ENVIRONMENTAL MANAGEMENT FOR ARABLE AGRICULTURE: AN ECO-RATING SYSTEM FOR PESTICIDE USE

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ABSTRACT

The University of Hertfordshire, funded by MAFF and in collaboration with ADAS and IACR-Rothamsted, is currently developing a computer-based decision support system to encourage and enhance best practice within arable agriculture such that environmental protection can be given a high priority without jeopardising profitability. A significant part of this system is focused towards the use and management of pesticides to ensure that protecting the crop does not conflict with protecting the environment. The software system aims to assess the farmer's use of pesticides. Using a multi-criteria approach, field techniques, pesticide choice and management practices such as storage, waste management and machinery calibration are all assessed. Although the system concentrates on field applications for crop protection, it also examines non-crop pesticides such as biocides and rodenticides. The eco-rating is derived by comparing actual practices with rules and heuristics describing best practice. Simple ranking and scoring techniques are used to derive an indicator of environmental performance with respect to the farmers use of pesticides.

INTRODUCTION

All pesticides in the UK carry mandatory label precautions regarding safeguards that are necessary when using these chemicals so that humans, wildlife and the environment in general are protected. These label precautions are assigned by the Pesticide Safety Directorate within the UK's Ministry of Agriculture, Fisheries and Food (MAFF) based upon comprehensive scientific data supplied by the product manufacturer. If the chemical is used in accordance with these precautions then environmental risk is minimised. Nevertheless, the use of these chemicals and their environmental impact is causing public and governmental concern. In 1994, over 830 pesticide poisoning incidents were registered by MAFF (1995), public concern is rising regarding pesticide residues in fresh produce and the National Rivers Authority recorded around 40 pollution incidents directly attributed to agricultural pesticides during 1993 (NRA, 1994). The UK Government has an established policy for optimising pesticide use and the safe management of these chemicals is given high priority by regulatory bodies (MAFF, 1996).

Compared with many other industries, agricultural practices at farm level are relatively unregulated. Few control procedures are in place to regulate either the quantity of chemicals applied to the land or the application techniques used. The need for the agricultural industry to apply best practice is clearly apparent. The introduction of environmental management systems such as BS7750 marked the beginning of a commitment to environmental management for many industries but not for agriculture. Maybe this is because the costs and effort required to introduce these systems is not seen to balance the few perceived market benefits.

There is substantial information on the environmental fate of pesticides, best practice and on environmental science in general. Guidance to farmers is available in a number of publications (e.g. MAFF, 1993). However, the uptake and implementation of this information appears to be slow (ACBE, 1996). One of the main reasons for this is that effective environmental protection is site specific. No two farms are identical; different crops are grown, various activities undertaken and there will be differences in soil type, underlying geology, climate and the presence of features such as surface water, groundwater's, woodlands and other habitats. Consequently, the general information available is rarely sufficient to allow the farmer to develop a coherent action plan specific to the farm. Much of the problem seems to lie with technology transfer. The information available is often produced by scientists for scientists or for policy makers and not in a format readily suitable for farmers. There is a need for a decision support system available which will help the farming industry distil information and produce a coherent action plan specifically designed for their own farm which will not jeopardise profitability, balancing implementation costs and environmental benefits.

