A COMPUTERISED SYSTEM TO SUPPORT ENVIRONMENTAL MANAGEMENT IN AGRICULTURE

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Abstract

This paper describes a computer-based system to support environmental management in agriculture. The overall aim of the system is to encourage and promote environmental responsibility through good agricultural practice with a profitable farming business. The system enables the user to assess environmental performance of a specific farm by comparison with sound practice and good housekeeping. The user can evaluate environmental impact by estimating environmental burdens using in-built mathematical models, expert systems, databases and utilising statistical information drawn from over a hundred years of agricultural research. A simple scoring approach has been used to quantify the scale of the impacts. A fully integrated hypertext advisory system has been developed to support these performance evaluations and also to aid the farmer navigate the wealth of information, science and legislation that is available.

This paper details the system design and reports the progress to date.

Introduction

The commitment to good environmental management still relies heavily on voluntary action. Much sound guidance has been published to help the agricultural industry adopt good environmental practices (e.g. 1-6) and a formal environmental management scheme, BS 7750 (7), has been available to the industry since 1992 although guidance on the use of this scheme is only now becoming available (8,9). Generally, the industry has been slow in adopting such practices, only making changes when forced by legislation. However, public and supply chain pressures are now becoming increasingly strong driving forces in the move towards more environmentally sustainable practices and the promotion of the concepts of 'Integrated Crop Management' and 'Environmental Audit' (10) by the LEAF organisation (Linking Environment and Farming) have further helped to raise environmental awareness throughout the agricultural sector.

Adequate environmental information is already available to the farmer. The problem facing the farmer, however, is how to distil this information into a coherent action plan to improve environmental performance without jeopardising profitability. This paper describes work being undertaken by the University of Hertfordshire in collaboration with IACR Rothamsted and ADAS to develop the practical decision support necessary to facilitate good environmental management in agriculture. The decision support system provides (i) structured access to the main official sources of guidance providing linkages and cross-references between individual published texts, (ii) technical support in the form of predictive models and 'expert' systems and (iii) a farm performance evaluation scheme based on audit and expert system evaluation.

System Overview

The system is being developed for use on Personal Computers running under the WINDOWS operating system. The general scope of the system is to provide an environmental assessment package which could examine all aspects of a farm's performance with respect to the environment but would initially concentrate on arable farming and intensive livestock farming practices. The system provides a basic audit in the form

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of a computerised questionnaire, linked to the environmental impact identification and evaluation routines and fully integrated with the information advisory and technical support sub-systems (figure 1). Each sub-system has been developed as a stand-alone module which can be decoupled from the main system and used independently.

It is expected that the principal users of the system would be agricultural consultants, specialists and managers of large farm holdings.
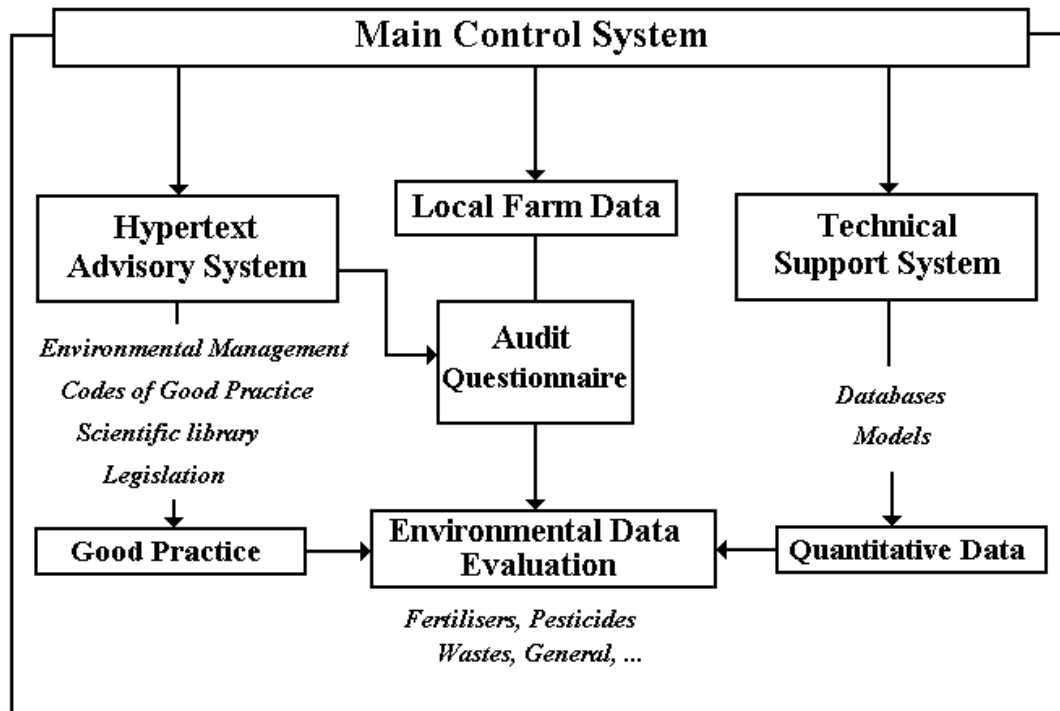

