

ENVIRONMENTAL BEST PRACTICE ADVISORY SYSTEM FOR AGRICULTURE¹

Kathy A. Lewis, John Tzilivakis and Keith S. Bardon

Department of Environmental Sciences, University of Hertfordshire,
Hatfield, Herts, UK, AL10 9AB,

K.A.Lewis@Herts.ac.uk; J.Tzilivakis@Herts.ac.uk;
K.S.Bardon@Herts.ac.uk

Abstract: A computerised informal environmental management system for agriculture is currently being piloted and tested. Based upon the principles of anticipation and prevention the system aims to encourage sound environmental management to ensure that detrimental environmental effects are minimised. The software uses a unique numerical index to assess current performance by comparing actual practices with site specific 'ideal' practices for a wide variety of farm activities. In support of the assessment routines, the system utilises a hypertext information system. Further support is available via a variety of modules allowing exploration of 'what-if?' scenarios to identify cost-effective means of improving performance.

Keywords: Environmental impact; environmental management; decision support system.

1. Introduction.

Agriculture accounts for around 75% of the UK's land area. Of this about 50% is either grassland or rough grazing and the remaining 25% is given up to crops or lies fallow. Agricultural practices with respect to environmental protection will ultimately affect farm quality. If the quality of the land degrades, its financial value will decrease as will its ability to grow crops and so the legacy to future generations will also decrease. However, practices can also affect environmental quality on a wider scale. Contamination of watercourses can seriously disturb aquatic eco-systems and may then contaminate drinking water supplies. Odours and other gaseous emissions such as methane, nitrous oxide and ammonia not only affect local air quality but may also contribute to other effects such as global warming or acid rain.

The types of environmental impact, their intensities and their significance depends on local practices, local decisions and the local site profile. These factors include the type of farm (e.g. arable, dairy, mixed), the soil type, underlying geology (e.g. principal aquifer present), meteorological conditions, the presence or absence of environmentally sensitive features (e.g. waterbodies, woodlands), the amount and choice of agrochemicals applied (e.g. fertilisers and pesticides) and what, when and how day to day farming activities are carried out.

A computer based system has been developed for use by farmers and their advisers to encourage more sustainable practices. The software acts as both a decision analysis and a decision

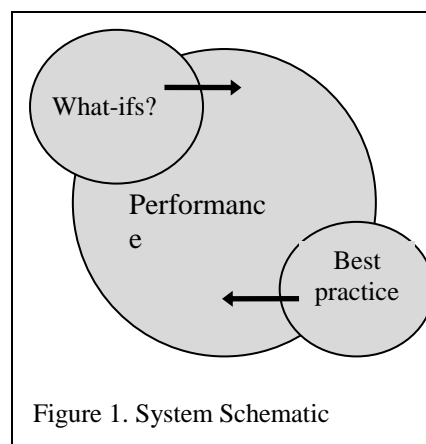
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support system. By analysing past decisions the system can identify strengths and weaknesses in environmental performance and so enable improved future decisions.

2. The software.

The software has three operational modes (Figure 1). The core of the system, the assessment mode, measures environmental performance by deriving unique indices, known as eco-ratings. The second mode comprises a collection of individual modules designed to help identify cost effective, site specific best practice. These modules include fertiliser recommendations for specific crops, a module to highlight the environmental risks associated with specific pesticide active ingredients and a risk assessment module for soil erosion. The final mode is a fully integrated hypertext information system which contains the UK's agricultural codes of good practice (MAFF, 1991a, 92, 93a), the UK's livestock welfare codes (e.g. MAFF, 1993b), other codes of practice, a regulation and legislation database for the UK and the EU, databases containing information on UK soil types and meteorological data, a science library containing files which highlight the agriculture-environment interactions and guidance on agricultural auditing plus glossaries, index and contacts database.

The software is essentially an exercise in technology transfer seeking to boost awareness within the farming industry regarding current understanding of the agri-environmental issues and how they can be controlled. It has been designed to run on an IBM compatible computer having a minimum 486 processor, 16 Mb RAM. The system framework has been written in Visual Basic, as has much of the system core although some C has also been used, the databases have been developed in Microsoft ACCESS. Microsoft Word 6 has been used as the authoring tool for the hypertext files.



