Constructing a Farm Level Indicator of Sustainable Agricultural Practice

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ANALYSIS

Constructing a farm level indicator of sustainable agricultural practice

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Abstract

There has been a concerted effort since the Rio Earth Summit to construct indicators to monitor progress towards sustainable development. This has included indicators of sustainable land management, land quality indicators and indicators of sustainable agriculture. It is argued in this paper that the design and use of such indicators can be extremely useful in that they force those involved in the discussion of sustainability to identify the key aspects of sustainable agriculture and to assign weights to them. In this process the discussion of sustainability may be coaxed from the realms of general discussion and abstraction to a more operational context, and ultimately to the discussion and classification of actual practices and farms. To this end, a farm-level indicator of agricultural sustainability, based on patterns of input use, is constructed for a sample of 80 organic and 157 conventional producers in the UK. The paper serves to highlight some of the conceptual issues, examines some of the technical issues and choices associated with indicator construction, and informs discussion of the relationship between organic production and agricultural sustainability.

Keywords: Sustainability; Indicators; Organic; Agriculture

1. Introduction

Developments in modern agriculture have led to doubts regarding the long-term viability of current production systems. These developments include heavy reliance on chemical fertilisers, pesticides and herbicides, the destruction of wildlife habitats, environmental pollution and risks to human health. These concerns have led to the development and promulgation of several alternative agricultural approaches, one of the most widespread of which in Europe and the USA is organic farming. In addition to the popularisation of concepts of sustainability and sustainable agri-

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culture, there is also a burgeoning literature on indicators of sustainability, sustainable development and sustainable agriculture.

This paper[1] reviews some of the issues underlying the development of sustainability indicators and highlights some of the potential strengths and weaknesses of this approach by constructing such an indictor and applying it to a sample of 237 horticultural producers in the UK. As the sample covers both organic and conventional producers, the results have relevance beyond a methodological discussion of sustainability indicators, allowing also an exploration of the 'sustainability' of agricultural practices employed (and perceived environmental impacts) on organic and conventional farms. This has implications for policy on UK organic regulations which are likely to receive increasing attention given the current rapid expansion of the organic sector in the UK and elsewhere (Soil Association, 2000; MAFF, 2000).

2. Sustainability and indicators

Almost as well known now as the definition of sustainable development presented in the Brundtland Report (WCED, 1987) is the fact that there is no consensus on its precise or operational meaning; its meaning differs across space and time and between individuals. Sustainability means different things to different people and hence Jacobs (1995), noting that there are at least 386 definitions of sustainable development, and that both Thatcher and Friends of the Earth signed up to it, asks if it might be so vague a concept as to be meaningless. He answers 'no' because: "…this is to mistake what it means for a political principle to be meaningful. There are far more than 386 definitions of democracy, but that doesn't mean the concept is meaningless. Nor does the fact that different people disagree on what counts as democracy. Key political principles like democracy...are contestable—they are open to different interpretations—but they carry a core meaning…which is substantive and important" (1995, p. 9).

It could be added that, as with terms like 'democracy' and 'sustainability' (concepts to which almost everyone would claim to adhere) the different interpretations held and operational conclusions drawn by those with differing perspectives, agendas and priorities can themselves be revealing and provide genuine insights.

Hueting and Reijnders (1998, p. 139) argue that "sustainability is an objective concept to the extent that natural science is objective", an argument which draws on the point that "we can only assess sustainability after the fact; it is a prediction problem more than a definition problem" (Costanza and Patten, 1995, p. 193). Costanza and Patten (1995, p. 196) add "the emphasis shifts to methods to enable us to better predict what configurations will persist". This observation has important implications for debates about the role of 'objective' or 'subjective' judgement in defining indicators of sustainability. The practice of predicting environmental impacts (and hence the sustainability of particular activities) invariably engages with conditions of complexity and uncertainty (Stirling, 1999), which inevitably reinforce the subjective element of assessing sustainability. This is evident, for example, in decisions about the relative weighting given to different dimensions of sustainability, an issue to which we return later in this paper. In this sense, design of sustainability indicators raises questions about the role of 'scientific' measurement and prediction in the realm of economic, social, and ultimately political decision-making.

The current momentum for the development of sustainability indicators arose from the 1992 Rio Earth Summit where the Commission on Sustainable Development (CSD) was established to monitor the progress of sustainable development using standards or indicators of sustainable development. This has received additional impetus in preparations for the 'Rio + 10' conference in 2002. As a consequence, there is now a rapidly developing literature on the use of sustainability indicators alongside indicator development pro-

[1] The analysis reported here is part of a larger project, "Adoption of Sustainable Agricultural Technologies: Economic and Non Economic Determinants', [award number L320253235] funded by the ESRC in its research programme, 'Global Environmental Change'.

grammes being undertaken by national governments as well as organisations such as the United Nations, OECD and the World Bank (see Moldan and Billharz, 1997). Agriculture has been included in this development with work on, for example, the Framework for the Evaluation of Sustainable Land Management (Smyth and Dumanski, 1993) and Land Quality Indicators (Pieri et al., 1995).