OVERVIEW OF A DECISION SUPPORT SYSTEM FOR ARABLE AGRICULTURE

The University of Hertfordshire is currently developing a computer-based decision support system to encourage and enhance sound environmental management within arable agriculture. Like formal environmental management systems, the computerised system aims to assess current performance, encourage improvements, identify significant effects and determine estimates of emissions in the form of an inventory. Performance is measured by comparing actual practices with what is perceived to be best practice. The major activities of arable agriculture which significantly impact on the environment arise from the improper use of fertilisers, pesticides, from unsustainable soil practices and from changes in land use. Consequently, the system focuses on these areas. However, in order to ensure that whole farm assessments can be carried out and to give a more integrated approach to environmental protection, other modules allow more marginal activities to be assessed such as energy and water efficiency, resource and waste management, conservation and the management and welfare of intensively kept livestock. Individual eco-ratings are determined which are weighted and aggregated to give a single index relating to the farm. The system has three modes of operation. The core of the system is the assessment routines. However, in support of this there is a second operational mode known as the '*technical system'* which consists of a collection of modules allowing the user to explore 'what-if' scenarios. The third mode is a fully integrated information system that is context-sensitively mapped to enable quick data identification. Each farming activity (i.e. use of fertilisers, pesticides, etc.) has one or more elements in each operational mode. This paper describes the development of the project with respect to a farmer's use of pesticides. Other aspects of the system are described in previous papers (Lewis *et al*, 1996a, 1996b)

PESTICIDE ASSESSMENT

Environmental performance with respect to a farmer's use of pesticides is represented within the system by the determination of a numerical eco-rating. Assessment is divided into two main parts: (i) assessment of field by field applications; and (ii) management techniques.

The eco-rating system

Generally, within the system the eco-rating used spans a positive-negative scale. Positive values represent an environmental gain, negative values represent environmental damage whereas the zero point indicates a neutral activity and the threshold of sustainability. With respect to the use of pesticides on arable crops, although there may be financial gains via increased yields and produce quality there is rarely a true environmental gain. Best practice therefore means a zero rating and the scale spans zero to a theoretical negative minimum. In contrast, for example, during the assessment of farmland conservation the selective control of grass weeds in a flower meadow or the careful use of pesticides for aquatic weed control to improve a watercourse would represent a true environmental gain. Therefore the eco-rating for conservation would span the full positive-negative scale.

Field applications of pesticides for crop protection

A database has been established which holds information on over 500 pesticides including insecticides, herbicides, fungicides and adjuvants commonly used in arable agriculture. Data is held by product brand name and information regarding approved crops, active ingredients and their concentrations within the formulation is stored. Also stored are data on maximum approved application rate, maximum number of applications and label precautions assigned by MAFF's Pesticide Safety Directorate derived from toxicity and other data provided by the manufacturer. The bulk of this data was obtained from the 1996 UK Pesticide Guide (Whitehead, 1996).

With respect to active ingredients a range of physico-chemical parameters are also stored which influence the environmental risk. Also stored are expert system rules representing best practice and regulations. Equation 1 is used to derive the pesticide eco-rating P-EMA. This is determined for each pesticide applied to the crop, weighted by application rate and summed to produce a field value. Each field value is then weighted by field size and aggregated to give a whole-farm value.

$$\text{p-EMA} = L_{SER} + \sum_{i=1}^{n} (E_i \, . Q_i) \qquad (1)$$

Where: L is the score derived from the label hazard relevant to the non-target group SER. E_i is the score derived from assessing the pesticides potential environmental impact based on its physicochemical properties. Q_i is the proportion of active ingredient in the pesticide formulation

The equation has two parts. The function (L, SER) provides an eco-rating specific to the product formulation. L represents a value derived from the label precautions. A system of around 85 label warnings is currently in use. These can be sub-divided into those effecting different non-target groups (known as 'Sensitive Environmental Receptors or SER's) such as humans, wildlife, bees and aquatic life with some labels falling into more than one group. Each label has been assigned a numerical score representing the level of environmental hazard. An example of this is shown in table 1.

Table 1: Examples of Label Precautions and Assigned Weighting Values

Hazard	**Caption**	**Receptor Group**	**Score**
48a	Extremely dangerous to bees...	Bees	- 5
48	Dangerous to bees ...	Bees	-4
47	Harmful to bees ...	Bees	-3
-	*none of the above, no label specific to bees*	Bees	0
51	Extremely dangerous to fish ...	Aquatic	-5
52	Dangerous to fish ...	Aquatic	-4

The scores within each receptor group are then summed and weighted according to the local site variables and conditions under which the pesticide was applied. For example if the field being assessed has surface water close by then the weighting factor attached to the aquatic receptor group would be 5 whereas if no surface water were present the value would be 0. Consequently the site-specific risk is more properly represented.

