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Measuring and Marketing the Environmental Costs and Benefits of Agricultural Practice

Assessing the costs and benefits of agricultural production using an ecosystem approach

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Summary

Integrated Farm Management (IFM) is seen as one way for agriculture to contribute towards the UKs challenging national targets for climate change, pollution, biodiversity and other environmental factors. Whilst it is clear that IFM and associated assurance schemes have a role in food quality and enhancement of the environment, they fail to address a number of issues. In particular, they fail to take sufficient account of 'impact' and 'outcome'. In contrast, the relatively new concept of an ecosystem approach does consider these and there is extensive synergy between this approach and IFM. This is pertinent because the UK Department for the Environment, Food and Rural Affairs (Defra) is taking steps to embed an ecosystem approach in policy-making and delivery. This paper sets out to explore the links between IFM and an ecosystem approach and introduces a simple matrix to show how an ecosystem approach might be used to assess the outcome of IFM practices. Limited use of an ecosystem approach suggests that this type of methodology could deliver useful results for IFM. However, it should be used as a decision-support tool rather than a decision-maker. The advantage of using an ecosystem approach for assessing the impact of IFM is that it provides a holistic assessment of land management strategies, rather than focusing on either cropping, or environmental management, alone. However, the values assigned to individual parameters are generally based on expert opinion and, as such, are open to interpretation. Indeed, an ecosystem approach should be interdisciplinary, utilising the knowledge and expertise of a range of stakeholders. Whilst the development of an ecosystem approach for use within an agricultural setting shows promise, it is still in its infancy. There is a need for much discussion, between many disciplines, before it becomes accepted practice.

Key words: Integrated farm management, IFM, ecosystem service, agriculture, production

Introduction

The UK has challenging national targets for climate change, pollution, biodiversity and other environmental factors and agriculture will have to contribute towards meeting those targets. Integrated Farm Management (IFM) is seen as one way of achieving a positive outcome in terms of these targets. There are a number of schemes that incorporate elements of integrated farming and, in the UK, LEAF (Linking Environment and Farming; LEAF, 2009) is perhaps the best known. LEAF suggests that IFM should combine the best of traditional farming methods with modern technology, to allow farmers to manage their farms in an informed, professional and caring way. LEAF's IFM principles are:

- a commitment to good husbandry and animal welfare;
- efficient soil management and appropriate cultivation techniques;
- the use of crop rotations;
- minimum reliance on crop protection chemicals and fertilisers;
- careful choice of seed varieties;
- maintenance of the landscape and rural communities;
- enhancement of wildlife habitats; and
- a commitment to team spirit based on communication, training and involvement.

In certain sectors of agriculture, IFM approaches have been supplemented, or sometimes replaced, by generic assurance schemes such as the 'Assured Produce Scheme' (Assured Produce) and GlobalGAP (GLOBALGAP) and retailer-specific assurance schemes such as 'Nature's Choice' (Tesco) and 'Field to Fork' (Marks & Spencer). Some of the principles and individual practices associated with IFM, especially those designed to protect the environment, are also part of Environmental Stewardship schemes (Natural England) and CAP/Cross Compliance schemes (Defra). Consequently, the majority of farmers and growers are contracted to an assurance scheme, an agri-environment scheme, or both.

Whilst it is clear that these schemes have a role in food quality, animal welfare and environmental planning, most fail to address a number of issues. At a farm level, they rarely consider the impact on crop yield or balance crop yield against environmental goals, and generally they do not consider land management at a larger, catchment scale. Perhaps more importantly, they fail to take sufficient account of 'outcome'. In their review of integrated farming standards and eco-labelling of agricultural products world-wide, Tzilivakis & Lewis (2007) concluded that in general, compliance with such schemes is based on undertaking various production practices to a set standard ('Best Practice') rather than on the outcome of such tasks. The tacit assumption is made that the relationship between various practices and the desired outcome is robust across a variety of situations. However, this may not always be the case. In addition, although IFM techniques generally have beneficial rather than adverse effects, there are some notable 'conflicts' where a technique that has a large beneficial effect in addressing one environmental target has a large negative effect on another (Cook *et al*., 2009; Defra, 2009).