3. The assessment system.

The assessment process methodology classifies farm activities into a number of sub-sections (crop production, crop protection, resource management, livestock, etc.) and around each sub-section a separate audit has been developed which elicits information from the user relevant to that activity. The information obtained is scored by comparing it to rules describing best practice for the specific site such that a performance index, known as an eco-rating is determined. Two main types of audit have been used depending upon the type and availability of farm data. Where reliable quantitative data is available on a field by field basis, i.e. fertiliser and pesticide applications, this data has been used to derive a compound index. The software uses application rates, parameters which affect the fate and transport of pollutants in the environment together with simple heuristical models to measure environmental performance.

Where only less reliable data, qualitative or observational data is available then a checklist type multiple-choice audit has been developed and used. This approach has gained favour in the United States where it has been used extensively especially to evaluate wetlands and wildlife habitats (Erickson, 1994). A multiple choice checklist questionnaire is used for information elicitation. For example in the pesticide general management audit the section concerning waste management asks how unwanted pesticide concentrate is disposed of. A range of options are provided from which the user must select those which apply. These options range from best practice to very poor practice and each option has an associated appropriate score depending upon how far that option digresses from the 'ideal'. Scores are then summed across the sub-section.

Final scores within each activity are normalised to lie on a pre-defined scale to aid interpretation and transparency. The eco-rating scale spans a positive maximum to a negative

minimum (± 100). A positive value represents an environmental gain such as improved soil condition or improved wildlife habitats. A negative score represents an environmental loss such as evidence of soil erosion or removal of hedgerows. A zero score then indicates a neutral activity and, possibly, the threshold of sustainability. The system user should seek to modify practices such that eco-ratings are as high as possible. Best practice does not necessarily mean that no environmental impact will occur. In many instances, such as with pesticide use or waste management, best practice can only seek to minimise negative impacts. In these cases the positive part of the eco-rating scale will not be utilised and best practice will produce a score tending from negative towards zero. A separate eco-rating is derived for each sub-activity.

Within the system all default weightings are set to 1. These can be over-ridden by the user to reflect local priorities and issues.

3.1 Crop production.

The main environmental impact that is likely to arise from general crop production is nitrate leaching which results from the over ambitious use of nitrate fertilisers. If an excess of nitrate resides in the soil then there is potential for leaching. The actual amount which will ultimately leach will depend upon the quantity of nitrogen applied, when it is applied, the crop requirements, the soil type and the amount of rainfall. UK policy to avoid nitrate leaching is aimed at encouraging efficient use of nitrate such that economic optimum yields are achieved without leaving a large excess of nitrogen in the soil available for leaching. Key factors for measuring best practice, therefore, focuses on assessing nitrogen application rates, looking at application timing and assessing the leaching risk from soil type and rainfall levels.

The eco-rating system derives the eco-rating score by comparing actual field applications of nitrogen (A) with the recommended rates (R) (MAFF, 1994). A simple relative error calculation derives the baseline score as shown in equation 1. These recommendations take into account the crop requirements, soil nutrient reserves and the soil type.

$$\text{Score} = ((R - A) * 100) / R \quad (1)$$

For example, if maincrop potatoes were grown on a sandy soil with typical soil nutrient levels, no organic manure added and 300 kg/ha N was applied. Standard recommendations suggest that 240 kg/ha would be required for a typical 40 t/ha yield. The baseline score under these conditions would be -25. This score is then decreased or increased according to the perceived risk of leaching i.e. depending on the soil type and rainfall level. If less fertiliser is added than recommended then although a positive score would be obtained with this particular rule, other rules associated with maintaining soil fertility levels may force the score into the negative.

3.2 Crop protection.

A variety of environmental impacts could arise for the use of pesticides. Again the type, intensity and significance will depend upon the site profile. For example, if surface water is nearby then the potential for water contamination will be significantly higher than if there is no water. Although many impacts are associated with crop applications (e.g. drift, damage to non-target species, pest resistance, residues in food) other impacts may arise from poor handling techniques and inappropriate waste management. UK policy on pesticide use is to encourage optimal use of pesticides i.e. to use the minimum amount necessary to achieve a satisfactory solution to the problem with due regard for the local environmental sensitivity. This latter point implies that the pesticide should be chosen to cause minimum impact to the site. The best practice assessment for pesticide use focuses on assessing how well the pesticide selected matches the site profile, how efficient pesticide has been and on the use of integrated crop management techniques (BAA, 1996) such as making better use of crop rotations, careful cultivation's and the use of resistant varieties. Also considered

are issues relating to storage, transportation, waste management, application techniques, training and staff awareness and pollution prevention activities

The software system for pesticides is divided into three areas: (i) assessment of field applications; (ii) general management issues; and (iii) non-crop use of pesticides such as biocides, sheep dips and rodenticides.