This literature provides a variety of definitions of what an indicator is and different understandings of the primary roles of indicators. Gallopín (1997, p. 14) surveys a wide range of literature and reports that in different sources an environmental indicator has been identified as "a variable…a parameter…a measure…a statistical measure…a proxy…a value…a meter or measuring instrument…a fraction…an index…something…a piece of information…a single quantity…an empirical model… a sign". Moxey argues that there is no widespread agreement on design and use of what he calls Agri-Environmental Indicators (AEIs) because "AEIs have to address interactions of both socio-economic and environmental factors. Consequently, the debate is inevitably complicated" (Moxey, 1998, p. 4).

Glenn and Pannell (1998) argue that "an indicator is a quantitative measure against which some aspects of policy performance or management strategy can be assessed". This role of quantification assigned by many authors is not universally accepted, however, since some authors regard qualitative indicators (e.g. visual assessment of soil erosion) as valid tools. A simple understanding of an indicator is as a proxy or measure of something in which one has an interest, but which is difficult to monitor exactly. There is typically a trade-off between the extent to which the indicator captures the necessary information regarding the underlying variable(s) and the ease of monitoring. Two points emerge from this. Firstly, indicators will often be proxies (possibly qualitative ones) for complex processes. Secondly, the interpretation and validation of indicators will depend on how they fit with our understanding of the interaction between the realms of biophysical 'environment' and those of 'economy' and 'society'. The latter is evident in the prominence within the literature given to 'indicator frameworks' such as 'pressure–state–response', 'driving force–pressure–state–impact–response' and others. For discussion of many of these issues, see Friend and Rapport (1979), Jesinghaus (1998), Rigby et al., (1999).

It is, however, worth noting Pearce's (1998, p. 5) observation: "some people do not want measures of sustainability. Indicators might show them up in a bad light, in which case it is always better to say that sustainable development is a fuzzy concept and has many meanings, but is, of course, something we all support. If indicators develop in particular ways, they may also force decision-makers to address questions they prefer not to address, for example, the real, underlying causes of environmental degradation rather than the cosmetic causes which can be addressed and for which, perhaps with adequate 'spin doctoring', good publicity can be obtained".

This paper is focussed specifically on the development of an indicator of sustainable agricultural practice (ISAP) at the farm level for a sample of 237 UK horticultural producers. Given the great interest in sustainable agricultural production and sustainability indicators, it is striking that there are very few published examples of farm-level indicators of sustainability. Two exceptions are papers by Taylor et al. (1993) and Gomez et al. (1996), which are discussed below. A possible disincentive to the development of real indicators, in addition to that identified by Pearce above, is the likely fierce response that the publication of any such indicator is likely to provoke. Given the strong and differing opinions regarding sustainability and sustainable agriculture it is likely that the omission, presence and/or weighting of any or all of the components of the index presented in this paper will provoke disagreements and debate. Without a clear and objective definition of sustainability is it useful to discuss or begin the operationalisation of the term via indicators?

The position we argue in this paper is that many of the current debates regarding the meaning of sustainability, the nature and purpose of indicators, and the frameworks in which they should be located will remain inconclusive, but that the development of transparent indicators offers an opportunity to clarify which aspects of these debates are relevant in practice. Thus, the identification and weighting of the different components of such indicators force one to be explicit about perceptions regarding the relative importance of the different aspects of sustainability, therefore, contributing an important element to the process of making choices between alternative technologies, or development actions more generally. Rennings and Wiggering (1997, p. 25) write that "operational definitions and indicators are a pre-requisite for implementing sustainability in practical policy decisions". We would argue that the development of indicators can be an effective tool in the operationalisation of agricultural sustainability.

We make no claim that the indicator constructed in this paper is definitive of sustainable agricultural practice. As is discussed in Section 3, we freely acknowledge that, for example, it takes no account of social and economic dimensions of sustainability. However, we contend that the development of such an indicator has value in a number of respects. The first is to promote and develop the discussion of sustainable agriculture in a more practically-orientated manner, by assessing real farms in terms of their observed patterns of input use. The second is to provide a better understanding of the nature of and demand for indicators as well as some of the practical issues that have to be confronted in design and validation. The third is to use the indicator to contribute to discussion of organic and conventional agriculture in relation to policy on agricultural sustainability. Finally, we believe the experience of constructing an indicator will highlight the potential and limitations of this approach and help identify where further effort is worthwhile.

3. A farm level indicator of sustainable agricultural practice

The indicator derived here draws on Taylor et al. (1993), one of relatively few published attempts to construct a farm-level sustainability indicator. In their paper the index is constructed for a sample of 85 agricultural producers in Malaysia with points scored under the headings of (i) insect control, (ii) disease control, (iii) weed control, (iv) soil fertility maintenance and (v) soil erosion control. Gomez et al. (1996) also construct a farm-level indicator of sustainability where six aspects of sustainability are monitored, one of which is profit. The six indicators used are (i) yield, (ii) profit, (iii) frequency of crop failure, (iv) soil depth, (v) organic C and (vi) permanent ground cover. The indicators are then constructed for a sample of 10 farms from the Guba region of the Philippines.

The index presented here resembles more that of Taylor et al. than that of Gomez et al., making use as it does of detailed information regarding the use of specific farming practices, but excluding economic aspects of sustainability for which no data were available. We first outline the nature of the sample and the information from each farm used to construct the index. We then discuss the criteria used for weighting and scoring the index's components leading to the overall indicator for each farm.