Recent work (Defra, 2008*a*, 2009; Cook *et al*., 2009) has revealed extensive synergy between IFM and the relatively new concept of an ecosystem approach. The use of the ecosystem approach is consistent with the Government's vision for the natural environment as described within Public Service Agreement 28 (HM Treasury, 2007): "The Government's vision is to secure a diverse, healthy and resilient natural environment, which provides the basis for everyone's well-being, health and prosperity now and in the future; and where the value of the services provided by the natural environment are reflected in decision-making". More succinctly, ecosystem services can be defined as components of nature, directly enjoyed, consumed, or used to yield human well-being (Boyd & Banzhaf, 2006). To help them deliver Public Service Agreement 28, the UK Department for the Environment, Food and Rural Affairs (Defra) is taking steps to embed an ecosystems approach in policy-making and delivery (Defra, 2007*a*).

All farming practices affect ecosystem services in some way, either positively or negatively. This paper sets out to explore the links between IFM and an ecosystem approach and introduces a simple method to show how an ecosystem approach might be used to assess the outcome of IFM practices.

Ecosystem Approach

The Millennium Ecosystem Assessment (MA, 2005) provided a framework for an ecosystem approach and allocated ecosystem services to four categories:

1. Supporting services (photosynthesis, soil formation, water and nutrient recycling)

2. Regulating services (regulation of air quality, climate, water quality, pests and diseases)
3. Provisioning services (food, fibre, fuel)
4. Cultural services (education, aesthetics, recreation)

Ecosystem services, like IFM, are delivered through 'land units', the spatial scale being defined at the level at which decisions are made; farmer, land manager and policymaker will all have different requirements. Land units may include: field, farm, catchment, region or country. Farming practices influence all four categories of service; for example, a land unit may produce food, fibre or fuel (provisioning services), contribute to climate regulation through, for example, carbon sequestration (regulating services), contribute to water and nutrient re-cycling (supporting services), whilst providing an area for human recreation (cultural services). The rationale for using an ecosystem approach is to attempt to identify and 'value' these diverse services and to understand how different management practices affect them, and the interactions that occur between them. The valuation of ecosystem services is still in its infancy and it may be difficult, if not impossible, to value all the services that an ecosystem provides (Defra, 2007*b*; O'Gorman & Bann, 2008). However, some services (food, fuel, fibre, water) already have economic values and studies are underway to work out how to fill the gaps. It is the holistic nature of such an approach, and the links to human well-being, which differentiate it from conventional approaches to environmental management.

Obviously, almost all land in the UK is 'managed'. In highly managed environments (e.g. agriculture), managed inputs (e.g. fertilisers) often have a negative influence on certain ecosystem services, as for example, with the release of greenhouse gases as a result of fertiliser application or the effect of pesticide application on non-target insect species.

Using an Ecosystem Approach

The 'services' identified as part of an ecosystem approach (regulation of air quality, climate, water quality, pests and diseases etc) are identical, or similar to UK government targets for the environment (climate change, waste, water, food and farming and resource protection). Importantly, in the light of recent national and international discussions on food security, an ecosystem approach can be used to consider agricultural production (provisioning services) and compare and contrast the benefits with the other services provided by a land unit (Defra, 2008*b*).

Haines-Young & Potschin (2006) stated that ecosystem services could be viewed as 'service themes' that capture a variety of 'products' with direct value to human well-being. Such themes can be refined and expanded to meet the circumstances of any particular study. 'Products' are defined as features and qualities of the natural environment that matter directly to people. 'Product' implies something physical, and this 'physical' quality is crucial to measuring the product and placing a value on it. 'Products' are a function of 'land units' which utilise natural and managed inputs and the ecological processes (e.g. soil microorganisms) and natural capital (e.g. soil type) pertaining to the land unit. As with the 'service themes', 'products' can be chosen to meet the circumstances of any particular study (Table 1).

To assess the potential outcome of different IFM practices on the delivery of ecosystem services, a simple spreadsheet matrix was developed to consider and compare the 'value' of a range of 'products'. It provides a framework in which the 'products' delivered by a land unit might be modified using different farming techniques. It can be used to derive an overall 'score' for a management option and can therefore assist in an assessment and decision-making process. The matrix allows for a semi-quantitative assessment of any number of different scenarios, within a holistic framework, of which production (provisioning services) is a part.