Equation 2 is used to derive the eco-rating P_f for field applications. P_f is determined for each pesticide applied to the field crop, weighted by application rate (l/ha) and summed to produce a field value. Each field value is then weighted by field size and aggregated to provide a whole farm value.

$$P_f = LR_{SER} + \sum_{i=1}^n (E_i \cdot Q_i) \quad (2)$$

where:

LR_{SER} is the eco-rating derived from the label precautions (LR) depending upon the site specific sensitive environmental receptors (SER).

E_{ai} is the sum of the scores derived from the physico-chemical properties of the active ingredient (ai).

Q_{ai} is the quantity of active ingredient (ai) in the product formulation as mg/l.

n is the number of active ingredients in the product formulation.

A system of 120 label warnings is currently in use for crop pesticides in the UK. These can be sub-divided into those effecting different non-target receptor groups such as animals, birds, bees and aquatic life, with some labels falling into more than one group. 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 to derive LR_{SER} . Once LR_{SER} has been derived, practices are assessed for regulatory compliance and the eco-rating adjusted accordingly.

The second part of the equation ($E_i \cdot Q_i$) is derived from the physico-chemical properties of the active ingredients within the product formulation. The value E_i is calculated for each active ingredient (ai) within the product, weighted by the quantity within the formulation (Q_i) and summed.

A range of parameters have been chosen to reflect the environmental fate and potential for damage by the pesticide 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 score value. E_i is determined by weighting and summing the parameter scores. The default weighting for each property is set to 1 however this can be adjusted by the user to reflect local priorities if required.

The assessment of best practice for general pesticide management and for non-crop usage a checklist audit has been developed which uses a multiple choice approach, each possible response having an appropriate score depending on how close it is to best practice for that site. Scores are summed and normalised to derive the eco-rating.

3.3 Grassland and grazing livestock.

This audit covers the environmental issues arising from grassland management and those arising from the welfare and husbandry of grazing livestock (beef, dairy, sheep and outdoor pigs). For grassland the system focuses on assessing potential impacts arising from the required inputs such as inorganic fertilisers, slurry and manures, seed and pesticides and the resultant outputs in terms of herbage as livestock feed, emissions, biodiversity and soil quality. The livestock audits considers animal welfare, silage production, management of wastes, emissions and the variety of impacts that may arise associated with these issues and the physical impact that livestock may have on the land such as erosion and compaction.

Due to the observational and non-quantitative nature of the type of data involved, again a checklist multiple choice audit has been used to assess environmental performance and regulatory compliance.

3.4 Intensive livestock.

The environmental effects associated with intensive livestock husbandry (indoor pigs and poultry) can be significant. Large numbers of livestock tend to be kept in relatively small areas which can result not only in welfare problems but also in the production of large amounts of wastes which require safe storage and spreading which should be done considering the environmental risks of nitrate leaching, unpleasant odours and water pollution. Again a checklist audit approach has been used although quantitative data for space has been utilised within the scoring system.

3.5 Soil sustainability.

The modules on soil sustainability seek to ensure that the soil as a natural resource is fully preserved. Within this sub-section there are several smaller audits including those which addresses soil fertility. Key factors here include ensuring that the levels of the major nutrients (N, P, K), trace elements and organic matter are maintained. A further audit assess the farms liming policy and the suitability of the pH maintained to the crop being grown and for biodiversity.

A risk assessment approach has been taken for soil erosion. This includes scoring activities which may contribute towards or protect against soil erosion and looking at the sites potential for erosion such as soil type, topography, soil exposure, crops grown and the prevailing meteorological conditions (wind and rainfall).