The second part of the equation (E_i . Q_i) is derived from the physico-chemical properties of the active ingredients with the product. The value E_i is calculated for each active ingredient weighted by the proportion within the formulation (Q_i) and summed. A range of parameters has been chosen to reflect the environmental fate and potential for damage of the active ingredient. These include solubility, vapour pressure and soil half-life. The octanol-water partition coefficient K_{ow} is used to reflect bioaccumulation and the organic-carbon partition coefficient K_{oc} used within the GUS formula (Gustafson, 1989) to represent mobility and groundwater risk. The data for each parameter is classified into one of five risk bands (very high, high, moderate, low and very low) and assigned an appropriate rating value. E_i is determined by summing the parameter scores.

Once all the product values have been derived, practices are compared with regulations and the eco-rating adjusted accordingly. For example, checks are done to ensure that the maximum dose of pesticide and the maximum number of applications have not been exceeded. This methodology allows a complex activities to be assessed including illegal off-label applications, low dose and low volume spraying and tank mixes including the use of adjuvants.

Management practices
The environmental risks associated with pesticide use come not only from applications but also from management practices. These include storage, handling, waste management, application techniques, pollution prevention activities and machinery calibration. Due to the non-quantitative nature of the data a different approach to the one previously described was required to determine the eco-rating. A multiple-choice questionnaire is used. This is divided into sections e.g. waste management, storage, training, protection of field margins and application techniques, and options of both good and bad practices are given each rated according to the perceived environmental risk. The users choices are then assessed, scored on the eco-rating scale and a report produced. A similar methodology has also been used to assess the farmers use non-crop pesticides such as biocides and rodenticides.

The Technical System
The Technical part of the Decision Support System has been designed to assist the user to identify practical, cost-effective ways of improving their eco-rating. A simple module, *'The Pesticide Informer'* has been developed which helps the user identify the most appropriate, approved pesticide for a specific job which will have the minimum environmental impact. Assistance on pesticide waste management specifically waste minimisation and approved disposal of concentrates, dilute solutions and empty containers is available with the '*Waste Management Advisor'* module.

The Pesticide Informer module uses an icon system to highlight any environmental hazard associated with a specific pesticide. For example, if the pesticide presents a high hazard to aquatic species a fish-icon is shown, if a high hazard to bees exists then a bee-icon is displayed. Other icons highlight the hazards to groundwater, birds, wildlife and humans, specifically organophosphates, carbamates and chemicals subject to the Poisons Law. This approach offers the user a simple, visual means of identifying a pesticide which will protect the crop without unnecessarily harming the environment. This module is again based upon the pesticide label precautions assigned by The Pesticide Safety Directorate of MAFF and uses the GUS formula to determine the groundwater risk (Gustafson. 1989).

The Information System
The Information System comprises a large range of text files providing instant, on-line access to a wide range of information relating to pesticides and how to minimise their impact on the environment. Within the Legislation Database summaries of various laws and regulations can be found including: The Food and Environmental Protection Act 1985, The Control of Pesticides Regulations 1986 and the 'Authorisation' Directive. The Codes of Practice Library includes the three MAFF Codes of Good Agricultural Practice and the Pesticide Code of Practice (MAFF, 1998). The Science Library includes a text file presenting a brief introduction on minimising the environmental impact of pesticides.

CONCLUSION
The Pesticides eco-rating system and supporting software described here is part of a more general system designed to be used by consultants and farmers to review environmental performance and to monitor progress towards improvements. The system is broadly comparable with the aims and objectives of the more formal environmental management systems such as the UK's standard BS7750 and ISO14001 in that it helps identify priority areas for action, encourages continuous improvements and allows monitoring towards targets and objectives. With respect to pesticides and crop protection the software helps ensure that the pesticide is selected such that the yield and quality of the crop are protected, that all regulations are met, the local environment is protected and that the risk of causing damage is minimised.

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