A COMPUTERISED DECISION MAKING AID FOR ENVIRONMENTAL MANAGEMENT IN ARABLE AGRICULTURE

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will be presented at IAIA' 96 Portugal in June

INTRODUCTION

In the past the environmental consequences of arable agriculture were often accepted without question. However, there is now increasing debate and public concern regarding the short and long term environmental impacts that might occur as a result of farming practices. Concern, within arable agriculture, is especially focused towards the over-ambitious use of fertilisers and the consequence of nitrate leaching, the use of pesticides and their environmental impact and the loss and degradation of soil as a resource through poor practices. Increasingly stringent regulations and supply chain pressures are now forcing farmers to assess their current practices and, in some cases, substitute current techniques with more environmentally acceptable alternatives. Farming needs to become an integral part of the environment and not peripheral to it.

The problems of how to achieve environmental improvements whilst still ensuring a profitable business presents a challenge to the farmer. The decision making process requires careful appreciation of all the risks and benefits. Environmental protection needs to be balanced against cost of implementation. The farmer needs to be able to assess his current situation and identify potential areas for change and in many cases expert help is needed. However, there is no shortage of information, much published practical guidance is available. The real problem facing the farmer is how to use this information to develop a coherent action plan for his or her specific situation. The answers are rarely straightforward, many factors are inter-related and inter-dependant and often depend on value judgements rather than hard facts. Environmental assessment activities can be a significant problem requiring multi-disciplinary expertise and it is probably unrealistic to expect farmers to have this expertise. For example, farmers need to assess the need to use pesticides on a regular basis both from a business view point and an environmental one. This involves a large number of decisions regarding the economics versus the risk to yields, the choice of pesticide and its potential for environmental harm, when to spray and how much to spray. In addition, other factors should influence the decision such as the areas pest history, weather and soil conditions and the local environment such as the proximity of surface waters, ground waters, conservation areas, public access areas and the protection of predator species.

The commitment to good environmental practice still relies heavily on voluntary actions. Market pressures are having some influence on the industry. Major supermarkets are developing environmental codes of practice which their suppliers of fresh produce must meet. Consumers are more environmentally aware, demanding high quality produce free of pests and preferably free from pesticide residues. Again this places conflicting demands on the farmer - how do you produce quality pest-free produce with out the use of pesticides?

The University of Hertfordshire, in collaboration with ADAS and IACR-Rothamsted, is currently developing a computer-based system to support environmental management in agriculture and to assist in overcoming some of the problems highlighted here. The project is funded by the UK's Ministry of Agriculture, Fisheries and Food. Other advantages offered by the computerised system include a fully integrated contextual information and advisory system to support the decision making process plus a technical system for exploring 'what-if' scenarios and identifying ways of minimising environmental impact in a no-risk situation. Figure 1 below shows a schematic of the computerised system.

ENVIRONMENTAL MANAGEMENT IN AGRICULTURE

Assessment of the principal significant environmental effects of arable agriculture in the UK identified three major causal activities and so three major activities which required monitoring and measurement at farm level. These are:

- the use, storage and handling of fertilisers both man-made and organic;
- the selection, usage, handling, storage and disposal of pesticides; and
- soil management.

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This work is funded by the UK's Ministry of Agriculture, Fisheries and Food. The views expressed are those of the authors and not necessarily those of the Ministry.

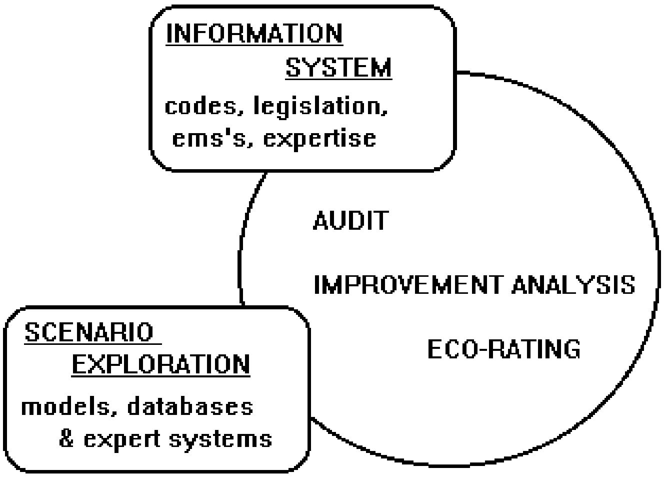

Figure 1: Schematic of the Computerised System

However, there are many other activities associated with arable farming which need to be considered in order to gain a measure of overall environmental performance. These include energy and water use, resource and waste management and farmland conservation.