3.6 Conservation.

Conservation carried out on a farm will cover a variety of activities. Some are specific to individual habitats such as ponds, rivers or woodlands. Others are more general relating to, for example, the protection of wildlife from farm chemicals and wastes or providing exit routes from cattle grids. The range of habitats present will vary from farm to farm. The computer system being described here divides conservation activities into a number of areas which can be linked in or omitted depending upon the site profile. The areas included are: general farm management, hedges, field margins, grasslands, woodlands and water bodies. Water bodies are further sub-divided into (i) standing freshwater systems such as ponds and lakes and (ii) running freshwater systems such as rivers, streams, ditches and wetlands.

3.7 Resource and waste management.

The resource management audits use checklist audits to assess water and energy efficiency. Within the water audit, irrigation efficiency is assessed, as is general farm water efficiency such as actions taken to preserve, recover and recycle water. A similar approach for energy efficiency is used, looking at the use of low energy light sources and equipment, the use of thermostats, timers and insulation. Both audits include sections on staff training and awareness.

4. Discussion and conclusion.

The system is designed to be used by consultants and farmers to review environmental performance and to monitor progress. The system is broadly comparable with the aims and objectives of more formal environmental management systems such as ISO14001 and the European Unions EMAS in that it helps identify priority areas for action, encourages continuous improvements and allows monitoring in the light of targets and objectives. More specifically the system is:

- generic in the context of agriculture;
- proactive based upon the principles of anticipation and prevention;
- systematic based upon detailed documented procedures;
- provides instant access to a wealth of appropriate and context-sensitively mapped data.

The development of such a software package brings together all relevant information required by the user to ensure that farming practices are inline with current understanding of best practice and where deficiencies are identified, cost effective and practical site-specific solutions can be identified which suit. The major drawback of this system is that it requires frequent updating. Obviously, data such as that within the pesticides database will change frequently as new pesticides are registered and marketed and as others have their licences revoked. Legislation and regulation changes regularly, the MAFF codes of good practice are currently under review and science and technology will evolve. Consequently, current understanding of what is perceived to best environmental practice will undoubtedly change - “a once and for all” definition is highly unlikely. The modular format and the gathering of activity-based rules into specific subroutines should allow these modifications to be made with little difficulty. This paper has provided just a brief overview of the systems scope, versatility and capabilities. More detailed information on individual areas of the system can be found in other publications (Lewis *et al*, 1996, 1997).

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6. References.

- BAA - British Agrochemicals Association. (1996). *Integrated Crop Management*.
- Erickson, P.A. (1994). *A Practical Guide to Environmental Assessment*. Academic Press
- Gustafson, D. I.(1989). Groundwater ubiquity score: a simple method for assessing pesticide leachability. *Environmental Toxicology and Chemistry*, **8**. Pages “339-357”.
- Lewis, K.A., Newbold, M.J., Hall, A.M. & Broom, C.E. (1996). Environmental management for arable agriculture: an eco-rating system for pesticide use. *BCPC Conference Proceedings The Brighton Conference: Pests & Diseases*.
- Lewis, K.A., Tzilivakis, J., Skinner J.A., Finch, J., Kaho, T., Newbold, M.J. and Bardon, K.S. (1997) Scoring and ranking farmland conservation activities to evaluate environmental performance and encourage sustainable farming. *Sustainable Development*. In press due Aug 1997
- Gustafson, D. I. Groundwater ubiquity score: a simple method for assessing pesticide leachability, *Environmental Toxicology and Chemistry*, 1989, **8**: 339-357
- MAFF - Ministry of Agriculture, Fisheries and Food. (1991). *The Code of Good Agricultural Practice for the Protection of Water*. MAFF Publications, London. PB0587.
- MAFF - Ministry of Agriculture, Fisheries and Food. (1992). *The Code of Good Agricultural Practice for the Protection of Air*. MAFF Publications, London. PB0618.
- MAFF - Ministry of Agriculture, Fisheries and Food. (1993a). *The Code of Good Agricultural Practice for the Protection of Soil*. MAFF Publications, London. PB0617.
- MAFF - Ministry of Agriculture, Fisheries and Food. (1993b). *Codes of Recommendations for the Welfare of Livestock - Pigs*. MAFF Publications, London. PB0075.
- MAFF - Ministry of Agriculture, Fisheries and Food. (1993b). *Fertiliser Recommendations*. HMSO Publications, London. RB209.