The matrix contains two parameters that can be altered to change the overall delivery of ecosystem 'services': 'product value' and 'marginal change in supply'. The range of both parameters is set between +10 and -10 and actual data values are scaled to fit into this range. 'Product values' are

Table 1. *Some potential ecosystem service themes and their associated products for agricultural systems*

Potential service theme	Examples of associated products
Cultivated food crops for human consumption	Wheat, milk, eggs
Cultivated non-food crops for human consumption	Woodland, oilseed rape for biodiesel, wheat for biofuel
Clean air for human consumption	Ammonia, tropospheric ozone, dust, pollen
Stable global climate: regulation of greenhouse gases	Carbon dioxide, nitrous oxide, methane
Stable local climate: regulation of natural hazards	Off-farm floods, storms, fires, landslides
Clean water for human consumption	Water quantity, nitrate, phosphate, sediment, Cryptosporidium, pesticides and other chemicals
Regulation of pests and diseases of humans	Coliforms, *E.coli*
Recreation	Woodland, skylark
Biodiversity	Woodland, aphids, Adonis blue butterfly

set at the outset of any investigation and any changes affect every scenario7 products had not been quantified (water quality and quantity, biodiversity).

Results

At this early stage in its development, the ecosystem approach is very basic and the results should be used for guidance only. An overview of the results, across all scenarios, illustrates the importance of product value (Fig. 1). Winter wheat is a staple food product which rates a high (positive) value. The emission of nitrous oxide was allocated a high (negative) product value to reflect its importance as a greenhouse gas since winter wheat receives relatively high inputs of nitrogen fertilizer compared to other arable crops. Initial product value, marginal change in supply and the threshold at which they are considered important will all vary with the system under study.

Although the scenarios presented here are simple, they illustrate how the ecosystem approach is holistic and how it highlights the advantages and disadvantages of the respective scenarios. For example, when Scenario 0 (set aside / do nothing) and Scenario 5 (organic winter wheat) are compared, Scenario 5 scores more highly because food production is considered more valuable than 'gains' in biodiversity. Scenarios 3 and 4 achieve similar scores using different approaches; a 50% reduction in pesticide use, with its associated loss of yield, scores the same as the loss of land due to the introduction of 6 m buffer strips as part of an Entry Level Stewardship scheme. A comparison of scenarios 2 and 6 demonstrates the holistic nature of the ecosystems approach. Scenario 2 reduces the use of nitrogen fertiliser with subsequent reductions in yield and N_2O emissions; scenario 6 has a higher yield, lower N_2O emissions as a result of using manures, but increased ammonia emissions. The result is that two different approaches return the same score.

The matrix described here is very simple and should be considered as the basis of a decision-support tool, rather than a decision-maker. However, limited use of the matrix to date suggests that this type of methodology could deliver useful results. The values ascribed to 'product value', and 'change in supply', are generally based on expert opinion and so are open to discussion and disagreement. Indeed, an ecosystem approach should be interdisciplinary, utilising the