Environmental evaluation needs to set objective criteria against which actual performance can be judged. Such criteria can be set empirically as specific targets of environmental policy or can be expressed more generically in terms of time-based assessments or against assessments of a 'model' farm where good practice can be observed. Comparisons against a 'model' farm, however, pose a new set of problems. No two farms are identical. As well as having differing combinations of activities, other important factors will also vary such as soil type, climate and geology. Some farms may have surface water close by or woodlands, others may be in environmentally sensitive areas and all these factors effect the intensity of the environmental impacts. For example pesticides which are considered extremely harmful to aquatic life will have a less impact on farms with no surface water close by compared to farms which do. It becomes evident that a more absolute measure of good practice is required.

The computerised system being described in this paper uses an eco-rating as a measure of good practice. For each farm activity (use of fertilisers, pesticides, energy, waste etc.) a separate rating is developed by comparison of actual performance with performance currently perceived as sound. A measure of the farm's overall performance is then determined by combining and weighting the various independent eco-ratings (figure 2). This allows the farmer to easily pinpoint areas which require improvement. An important requirement of any quantitative evaluation system is a mechanism to enable all the different activities to be combined in a rational, reproducible and acceptable manner. One commonly used approach, and that used in this system, is a simple scoring method, each activity, impact or indicator is assigned a numerical score based on its magnitude or significance, with the total score representing the total impact. Examples of this are often cited in environmental impact assessments (Leopold *et al*, 1971, Solomon *et al*, 1977) and tend to be criticised for being simplistic in approach. However, this method does offer a good starting point and in many cases the only practical means where the underlying complexities are not fully understood.

Using standard and nationally accepted guidelines on environmentally sound practices a rule-base has been established for each of the major activities which require monitoring and control. Associated with each rule is the score range (say +10 to -10) reflecting maximum benefit to maximum harm. The half-way mark (0) indicates an environmentally neutral practice and, an indication of the threshold of sustainability. Actual farming operations are then compared with the rule-base and an eco-rating is established. In practice, the system has been designed to be used annually aiming, over time, to ensure continous improvements in environmental performance and so push the overall farm eco-rating as far into the positive as possible.