Figure 1. System Structure

Advisory Sub-System

The advisory mode of the software provides a library of information on:

Environmental Management. This section gives guidance on the application of environmental management systems to agriculture. It concentrates on the BS7750 and ISO systems. The European Eco-Management and Audit Scheme (EMAS), although not currently applicable to the agricultural industry, is included for completeness. A practical guide to agricultural auditing will be developed plus a glossary of terms. The information has direct context-sensitive links to appropriate supporting information elsewhere within the advisory system.

Codes of Good Agricultural Practice. Source material has been transcribed from a series of UK Government publications (1-6) which give clear guidance on what constitutes good practice in order to protect the environment. The codes have been reproduced in a hypertext format with context sensitive links to connect the codes to each other and to appropriate legislation and other library information.

Legislation and Regulation. This takes the form of a database holding information on UK and EU environmental legislation for England and Wales. Other legislation, not specifically environmental but still

appropriate in some areas (e.g. the spillage of slurry onto a public road may be an offence under the Highways Act 1980) is briefly summarised and a full reference given.

Library Information. This is presented as a series of scientific reviews detailing the current thinking on the science behind agriculture. Full hypertext links are provided to other parts of the advisory system. Information is being included on:

Agricultural air emissions
Forestry and habitat management
Nitrate and phosphate leaching
Biomass crops
Resource conservation (energy, water and raw materials)
Waste management
Set-aside management
Soil erosion

Additional Information. This is being developed to include a general index, contact information, a glossary of terms, an on-line user guide and a tutorial.

Technical Sub-System

This sub-system is being developed to include mathematical models, expert systems and databases designed to generate quantitative data. Each individual model will have two modes of operation. The first will be interactive, allowing the user to analyse their own operations and to explore what-if scenarios. The second will be remote usage by the *Evaluation* sub-system to assess and calculate environmental burdens.
Models being considered for inclusion are:

Nitrate and phosphate leaching
Soil erosion
Pesticide attenuation in soils
Atmospheric dispersion

A waste management advisor has been developed as part of the technical sub-system. The prototype advisor is built mainly on textural information although it is planned to progressively incorporate expert system type rules into this system. The agricultural wastes covered include animal wastes (e.g. slurry, manure, sewage sludge), crop wastes (e.g. tops, straw, vegetable washings), chemical wastes (e.g. sheep dip, veterinary wastes), workshop wastes (tyres, oil), packaging (plastic sheets, paper sacks) and miscellaneous wastes such as wood and contaminated soil. The system indicates the environmental and health and safety risks associated with each waste and provides information on options for source reduction, re-use and recycling, treatment and ultimate disposal. For organic manures, information is also provided on how to develop a waste management plan and help is given in identifying areas and times when spreading should be restricted and on how the waste should be stored prior to spreading. A calculator template is provided to define the minimum area of land upon which the manure can be safely spread.

Reference databases hold soil, climate and other data at a 25 kilometre resolution across England and Wales. Specific data refer to soil type, erosion risk, nitrate leaching potential, mean annual rainfall, mean average temperature, prevailing wind direction and speed. Whilst it is recognised that this information is at a rather coarse resolution, it will provide baseline default values, for evaluation and modelling, when the user is unable to specify precise local conditions.