Products			Scenarios / Land management													
Ecosystem Service Category. IFM Policy Area	Ecosystem services / IFM techniques		Scenario 0 Do nothing / set-aside		Scenario 1 Winter wheat (conventional) 200 kg/ha N		Scenario 2 Winter wheat (conventional) 100 kg/ha N		Scenario 3 Winter wheat (conventional) 50% pesticide load		Scenario 4 Winter wheat (conventional) ELS		Scenario 5 Winter wheat (organic)		Scenario 6 Winter wheat (conventional) Manure applied	
		Product Value (PV)	Marginal change in supply (S)	Marginal change in value (PV x S)	Marginal change in supply (S)	Marginal change in value (PV x S)	Marginal change in supply (S)	Marginal change in value (PV x S)	Marginal change in supply (S)	Marginal change in value (PV x S)	Marginal change in supply (S)	Marginal change in value (PV x S)	Marginal change in supply (S)	Marginal change in value (PV x S)	Marginal change in supply (S)	Marginal change in value (PV x S)
Provisioning	Wheat	10	0	0	9	90	7	65	6	60	9	85	4	40	8	80
	Timber	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Biomass for fuel	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Regulating	Ammonia	-5	0	0	0	0	0	0	0	0	0	0	0	0	2	-10
	Tropospheric ozone	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dust	-1	0	0	3	-3	3	-3	3	-3	3	-3	3	-3	3	-3
	Pollen	-1	0	0	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1
	Carbon dioxide	-4	0	0	1	-4	1	-4	1	-4	1	-4	1	-5	1	-6
	Nitrous oxide	-10	0	0	8	-75	6	-60	6	-60	7	-70	2	-20	5	-47
	Methane	-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Off-farm flood prevention	3	0	0	-1	-3	-1	-3	-1	-3	-1	-3	-1	-3	-1	-3
	Storm regulation	1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
	Fire regulation	1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
	Landslide regulation	1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
	Herbicide residues	-1	0	0	2	-2	2	-2	1	-1	2	-2	0	0	2	-2
	Fungicide residues	-1	0	0	1	-1	1	-1	0	-0	1	-1	0	0	1	-1
	Insecticide residues	-2	0	0	3	-7	3	-7	2	-3	3	-6	0	0	3	-6
	PGR residues	-1	0	0	3	-3	3	-3	1	-1	3	-3	0	0	3	-3
	Molluscicide residues	-2	0	0	4	-8	4	-8	2	-4	4	-8	0	0	4	-8
	Water availabilty	10	0	0	-1	-10	-1	-10	-1	-10	-1	-10	-1	-10	-1	-10
	Phosphate	-1	0	0	2	-2	2	-2	2	-2	2	-2	0	0	3	-3
	Nitrate	-1	0	0	6	-6	3	-3	6	-6	6	-6	1	-1	5	-5
	Faecal Indicator Organisms	-1	0	0	0	0	0	0	0	0	0	0	0	0	5	-5
	Biological water quality	-1	0	0	1	-1	1	-1	1	-1	1	-1	0	0	2	-2
	Coliform bacterias	-2	0	0	0	0	0	0	0	0	0	0	0	0	2	-4
	E. coli	-2	0	0	0	0	0	0	0	0	0	0	0	0	2	-4
Supporting	Soil status - physical	5	0	0	-1	-5	-1	-5	-1	-5	-1	-5	-1	-5	-1	-5
	Soil status - chemical	2	0	0	1	2	1	2	1	2	1	2	0	0	2	4
	Preventing soil erosion	1	0	0	-2	-2	-2	-2	-2	-2	-2	-2	1	1	-2	-2
	Skylarks	1	0	0	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
	Crop Pollinator 1	1	0	0	-2	-2	-2	-2	-2	-2	-2	-2	0	0	-2	-2
	Wildflower Pollinator 1	1	0	0	-2	-2	-2	-2	-2	-2	-2	-2	0	0	-2	-2
	Freshwater invertebrate 1	1	0	0	-4	-4	-4	-4	-4	-4	-4	-4	0	0	-4	-4
	Habitat provision	4	0	0	-2	-8	-2	-8	-2	-8	-2	-8	-1	-4	-2	-8
	Food security	8	0	0	5	20	4	16	4	16	4	14	3	12	5	20
	Countryside visit expenditure	5	0	0	2	10	2	10	2	10	2	10	2	10	1	5
Overall score				**0**		**-31**		**-41**		**-39**		**-36**		**6**		**-41**

Fig. 1. The ecosystems approach / IFM matrix for 6 scenarios of winter wheat cultivation.

knowledge and expertise of a range of stakeholders (Defra, 2008a). Even when many different stakeholder groups are consulted, it is inevitable that some aspects will be overlooked. However, the solution should be based on 'best available' knowledge and resources. 'Valuation' and other issues surrounding the use of an ecosystem approach are to be the subject of further Defra-funded research.

The advantage of using an ecosystem approach for assessing the impact of IFM is that it provides a holistic assessment of land units and management strategies, rather than focusing on either cropping, or environmental management, alone. The matrix enables users, from farmers to policymakers, to compare different management approaches and change the relative values of different 'services'/'products'. It is also very flexible, since it can incorporate any number of services, products and management techniques. No single input parameter is dominant and all parameters contribute to the overall score.

Although the term 'Integrated Farm Management' is used widely, it means different things to different people. Indeed, a recent review (Garstang, 2003) stated that 'Integrated Farm Management and other integrated systems have volatile definitions which can lead to confusion about what they actually mean'. Whilst it is clear that IFM schemes have an important role in food quality and environmental management, they fail to take sufficient account of production (Tzilivakis & Lewis, 2007), which is critical to the achievement of overarching government objectives. IFM rarely considers crop yield and does not balance crop yield against environmental goals, an important factor in terms of the current debate about food security and a perceived 'conflict' between land use for food production and the provision of environmental benefits (Swales & Woods, 2008; Defra 2008*b*; Natural England 2009). The use of an ecosystem approach within an agricultural setting can address some of these competing issues. The approach shows promise but is still in its infancy and there is a need for much discussion, between many disciplines, before it becomes accepted method.

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