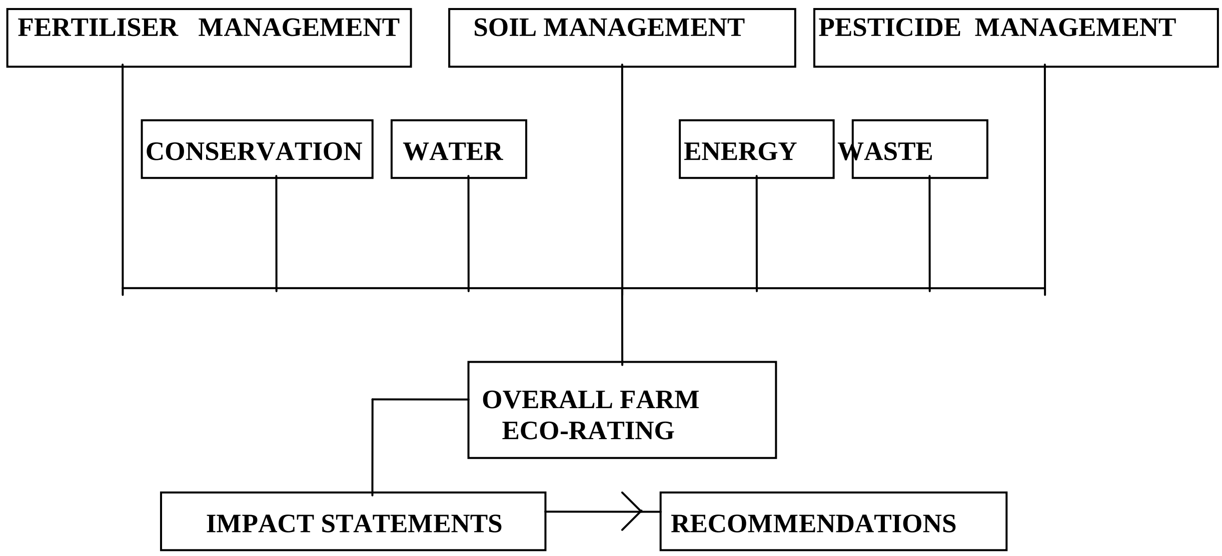

Figure 2: Structure of the Overall Farm Eco-rating

Two different approaches were taken in the scoring methodology. As the system has a broad base, a balance was required between the quantity of input data and the quality of the output results. If the system is to be useable the input data need to be readily available and the system reasonably quick to use. If data entry is too tedious the tool may lose some of its potential.

The inappropriate use of fertilisers significantly contributes to nitrate pollution and the contamination of drinking water supplies. Fertiliser use also contributes to excessive concentrations of phosphate in surface waters within the UK resulting in eutrophication. In addition, many major water pollution incidents occur every year due to farms having inadequate storage facilities. Quantitative recommendations for the amounts and application timing of crop nutrients are available to farmers in varying formats, one of the most commonly used is that produced by the UK's Ministry of Agriculture, Fisheries and Food (MAFF, 1994). This booklet has been the basis for the fertiliser eco-rating. Actual field applications of nitrogen, phosphate and potash are compared with that recommended in the booklet considering soil type and existing soil nutrient levels. Using a simple relative error calculation a base line for the eco-rating can be established (equation 1).

$$S_F = (F_R - F_A) / F_R \qquad \text{..... Equation 1}$$

Where: S_F is the baseline eco-rating for fertiliser use. F_R is the recommended fertiliser application in Kg/ha and F_A is the actual quantity of fertiliser added in kg/ha.
This factor S_F is then enhanced by considering other factors such as rainfall, soil porosity and the proximity of surface water to, simplistically, establish a measure of the environmental impact particularly with respect to nitrate leaching. Recommendation's for application techniques, storage and handling of fertilisers are available to farmers in a range of publications. These include the Code of Good Practice for the Protection of Water (MAFF, 1991) and the Code of Practice for Handling Fluid Fertilisers (FMA, 1995). Rules and heuristics have been elicited from these and other publications such that a measure of the farmers responsibility with respect to the application and management of fertilisers is reflected in the eco-rating.

All pesticides in the UK carry mandatory label precautions relating to how and where the pesticide can be used. If the chemical is used in accordance with these precautions the environmental risk is minimised. Nevertheless, a significant number of pesticide poisoning incidents occur each year (MAFF 1995) and public concern regarding residue levels in fresh produce and in water supplies is rising. Assessment of the farmer's use of pesticides and the possible environmental impact is achieved using a multi-criteria approach looking at the pesticide selected, how it is applied, storage, handling and waste management plus a simplified measure of the farmers need to spray. The pesticide rule-base has been developed using the label precautions on 500 commonly used fungicides, insecticides, herbicides and rodenticides in arable agriculture. The system checks to see if actual farm practices compare favourably with official recommendations. For example some pesticides are labelled as particularly dangerous to fish. If this pesticide has been used by the farmer in a field close to surface waters then he or she will be penalised by a significantly lower eco-rating, unless of course, no alternative pesticide is available and considerable care in application has been demonstrated. The scoring methodology used considers a wide range of parameters including the concentration of active pesticide ingredients used, the local farm profile (soil type, weather, presence of environmentally sensitive features etc.), several physico-chemical properties of the pesticide reflecting its rate of soil degradation and mobility and its formulation. The main source of this information was the UK Pesticide Guide 1995 (BCPC 1995). Other rules concerning the application, handling, storage and waste management of the pesticides have been developed using UK legislation, again the Code of Practice for the Protection of Water (MAFF, 1991) and the UK's Department of the Environments Code for the Safe Use of Pesticides (DoE, 1990)

Both the fertiliser and pesticide assessment routines base the determination of their eco-ratings on quantitative data, that is field application rates and quantities of active ingredient applied. The majority of the other routines make greater use of qualitative and observational data, although is some cases, for example energy, the assessment does involve usage quantities.