3.1. Data used for the farm sustainability index

The data[2] used here come from a survey in the UK of 80 organic and 157 conventional horticultural producers in 1996, using a structured questionnaire completed during face-to-face interviews. The information used to generate the ISAP for each farm relates to five aspects of horticultural production on the holdings:

- seed source
- pest/disease control
- weed control
- maintenance of soil fertility
- crop management

The different farming practices within each of these categories are identified in Table 1. In most categories the range of practices is more detailed than a dichotomy between those either permitted or prohibited for organic production. For exam-

[2] The survey data have been lodged at, and are available from, The Data Archive, University of Essex, Wivenhoe Park, Colchester, Essex, England, CO4 3SQ. Study Number: 3900.

Table 1
Farm practices used in the index

Seed source	Fertilisers	Pest/disease control	Crop management	Weed control
Conv = Conventional Supplier	Synth = Synthetic Fertilisers (e.g. superphosphates, urea, nitrate fertilizers, muriate of potash, mixed or granulated NPK compound fertilizers)	Nat = Natural Pest Control: Any of the following: *Permitted Chemicals* (Bordeaux mixture, copper sulphate, copper oxychloride, copper ammonium carbonate, sulphur), *Plant Extracts*, (Derris, Quassia, Pyrethrum) *Preparations for Propagating Biological Control Agents* (e.g. natural predators, *Bacillus thuringiensis*, granulose virus) *Mechanical Controls* (traps, barriers)	R.Var = Resistant Varieties/Root stocks	Herb = Chemical or Hormone Herbicides
Org = Organic Supplier	Nat = Natural Fertilisers Permitted fertilisers which may be *Inorganic* (e.g. rock phosphate, basic slag, gypsum, chalk, wood ash.) or *Organic* (e.g. processed animal and plant products: hoof, horn, bone, meat and fish meal; plant extracts, dried seaweed)	Synth = Synthetic Pesticides All other pesticides	Rotat = Crop Rotation	C&C = Crop & Compost Control (rotations, cover crops chosen to suppress weeds, composting manure and plant wastes to kill weed seeds)
Own = Own Farm	Org = Organic Fertiliser Non-Composted organic fertilisers (e.g. straw, FYM, slurry, pig and poultry manure, plant wastes, and by-products from food-processing industries)		Inter = Intercropping or Companion Cropping (to encourage ecological diversity; management of field borders to encourage predators of pest species)	C. Mgt = Management of the Crop (mechanical or manual cultivation; mulching; flame weeding)
	Comp = Composted Fertiliser Organic fertilisers aerobically composted to kill pathogens			
	G.Man = Green Manure			

ple, of the five methods of maintaining soil fertility in Table 1, four ('Natural', 'Organic', 'Composted' and 'Green Manure') are permitted under standards defined by the UK Register of Organic Food Standards (UKROFS) in line with EU regulation.

3.2. Scoring and weighting sustainability of farming practices

The impact of these farming practices on farm sustainability was assessed by identifying from the literature criteria commonly adopted for agricultural sustainability, and then allocating simple scores to each farming practice according to whether a particular practice was considered to improve or diminish a farm's performance according to a given criterion. The criteria are discussed below and the scoring system is then outlined.

Three major facets of agricultural sustainability are listed below, and these are broken down into component parts. These features are commonly found in the vast literature on agricultural sustainability and the sources cited alongside these components are far from exhaustive, but meant simply to indicate the diverse range of sources in which these facets are typically identified.

3.2.1. Improved farm-level social and economic sustainability

- enhances farmers' quality of life (US Farm Bill, 1990)
- increases farmers' self-reliance (Pretty, 1995)
- sustains the viability/profitability of the farm (Pretty, US Farm Bill, Ikerd, 1993).

3.2.2. Improved wider social and economic sustainability

- improves equity (Pretty), 'socially supportive' (Ikerd)
- meets society's needs for food and fibre (US Farm Bill).

3.2.3. Increased yields and reduced losses while:

- minimising off-farm inputs (Hodge, 1993; Pretty, US Farm Bill)
- minimising inputs from non-renewable sources (Hodge, Ikerd, Pretty, US Farm Bill)
- maximising use of (knowledge of) natural biological processes (Pretty, US Farm Bill)
- promoting local biodiversity/'environmental quality' (Hodge, Pretty, US Farm Bill).

The analysis here concerns only aspects of sustainability for which data were available: those identified under facet 3.2.3. It should be clear, however, that it is unlikely that a single indicator could combine all information relevant to facets 3.2.1 and 3.2.2, dealing, respectively, with social and economic sustainability at the level of the individual farm and wider society. This reflects a problem of incommensurability between different facets or dimensions of sustainability, and a need to identify different indicators depending on the areas of decision-making with which one is concerned.

The problems of incommensurability, as well as data requirements, become stronger as the analysis moves to the system beyond the farm boundaries:

> Part of the difficulty in assessing the sustainability of agricultural systems…is the fact that both the units of measurement and the appropriate scales for measurement differ both within and across the commonly identified economic, biophysical and social dimensions of sustainability. For example, consideration of the effects of organic production on farm margins, soil fertility and rural employment are difficult to combine in an overall measure. This is an issue which will not be solved simply by greater knowledge of the impacts of different production systems; even with complete information regarding impacts one will still have to consider trade-offs with movement towards targets in some respects accompanied by reverses in others (Rigby and Cáceres, 2001, p. 30).

