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What is the value of a sustainability indicator? Economic issues in monitoring and management for sustainability

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Abstract. Many factors influence the value to a farmer of monitoring a sustainability indicator. Based on an economic model, a survey of farmers and data on actual farmer monitoring of piezometers, a number of important insights are obtained, including the ones listed below.

The value of monitoring indicators will vary by issue, by indicator, by region and by farm. In many cases, the value of continuing to monitor would fall over time as knowledge and understanding increase. For this reason, even successful programs to promote monitoring by farmers may have a limited life expectancy. If monitoring an indicator is to be valuable to a farmer, the indicator must be related to management options which make a difference in achieving the farmer's objectives. However, if the achievement of objectives is very sensitive to management choices, the optimal choice may be so obvious that there is little value in collecting further information about it. The greater the current level of uncertainty about a variable, the greater is the value of monitoring that variable, provided that monitoring does lead to reductions in uncertainty. The greater the degree of uncertainty about the consequences of different management strategies, the lower will be the value of a related indicator. It is not possible to conclude that monitoring indicators is, in general, a good thing.

Introduction

Interest in the use of sustainability indicators (or environmental indicators) has been high among those concerned with resource management in agriculture (e.g. Lefroy and Hobbs 1992; Oades and Walters 1994; Sands and Podmore 2000). However, there is a large gap between the kinds of sustainability indicator monitoring programs advocated by some scientists and what farmers will do in practice. Farmers do monitor a range of 'indicators', sometimes very intensely: e.g. prices, annual profit, debt, and interest rates. Each of these variables relates directly to a farmer's management decisions, and if the variables take different values, management decisions are likely to change. For sustainability indicators to be routinely monitored by farmers in the long term, they probably must similarly be directly relevant to, and useful in, important management decisions.

Clearly, not all indicators will be sufficiently useful in ongoing management decisions to be worth including in a continuing monitoring program. An additional, but distinct, role for indicators is to raise awareness of a resource management issue and to provide an impetus for learning about that issue, hopefully leading ultimately to a change in management. This type of role may be very valuable but it is quite different to the mode of usage for the economic 'indicators' described above. Perhaps some of the disappointment with farmers' modest response to the promotion of sustainability indicators arises from a failure to appreciate this distinction. Pannell and Glenn (2000) note that most of the indicators included in the long lists provided by some authors (such as Walker and Reuter 1996) are more likely to be suited to 'awareness raising' than to 'ongoing management'.

A third impetus for monitoring sustainability indicators is as an aid to accountability. Monitoring may be undertaken as part of a quality control system, or a so-called Environmental Management System (e.g. Wall *et al*. 2001). It may help to provide market access, or to secure access to finance. This category is relatively straightforward, in the sense that if it provides a sufficient incentive for monitoring indicators, this will probably be clearly apparent to managers. The first 2 categories are less transparent, and will be the focus of most of this paper.

The next section briefly outlines the key insights obtained from a detailed economic framework for understanding the role and value of indicators, as developed by Pannell and Glenn (2000). This is followed by a summary of findings from a case study of actual farmer monitoring of saline groundwater levels in a region of Western Australia. Thereafter, the theoretical and empirical insights are combined to guide a discussion of the usefulness of sustainability indicators as resource management tools in agriculture.

Theory

Pannell and Glenn (2000) developed a detailed framework for understanding the value of a sustainability indicator. Here

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I present a broad outline of the framework and the insights it provides. Technical detail is available in the original reference.

If monitoring a sustainability indicator is to have value in the ongoing management of a farm, then that value must arise from better management decisions as a result of reducing the farmer's uncertainty about the variable being observed. This insight is at the core of the framework.