Evaluation Sub-system

This mode provides the assessment of environmental performance and environmental impact. The first stage of the assessments the user input of local farm data. These data include the farm's geographic location, size, local climate, soil types, soil nutrient analyses and pH and an outline of farming operations. Other information such as the nearby presence of surface water, woodlands, environmentally sensitive areas or archaeological features are also input at this stage. The second stage of the assessment requires the user to answer an audit questionnaire. This questionnaire will establish current practices and enable these practices to be evaluated against good practice standards or regulations. The audit is divided into sub-audits each addressing a particular issue:

Fertiliser management
Pesticide management
Soil management
Habitat conservation
Energy management
Waste management
Animal welfare
etc.

Performance evaluation is undertaken on the audit response through scoring the answers against objective criteria. These criteria have been set through an expert system approach. The kernel of the expert system rule base was established from UK Government publications including the MAFF Codes for Good Agricultural Practice , (1-3), Codes of Recommendations for the Welfare of Domestic Fowls and Pigs (4,5), Codes of Practice for the Safe Use of Pesticides on Farms and Holdings (6) and Fertiliser Recommendations for Agriculture and Horticultural Crops, RB209 (11). Additional heuristics, where necessary, were elicited from leading practitioners in the industry. The expert system works by returning a numerical score in the range +10 (maximum positive impact) to -10 (maximum negative impact) from each relevant rule for each individual practice or action. A score of 0 represents an environmentally neutral practice. To date, over 300 rules have been compiled, an example of which is given below:

Rule: Nitrogen Application Rates (Nitrate leaching)
This rule compares actual soil mineral N quantities with that recommended by RB209 (11). Recommendations are crop specific and consider soil type, the quantity of mineral N already in the soil either by analysis on based on the previous crop and any organic manure, sewage sludge or other soil conditioner applications. The scoring system is based on the relative error on the recommended application.

Score $(s1)$ = integer [10 x (recommended - actual) / recommended)]
where if $|s1| > 10$ then $|s1| = 10$

Clearly, if less fertiliser than recommended is applied, the potential for leaching is low and the possibility of consequent environmental impact is small. Although this results in a positive environmental impact from this rule, this does not imply that it is in fact good practice. Crop yields may suffer and soil degradation may occur. Resultant soil degradation is accounted for in a separate rule based on satisfying the minimum fertiliser maintenance levels.

An overall performance assessment is achieved by aggregating the individual scores from all applied rules into a single performance parameter S:

$$S = \sum_i (s_i . w_i)$$

where w_i is a weighting factor describing the relative importance of each rule against all the others. Currently the w_i have been set according to the authors' best opinion. These default values are not considered prescriptive and will inevitably evolve as wider expert consensus is reached and more practical understanding is gained. If a system user has good reason to override the default values then he/she should do so.

The overall performance indicator, S, provides the comparative measure of environmental performance and provides the farm with a local baseline upon which an assessment of environmental improvement can be based.. The methodology will generate S indices most precisely when the evaluation is performed on a field by field basis, although aggregated whole farm values can equally be estimated. A positive S indicates a probable overall beneficial affect on the environment with a negative S implying a probable detrimental effect. The value S = 0 (environmentally neutral) might be taken as indicative of the threshold of sustainability.

The performance scale, S, does of course depend very much on value judgements made on the relative importances of diverse effects and practices. Although these value judgements have been made to best reflect expert opinion, there is no right or wrong answer for any of them and, as such, can not provide absolute judgement on the farmer. The scale does however provide an objective criterion for the farmer to work to in monitoring the continuous environmental improvements demanded of the formal environmental management schemes and allows comparisons to be made with 'model' farms where good environmental practice is assumed.

Conclusions

The drive towards increasing environmental accountability is progressively impacting on the agricultural industry. The farmer is becoming faced with complex decisions on how best to improve environmental performance without jeopardising profitability. A decision support system has been developed to help facilitate such decisions. The means for a structured farm evaluation provides a tool for realising the commitment to good environmental management. Recommendations arising from this evaluation are supported by sound evidence,. This is provided through cross referencing the evaluation system with the source literature that provides the basis for the rules. Context sensitive mapping provides hypertext jumps from the evaluation results directly to the relevant source material. These sources of guidance can also be accessed independently of the evaluation system.

The system prototype is currently under evaluation by leading practitioners from the farming industry. The information and rule bases within the prototype have been focused on England and Wales, however it is believed that the concepts should be generally applicable.

Acknowledgements

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