Clearly there are major issues to be addressed about whether, and how, biophysical, economic and social information may be combined. Our purpose here is more modest: to use the four criteria of sustainability identified under 3.2.3 above to score the relative impact of farming practices on

Table 2
Scoring practices with respect to sustainability

Farm practice	Dimension of sustainability				Total
	Minimises Off-Farm Inputs	Minimises Non-Renewable Inputs	Maximises Natural Biological Processes	Promotes Local Biodiversity	
Seed sourcing					
Conv					0
Org					+1
Own	+1	+1			+1
Soil fertility					
Synth	−1	−1	−1		−3
Nat	−1	−1			−2
Org	+1			+1	
Comp	+1	+1		+2	
G.Man	+1	+1	+1		+3
Pest/disease control					
Nat		+0.5	+1	+1	+2.5
Synth	−1	−1	−3	−3	−8
Weed control					
Herb	−1	−1	−1	−0.5	−3.5
C & C	+1	+1	+1	+1	+4
C.Mgt	+1	+0.5	+1	+0.5	+3
Crop management					
R.Var		+1	+1	+1	+3
Rotat	+0.5	+0.5	+1		+2
Inter	+1	+1	+1	+1	+4

farm sustainability for our sample of 237 organic and conventional farms.

The scoring system is shown in Table 2 which combines information from Table 1 on practices with sustainability aspects from 3.2.3 above. Each farming practice is simply scored (in absolute terms) with either 0, 0.5, 1, or 3 points for each criterion. The scoring system could be interpreted as: 0 indicates ‘no significant impact’, 0.5 indicates ‘marginal impact’, 1.0 indicates ‘significant impact’ and 3 indicates ‘strong significant impact’. Thus it can be seen in Table 2 that use of synthetic fertilisers to maintain soil fertility registers −1 with respect to each of: ‘minimising off-farm inputs’, ‘minimising use of non-renewable inputs’ and ‘maximising natural biological processes’. It is classified as having no significant effect (positive or negative) with respect to ‘local biodiversity’ and hence no point is scored under this category. Hence, the minimum number of points that can be generated with respect to synthetic fertilisers is −3 (for use on all crops) and the maximum is zero (for use on none).

The information in Table 2 regarding the range of points that can be scored for each farming practice is summarised more accessibly in Fig. 1. As is apparent from Table 2 and Fig. 1, the five categories of farm practice represent different proportions of the total number of points available. In fact, ‘pest/disease control’, ‘weed control’, ‘maintenance of soil fertility’ and ‘crop management’ each account for between 21 and 26% of total points available, with ‘seed source’ representing 5%. Although ad hoc, this system of approximately equal weight for these first four categories, with seed source playing a minor role,

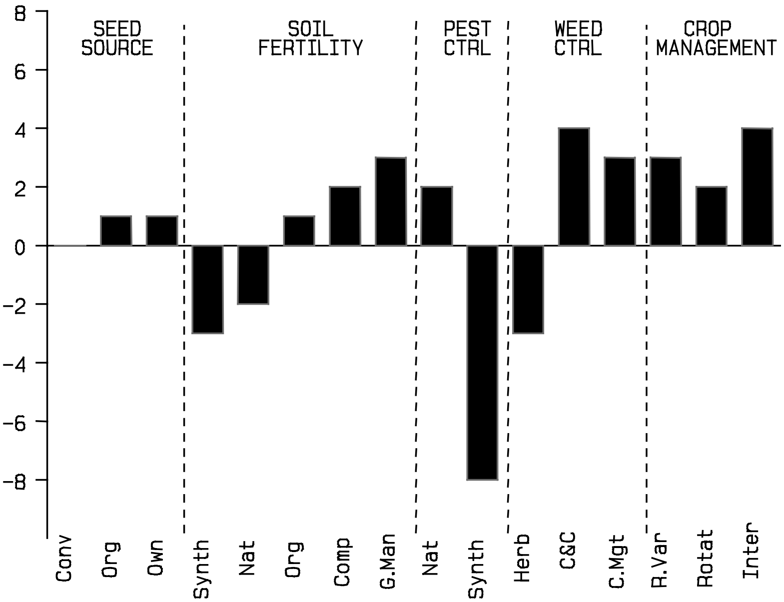

Fig. 1. The range of ISAP points available by category.

was considered acceptable. Transforming the index to give equal weights to these four categories was rejected on the grounds of making the process less transparent with minimal substantive change resulting.

The score for each holding is then calculated by multiplying the 'Total' score attributed to each farming practice in Table 2 by the proportion of crops receiving that input. Hence, if all crops on a farm are fertilised using green manure then that contributes +3 to the index, whereas if 50% of them are fertilised in this way then this will contribute +1.5 to the index. Index values calculated in this way can range between −16.5 and 26.5, depending on each farm's pattern of input use in horticultural production. It is convenient to use a linear transformation so that the index scores lie between 0 and 1.