How, then, does the observation of a sustainability indicator fit into the farmer's decision making process? Consider 2 management decisions which each depend on the values of observable physical variables. Examples with sustainability and production orientations are given below to emphasise the parallels: (i) the decision to switch land use from production of annual crops and pastures to production of perennial pasture, which depends in part on the current depth to a saline groundwater table and its rate of rise, and (ii) the optimal application rate of a nitrogen fertiliser, which depends in part on the level and timing of rainfall at the start of the growing season. Both decisions would also depend on an additional range of factors, but for simplicity we will narrow our focus to just 2 factors for each decision: (i) groundwater depth and rate of rise, and (ii) level and timing of early rains. These are the 'indicators'.

In general, the farmer will have some preconceptions about the indicators. Without making observations of the indicators, their values are not known with certainty, but the farmer has subjective views about the ranges within which they are likely to fall, and the likelihood that they will take different values within those ranges. In the case of rainfall, these preconceptions would be based on past experience and perhaps on long-term forecasts. In the case of the watertable, the preconceptions might be based on information from other paddocks or even other farms, or they may be based on a previous observation within the same paddock.

For both decisions it would be possible for farmers to go ahead and make a best-bet decision based solely on their preconceptions (e.g. the best-bet decision might be to establish perennial pasture, or to apply 60 kg of nitrogen). Alternatively, the farmer could make observations of the indicators (observe the watertable in a bore installed in the paddock, or wait and observe actual rainfall) before making a decision. The extra information from these observations may enable an improved decision to be made. This depends on issues such as whether the observation is significantly different to the farmer's preconceptions, how accurately the observation can be made, how applicable the observation is to the whole area for which a decision is needed, and so on. Considering issues such as these, it is possible to make an assessment in advance of the likely benefits from observing the indicators. In the next step, the benefits from any improved decisions must be set against the costs of observing the indicators. Costs could include the time and effort involved, or a possible yield loss from delaying fertiliser application in order to observe the rainfall over a longer period. Looking at the issue in advance, whether it seems worthwhile to observe the indicators depends on whether the expected benefits from the potentially improved decision outweigh the costs of making the observation.

Pannell and Glenn (2000) applied a more detailed version of this framework to a numerical example of monitoring saline groundwater levels. Combining the framework and the numerical example, they reached a number of conclusions about the use and value of sustainability indicators, some of which are presented below. The first several insights are general and relate to the whole process of valuing a sustainability indicator.

(i) If an indicator does not have the potential to change a management choice, it has no value, economic, social or environmental, other than perhaps its intrinsic interest value.

(ii) The change in management, if it occurs, is the result of a reduction in uncertainty about the impacts of different management strategies. The reduction in uncertainty allows decision makers to refine their best-bet strategy.

(iii) There is likely to be wide variation between the values of different sustainability indicators in a given situation, and wide variation in the value of a given sustainability indicator in different situations. It is not possible to conclude that monitoring indicators is, in general, a good thing. Each indicator has to be assessed separately in different regions and farming systems.

(iv) In many cases, the value of continuing to monitor would fall over time as uncertainty is reduced. In some cases, the value of observing a sustainability indicator may be dramatically reduced after a small number of observations, potentially just one. This applies particularly to cases where the value of the indicator is derived from improved qualitative understanding of the system. Once this understanding is obtained, further monitoring has little or no additional value of this type. This is not necessarily a bad thing, but it does mean that farmers are unlikely to be willing to invest in regular ongoing monitoring of sustainability indicators unless the results feed directly into ongoing management decisions.

The next set of observations deals with factors that influence the magnitude of the value of monitoring a sustainability indicator.

(v) The gross value of monitoring a sustainability indicator (the value before deducting the cost of monitoring) can never be negative. At worst, its value would be zero if there was no realistic probability of any resulting change in management.

(vi) A necessary (but not sufficient) condition for the value of monitoring an indicator to be high is for the payoffs to be sensitive to management choices. Commonly in agriculture the payoff curve to different input levels is relatively flat (e.g. Anderson 1975). In this situation, the benefits of monitoring sustainability indicators are low, since monitoring can have little impact on the payoff even if it does lead to changed management.

