used to determine the land capability are outlined in the expert system solution.

However, the initial success of the system in simulating a single expert's judgement for this region implies several practical applications to agricultural land management. First, similar expert systems may be developed for other regions which may have a similar level of performance. Secondly, the training of land management professionals for agricultural land capability assessment is example based, with greater skill being developed with experience. The advantage of the expert system is its explicit description of the factors and rules used to interpret the land attributes during a land capability assessment. The expert system will provide a useful learning tool for land management professionals moving to new areas. Thirdly. land capability forms part of the information used in land use decision-making in NSW. However, the subjectivity of land capability assessment is often a source of conflict. Expert systems tailored to their specific regions will significantly increase the consistency of interpretation, as well as explicitly indicate the reasoning and criteria used. This formalisation of judgement is the most important advantage of expert systems.

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