4. Discussion of indicator construction

4.1. Sustainability impact assumptions

The indicator is constructed according to patterns of input use rather than their impacts. The latter would clearly be more desirable, but field monitoring data on such a large number of enterprises is very rarely available. Moreover, as observed in Section 2 above, it is commonly the case that assessment of sustainability operates by prediction rather than direct evaluation of impact. This prediction is, of course, based on an understanding of physical, chemical and biological processes and the way that particular practices are likely to affect them. In this context one of the key issues is the extent to which one can map with confidence from inputs to environmental impact. In this exercise we have scored different farming practices using some crude, but we hope robust, assumptions about their impacts on ecological processes and local biodiversity. The need for these assumptions was dictated by the rather general categories of input use in the survey data. We have assumed, for example, that insecticides will in general be more damaging (via impacts on animal food chains) than herbicides. Further, we assumed that synthetic insecticides and herbicides, which generally are biocides not found in nature, are more likely to be damaging than synthetic fertilizers, which supply the same nutrients as organic manure, but in soluble form. We have, however, scored organic forms of fertilizers as being more benign than synthetic fertilizers on the grounds that the former are likely to confer physical improvements to the soil, in addition to nutrient supply. Two points can be made here: firstly in relation to the scope for validation and refinement of these assumptions; secondly in relation to the contribution this approach may make to the evaluation of sustainability of alternative technical approaches to farming.

4.2. Refinement of sustainability assessment of farming practices

With respect to validation and refinement of the index, there is scope for much greater sophistication in assessing the environmental impact through, for example, greater precision in measuring the fossil fuel use of different practices, or by discriminating between pesticides which present greater or lesser environmental hazards by making use of objective biohazard data for specific substances. While attractive, this is not straightforward. In relation to a comparison of environmental impacts of different pesticides, Levitan et al. (1995) point out that the numerous initiatives during the past two decades have failed to identify an index which can be widely applied. One obstacle is the complexity of combining in a single index the effects of a pesticide on aquatic and terrestrial ecosystems, on flora and fauna, and on mammals, birds, insects, and microbial elements of ecosystems. Further issues to be taken into account are long-term effects and persistence, which may rank substances differently from impacts due to short-term toxicity, and the influence of dosage and product formulation (e.g. spray or granule application).

In one respect the scoring system proposed in this paper simplifies the task of devising indices of pesticide hazard by separating ecological impacts from those which affect human health more directly. Previous attempts at constructing indices of pesticide impact have often attempted to combine these in a single impact, and it is arguable that this is one reason why their applicability has been restricted. Indices for pesticide hazard which would be relevant to the ISAP scoring schedule in Table 2 would need to address only impacts on the local ecology ('biodiversity'). Other important, and possibly related, hazards in relation to handling and application of pesticides could be more properly regarded as impacts on 'farmers' quality of life' (farm-level social and economic sustainability—'facet 3.2.1' of sustainability (Section 3 above). Similarly, hazards related to pesticide residues in food could be appropriately assessed with respect to 'society's needs for food and fibre' (wider social and economic sustainability—'facet 3.2.2'). This suggests that discriminating between different scales of activity in the analysis of sustainability may be an important way to focus the search for relevant indicators.

A second obstacle is that little basic data on the toxicity of pesticides have so far been published in a systematic way (Levitan et al. 1995, p. 157). Nonetheless, the work done on composite indices of the environmental impact of pesticides shows useful experience has been gained, and there is potential for the generation of indices from standard hazard information such as LD_{50}, and analogous toxicity test data for aquatic organisms: LC_{50} for fish, EC_{50} for daphnia, IC_{50} for algae (HSC, 1997, p. 31).

4.3. Evaluation of farming alternatives

In relation to evaluation of sustainability of alternative technical approaches to farming, differentiation between chemical inputs is an aspect of the index which marks a departure from the more traditional organic-conventional dichotomy. While all synthetic chemical inputs are prohibited from organic systems, giving implicit equal weighting to the hazards posed by these inputs, the assumptions of differential hazard, discussed above, underlying this index open the possibility of a more transparent debate about threats to sustainability posed by current farming methods.

This point is significant in the context of the current rapid expansion of organic production in the UK and elsewhere. Organic certification standards are driving increasing proportions of national agricultural sectors: in both Sweden and Austria in 1999/00 more than 10% of agricultural land was being farmed organically (Soil Association, 2000) and these figures are set to rise at least in the short to medium term. It is debatable whether this is the most efficient way to improve sustainability of farming as a whole. Organic standards have developed and been codified, often on the basis of quite ad hoc assessments of particular inputs. In adopting a more differentiated approach to assessing hazards posed by specific inputs and practices, the index constructed here offers a first attempt to compare input use for a large sample of organic and non-organic farms and a more graduated assessment of sustainability on a common scale.

This graduated scoring of sustainability hazards also offsets a danger of tautology. For example, scoring inputs prohibited under organic regulations as 'bad' and scoring those allowed/encouraged as 'good', and then producing a result in which organic farms are declared 'more environmentally friendly' is clearly a self-fulfilling prophecy. This danger of tautology is avoided here because it is not simply the case that organic-approved inputs score uniformly well and those prohibited score uniformly badly. As discussed above, differentiated scoring of synthetic inputs means fertilisers are scored very differently from pesticides, with pesticides scoring more than twice as heavily. In Table 2 synthetic pesticides are the only input to generate scores which lie outside the ± 1 range, and pesticide use generates negative points under all four headings whilst chemical fertiliser scores under only three categories.

4.4. Index validation

The correct methodology for validating this index of sustainability is not immediately obvious. Despite the great interest regarding indicator development, relatively little is written in terms of validation processes. Perhaps the most desirable approach would be to re-visit the 237 farms in the sample and take a series of measurements on components of sustainability, such as biodiversity levels. This is not feasible, and does not seem to be a technique applied in the previously cited examples of farm-level indicator construction.