(vii) If productivity is very sensitive to management choices, the optimal choice may be so obvious [perhaps after an initial period of monitoring/learning as in point (iv) above] that there is little value in collecting further information about it.

Points (vi) and (vii) indicate that the value of monitoring indicators can often be low. Assumptions of the numerical example used by Pannell and Glenn (2000) were selected in such a way that the value of monitoring would be overestimated. For example, the indicators used in the example were closely related to the management problem, and the other parameters and relationships of the model were assumed to be known with certainty and with perfect accuracy. Nevertheless, the estimated gross value of monitoring the indicators was generally low — as low as zero in some cases.

(viii) If there is a high level of uncertainty about the relationship between the level of an indicator and the value of production (or, perhaps, of an environmental outcome), the economic value of monitoring the indicator will be low, since monitoring will not reduce the uncertainty inherent in the decision. This probably applies to many of the more specialised indicators that have been suggested, such as soil enzymes (e.g. Mannipieri 1994) or detailed soil biological properties (e.g. Pankhurst *et al*. 1995).

The final 2 points deal with the idea of 'thresholds' for indicators, which have been considered by some as the vehicle for operationalising the use of indicators.

(ix) Unless the management options are dichotomous, there is no sense in which a sustainability indicator has a threshold level (as supposed in some parts of the literature; e.g. Syers *et al*. 1995). There may be different optimal management strategies for many different indicator levels.

(x) Even if there are only 2 management options, the threshold indicator level for switching from 1 to the other is 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 summary, the theoretical framework provides a basis for understanding why the level of monitoring of sustainability indicators by most farmers has been less than advocates of the approach would like. In essence, theory predicts that very special circumstances must prevail for monitoring to be worthwhile. The next section provides empirical evidence which tests and extends these insights.

Empirical evidence from a case study

In general, farmers have been relatively unresponsive to calls for increased monitoring of environmental indicators. In the case of salinity, for example, the proportion of farmers who are monitoring their groundwater levels has been observed to be low (e.g. Kington and Pannell 1999) even amongst farmers who are situated in regions of high salinity risk and who have already borne the expense of installing piezometers. Given the serious and largely irreversible consequences of land salinisation, this observation may be considered surprising.

Marsh *et al*. (2000) studied farmer monitoring of salinity in a Western Australian catchment where the level of farmer participation has been exceptionally high. In 1989–90, more than 100 new bores were established on farms in the Jerramungup district with the assistance of the Jerramungup Land Conservation District Committee and the Department of Agriculture. Figure 1 shows that more than 90% of farmers in the scheme were monitoring these bores in early years, but that the level of monitoring has fallen to below 50% over the following decade. Marsh *et al*. (2000) used physical data from the bores supplemented by socio-economic data from a survey of farmers to explore reasons for monitoring or not monitoring.

Using a probit analysis, Marsh *et al*. (2000) found that a range of factors explained patterns of monitoring in statistically significant ways. A selection is listed here and some are discussed further below.

Monitoring used to assess management practice. Farmers who reported that they were making use of the monitoring to evaluate a specific management practice were more likely to monitor.

Catchment. Farmers in different subregions or subcatchments varied in their level of monitoring.

Time. Participation in monitoring fell over time (although it has since stabilised).

1993 dummy variable. Farmers received the first detailed assessment of information from their bores in 1992. A dummy variable indicates that monitoring fell significantly after this date. A distinct drop is not visible in