The kernel of the rule base for soil management was the Code of Good Practice for the Protection of Soil (MAFF, 1993). Soil resources have deteriorated rapidly over recent years due mainly to socio-economic development and population pressures (Council for Europe, 1992). Although the effect of these pressures has not been so profound in the UK, the farmer must protect against soil degradation if he is to strive for sustainability (Johnston and Lewis, 1995). The Soil Code provided the rules governing legislation, soil fertility and both physical and chemical degradation. Although the Code does provide some guidance to farmers on soil erosion, a fully comprehensive data set was more difficult to collate. Scientific understanding, although well advanced, has been less well transferred to the farmer. A literature search provided a host of information which was then assimilated and common consensus amongst authors formed the bulk of the rules (Evans, 1990a, 1990b). A similar problem existed with energy management and farmland conservation. Again the Air and Water Codes (MAFF, 1991, 1992) provided some assistance with the rule base development. Additional information was obtained from sources such as the Energy Efficiency Office (Best Practice Programme, 1992, 1994) and conservation bodies such as the Farming and Wildlife Advisory Group (FWAG, undated). Currently the rule-base developed contain close to 600 rules.

Although the eco-ratings provide the system user with elementary indicators of environmental performance, the computerised system goes much further towards environmental assessment. Each rule has associated 'consequences' attached to it, allowing textual information to accompany the eco-rating. For example each unit measure of electricity used can be associated with a net release of carbon dioxide or for every excess of nitrogen fertiliser applied to the soil an estimate of nitrate leaching can be made. This information, although again simplistic in nature, is presented to the user as impact statements and, from this, areas which require improvement can be easily identified.

In support of these recommendations the system also incorporates a number of modules which allow the user to explore 'what-if' scenarios in a no risk situation. For example a module on fertiliser use allows the user to study how nutrient requirements change with changing soil type, crop and organic manure applications. Another module gives advice on waste management. Also included are databases on typical soil type distributions and climate data for England and Wales. A contextual help system has also been integrated into the whole system. This offers two modes of operation. Firstly it provides instant on-line help to the user regarding operation of the system. Secondly, and more importantly, it provides a comprehensive advisory system for agriculture and the environment containing information on UK and EC legislation and regulation, a library of short textual files explaining the science behind agriculture, glossaries, information on formal environmental management and a contacts database.

CONCLUSION AND RECOMMENDATIONS

The computerised system described above acts as an informal environmental management system having the same objectives as formal systems such as the British Standard BS7750 (BSI 1994) or the draft ISO 14001 system (ISO 1995) in as much as it aims to encourage continuous improvements in environmental performance and seeks to identify and control significant impacts. However, this informal approach does not involve as much prescriptiveness or expense, does not require formal accreditation nor public declarations. Consequently, this approach tends to be more attractive to smaller companies and those, such as farms, which are run on less formal procedures.

Other organisations, such as LEAF (Blake, 1994), have developed informal approaches to environmental management with respect to agriculture typically through check-list type questionnaires. The LEAF approach is effective in the fact that it is broadly-based, however, it is essentially qualitative in nature and as such can only act as a catalyst for thought. As no analysis of the results is carried out it relies entirely on the users interpretation and the correct voluntary action. In addition, the qualitative nature of the audit questionnaire can only hint at possible environmental impacts, as transition into quantifiable performance indicators is not possible. The system described in this paper is the next step in farm appraisal.

Conference Recommendation: Computerised techniques offer a valuable opportunity for introducing simple EA techniques to a wider audience.

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