Taylor et al. (1993) adopted a two-step approach to validation. First, those components of the index which were poorly correlated with the overall index scores were removed. Second, the scoring system was shown to a number of natural scientists who gave their opinions regarding the relative weights used. The weights used were adjusted until consensus was achieved.

The first of these steps, removing those components not strongly correlated with overall scores, was not adopted in this study on the grounds that if a component is identified as important in terms of the sustainability of agricultural practices then it should be retained regardless of whether or not it plays a distinguishing role in the particular sample being studied. Taylor et al.'s second step, circulating the proposed ISAP scoring schedule to expert and interested parties, has been employed in this study,[3] and, we would argue, should form an important part of any of the future refinements of assessment of sustainability hazards identified earlier. The role of consultation in determining the weighting and scoring of specific practices not only offers the possibility of establishing a consensus of technical opinion, but also brings into the process an explicit consideration of the relative priorities to be allocated to different criteria of sustainability (e.g. those of minimising off-farm inputs or promoting local biodiversity—see Table 2), and a recognition that the contested nature of the concept of sustainability may not be an obstacle if engaging opposing viewpoints in attempts to operationalise the concept generates new insights, clarifies disagreements, and makes the debates more practically useful.

Criteria appropriate to the selection of sustainability indicators for agriculture have been developed by, among others, the Land Quality Indicators (LQIs) programme of the World Bank (Pieri et al., 1995) which follows Adriaanse (1993) and Hammond et al. (1995) in arguing that indicators should:

- select the most significant information;
- simplify complex phenomena;

[3] The authors wish to thank the participants at the EU Advanced Course on Sustainability Indicators, San Miniato, Italy 1998, the Sustainability session at the 2000 Agricultural Economics Society Conference, and also Professor Joyce Tait of the Open University for helpful comments in this regard.

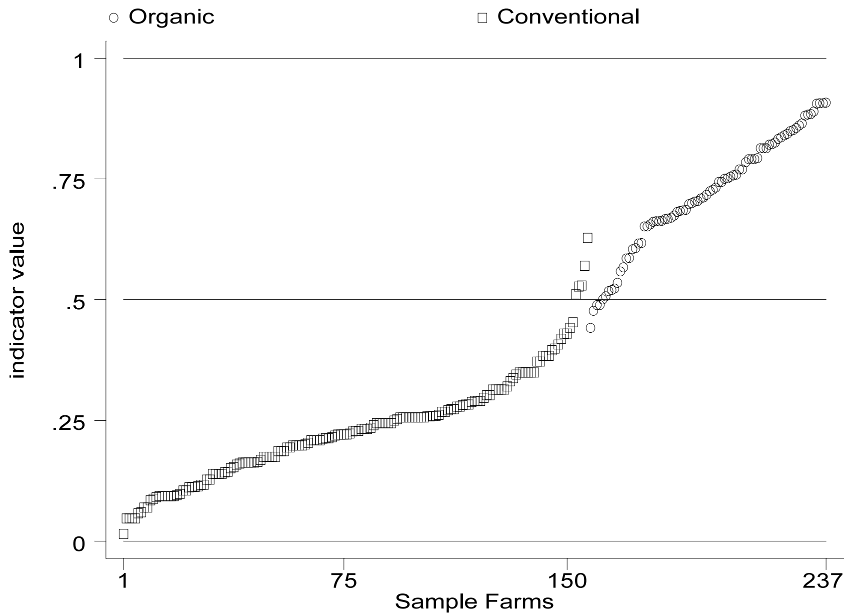

Fig. 2. ISAP values split by organic and conventional farm type.

- quantify information, so that its significance is more readily apparent; and,
- communicate information, particularly between data collectors and data users.

Guijt (1996) argues that good indicators should be user derived as well as policy relevant and highly aggregated.

In terms of these criteria, the indicator developed here takes a complex set of agricultural practices for more than 2500 crops on 237 farms and simplifies this information. The measure is aggregated and quantitative and allows a great deal of information to be presented in an accessible form, despite the inevitable compression and, therefore, loss of detail. The policy relevance of the indicator used in this study relates to:

- concern for development of a more sustainable agriculture;
- the development of the organic sector and adoption of organic standards as a 'benchmark' for sustainability in farming, and the associated agricultural policy implications;
- the current demand for effective, practical indicators of sustainability.

Users of the work are those involved in any of these three policy areas, including a range from academics concerned with sustainability assessment to those involved in the appraisal and potential overhaul of UK organic standards.

5. Results and discussion

ISAP scores were calculated for each of the 80 organic and 157 conventional horticultural producers in the sample using the approach outlined above. Since the sample comprises both organic and conventional producers, the range of index scores was assessed within each of these groups. Fig. 2 depicts the distribution of ISAP values distributed between organic and conventional farms in the sample. This shows that the scores generated cover almost the entire range of possible scores and suggests that the farm ISAP scores

Table 3
Summary of ISAP Scores

	Mean	S.D.	Minimum	Maximum
Organic	0.72	0.12	0.44	0.91
Conventional	0.23	0.11	0.01	0.63

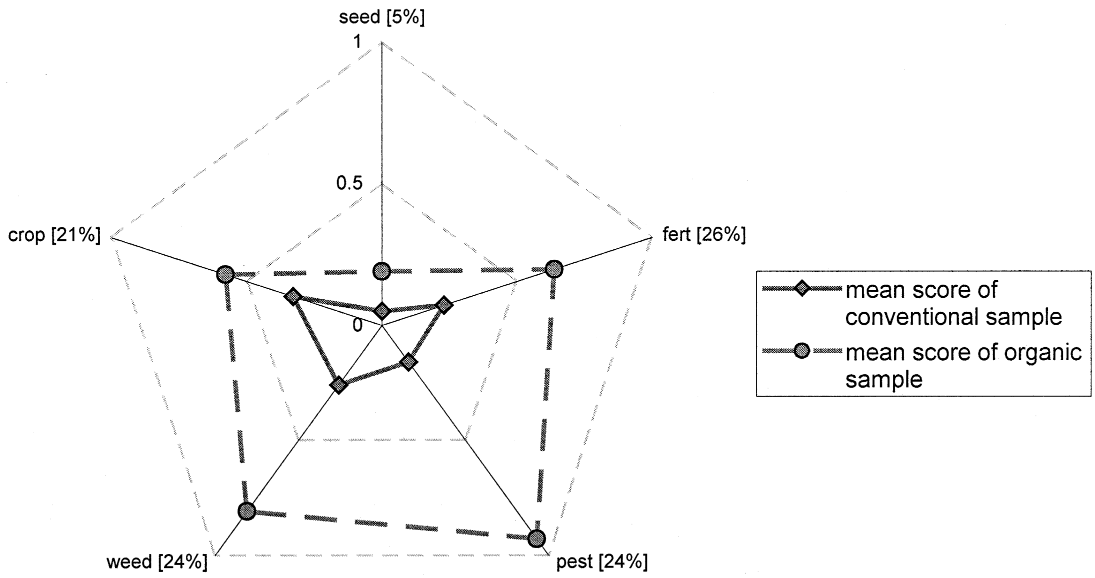

Fig. 3. Mean values of ISAP components for organic and conventional farms.

of the bulk of the organic producers are indeed to be found in the upper range, whereas most conventional producers' scores are in the lower range. Analysis of variance (ANOVA) confirms that scores within the organic group are significantly different from those in the conventional group [F value = 943.88, critical value at 5% = 3.84]. However, there is considerable variation within each group (Table 3) and some overlap between scores in the two producer groups; 18 of the 80 organic producers have ISAP values below the highest score attained by a conventional producer.

This analysis[4] suggests that, although organic producers generally record higher ISAP scores than conventional producers, the scores within the organic group are so wide-ranging that it would be an over-simplification to equate organic production with farm-level sustainability (for further discussion of this issue, see Rigby and Cáceres, 2001). A single index score as sustainability assessment (in Fig. 2) inevitably involves aggregation across a number of different dimensions of sustainability. This presents a problem identified by Bockstaller et al. (1997, p. 261) "[a] problem of a single aggregated indicator is the compensation which can occur between the values of its components. For instance, low nitrate leaching risk cannot balance a higher risk of pesticide volatilization".

A method of overcoming this compensating effect of aggregation is to use sustainability polygons/webs/radars (Swete-Kelly, 1996[5]; Bockstaller et al., 1997; Gomez et al., 1996) that simultaneously display scores for different index components and avoids having to aggregate across different scales. 'Sustainability webs' in Figs. 3 and 4 present scores for the five cate-

[4] A potentially interesting extension to this research would be an analysis of the determinants of the farm ISAP scores. Our preliminary attempts to do this, using characteristics of the farm and farmer as explanatory variables, have produced mixed results. Although the full range of data on ISAP scores can be satisfactorily explained by variables such as household size, gender, sources of information and attitudes, the same variables have little power in explaining the scores *within* the organic and conventional groups.

[5] Swete-Kelly presents such diagrams in his paper but they are actually for hypothetical farms.

gories of farming practices (seed source, fertility maintenance, pest control, weed control and crop management) on individual spines. Each spine is calibrated from zero at the origin to 100% furthest from the origin, so the further the web is from the origin the 'better' the system has scored. The five spines on each of the webs are labelled with the weight assigned to each of the categories within the index (seed source 5%, soil fertility 26%, etc. as discussed in Section 3).

Figs. 3 and 4 do not display threshold ISAP values, although many regard thresholds as the boundary levels of a variable at which significant changes occur: "thresholds are particularly important in an agri-environmental context given the propensity of ecological systems to 'flip' from one state to another" (Moxey, 1998, p. 14). "The identification and quantification of such thresholds should receive a high priority in sustainability research as evidence concerning these thresholds is insufficient" (Izac and Swift, 1994, p. 120).

However, Glenn and Pannell (1998, p. 13) reject the common view that thresholds exist, arguing that "there is no sense in which a sustainability indicator has a threshold level…the threshold indicator level for switching from one [management option] to the other is determined in an economic decision problem. This depends on the biological and physical relationships of the problem, but in no way can be divorced from economic considerations. Consequently it is pointless to attempt to determine threshold indicator levels based only on biological or physical criteria".

In terms of applied work, Taylor et al. do not use thresholds, Bockstaller et al. (1997) apply them on the basis of 'recommended values', while Gomez et al. use community averages. In this study, appropriate or recommended values were not apparent and the usefulness of community averages was questioned since different 'communities' at different moments in time will generate different averages whose usefulness in assessing the sustainability of the farming systems concerned was considered doubtful.

Fig. 3 shows the mean values across the five index categories for the conventional and organic samples. It is immediately apparent that farms of both types are not typically scoring many of the points available with respect to seed source. The impact of this on the overall index scores is, however, relatively small because of the low proportional value of this particular category which may contribute a maximum of 5% of the total ISAP score.

The greatest gap between the mean scores for the two samples is in the pest control category

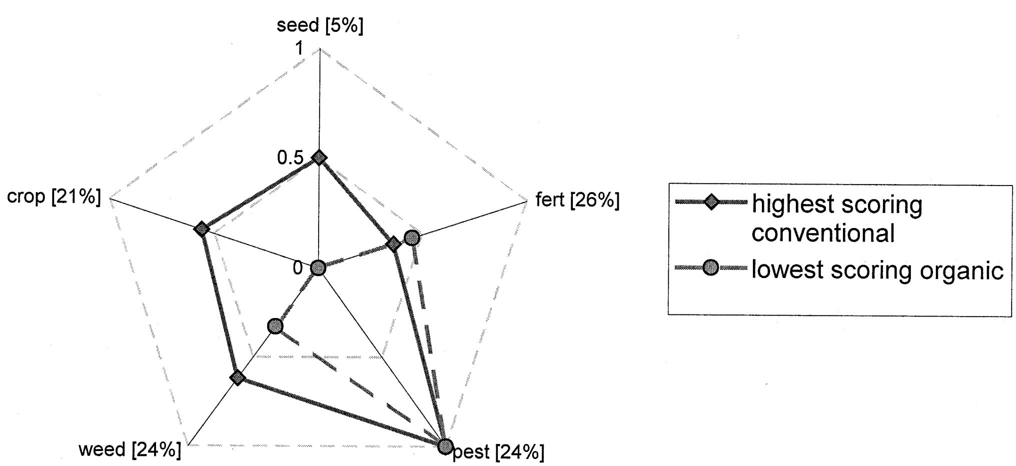

Fig. 4. Values of ISAP components for lowest scoring organic and highest scoring conventional farms.

where the organic farms are typically scoring nearly six times as many points as their conventional counterparts. This compares with a factor of between 2.8 and 3.8 for seed source, weed control and soil fertility between the two samples. The margin is smallest for crop management.

It should be noted that the large gap between the samples in terms of pest control might be viewed as inevitable given the heavy loading of the use of synthetic pesticides within the index. It is, of course, true that the value of any multi-component index will be determined by the weighting of its component parts; the question, therefore, is whether the differentiated loading of the different synthetic inputs is justified. Furthermore, as Fig. 4 indicates it is certainly feasible for conventional farms to be implementing non-synthetic and natural pest control.

The web diagram in Fig. 4 represents the scores for two farms within the sample: the lowest scoring organic farm and the highest scoring conventional farm. This allows some further insight regarding those farms in the range where the scores for the two sets of farms overlap. As Fig. 4 indicates, the highest scoring conventional farm outscores its organic counterpart in terms of seed source, weed control and crop management while both score maximum points with respect to pest control.

The web diagrams in Figs. 3 and 4 highlight some of the differences and similarities between the organic and conventional samples, and subsamples thereof, in a way which cannot be matched by Fig. 2 where the information has been aggregated. As always, there is a trade-off between the more detailed information available when considering a small number of cases and the broader perspective possible when aggregated index scores are used.

6. Conclusions

Some preliminary work to construct an indicator of farm level sustainability has been outlined. The use of different inputs was scored according to their relation to different aspects of agricultural sustainability identified in the literature. Of particular interest is the markedly different scoring of different types of agrochemical inputs. This is motivated by a belief that although all such inputs are prohibited from organic production systems, there are great differences in the type and magnitude of their effects on the environment.

The pattern of ISAP scores generated indicates that the discrete categorisation of organic farms as sustainable and non-organic farms as unsustainable may be a gross over-simplification in many cases. Furthermore, even suggesting that all organic farms, as a group, have progressed further towards sustainability may also be inappropriate. The approach employed here raises questions regarding trade-offs, in terms of environmental impacts, between different farm inputs.

The index used here involves assumptions and simplifications, but serves three key additional purposes. First, it focuses attention on the purpose and limitations of such measures. In particular, we would argue that an index serves to compare the relative hazards to sustainability posed by different farming methods. It should not be regarded as a means to calculate quantitative impacts of a particular farming system. Second, it attempts to construct an indicator of sustainability from data not originally designed specifically for that purpose. One would always prefer to have a more detailed and richer dataset with which to work, but the paper suggests it is possible to make comparative assessments with a fairly detailed but far from compete dataset. We would argue that, for an index of sustainability of farming practices and systems to have wide application, it is desirable to minimise the need for data collected specifically for that purpose and explore the extent to which existing data sources provide enough information for an acceptable approximation in this respect.

Finally, the objection to the inclusion/exclusion of specific components of the index, or the weighting of those components, does not, we would argue, detract from the use of such indices in forcing an explicit consideration of the relative importance in practice of the various facets of agricultural sustainability which have been acknowledged in the literature for so long.

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