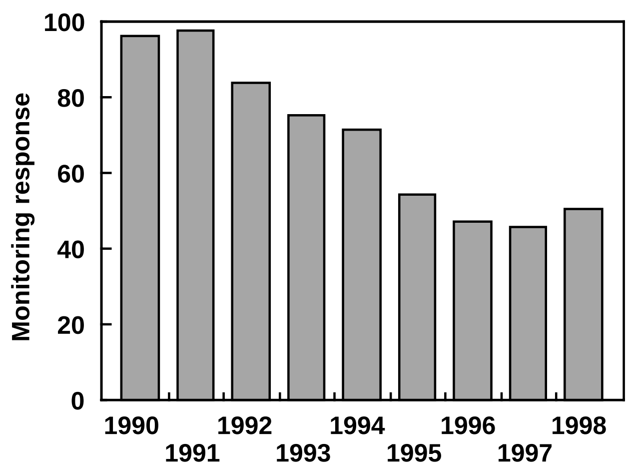

Figure 1. Percentage of farmers who monitored bores in the Jerramungup Land Conservation District (110 bores on 81 farms were installed in 1989–90).

Figure 1, but is highly significant (statistically) when other influences are factored out in the probit analysis.

Groundwater depth. Farmers for whom saline groundwaters were still deep below the surface were less likely to monitor.

Salt storage. Bores at locations where the total level of salt stored in the soil profile was relatively high were more likely to monitor.

Perceived threat from salinity. Farmers who reported that they perceived a relatively high threat from salinity on their farm were more likely to monitor.

Landcare participation. Farmers who were actively involved in a Landcare group were more likely to monitor.

Marsh *et al*. (2000) supplemented these quantitative findings with qualitative evidence drawn from the farmer surveys. A number of the survey respondents said they were using data from their groundwater monitoring to assess management strategies that they had implemented, such as establishing lucerne or surface water management. Marsh *et al*. concluded that this was the most powerful reason to continue monitoring. Associated with this was a desire in some cases to 'prove a point', especially if the strategy being implemented was against conventional wisdom or against the law (e.g. clearing). There were farmers who wished to clear further areas of their land (an action currently prevented by law) and who were anxious to demonstrate that tagasaste, lucerne or other perennial alternatives will substitute hydrologically for native vegetation.

Groundwater monitoring has the potential to create a district awareness that is necessary to gather local support for district initiatives to obtain funding and support to address salinity issues. Once that funding has been obtained, continued monitoring serves a number of purposes. It provides information to funding bodies and government agencies that addresses accountability requirements, such as data that plot district trends, record the response to different management options, and contribute hydrological information to large-scale projects. Further to this it helps in 'creating an impression' of awareness and willingness to act that attracts both outside expertise and further funds for a range of Landcare and production purposes. Thirteen per cent of the survey respondents indicated that their main reason for monitoring was to provide 'data that is needed for community and regional hydrology purposes'. Some farmers also continued to monitor bores out of habit and/or a feeling of responsibility.

Groundwater monitoring appears to be a powerful awareness-raising tool, but some farmers discontinue monitoring even though they have a rising saline watertable, presumably because their awareness has now been raised. Some who felt that suitable management responses are not available stated that they discontinued monitoring because they did not wish to continue receiving bad news about which they could do nothing.

Implications

Conclusions from the analytical framework and the case study have implications for the future role of sustainability indicators in agriculture. Firstly, it seems unrealistic to expect that monitoring sustainability indicators will, in itself, be sufficient to prompt substantial changes in farm management practices. The problem of technology adoption is too complex and multifacted for that (e.g. Lindner 1987; Pannell 1999, 2001). In many cases, awareness of a resource management problem is probably not the factor holding back management changes.

The focus on monitoring by some of its advocates is probably not sufficiently grounded in an understanding of farm management. It would probably be more productive in many cases to focus on management practices first and allow monitoring to follow, if that is appropriate.

Even if management changes are made to avert a problem of land or water degradation, it does not necessarily follow that monitoring of indicators will form part of the management package. This depends on factors such as how useful the indicators are to subsequent management decisions, and how accurate they are.

We should accept that most farmers will not choose to monitor a wide range of sustainability indicators unless it is beneficial to do so, and that economic motivations will play an important role in that decision. Some of the benefits from monitoring indicators accrue to the broader community, particularly where farmer data is used by agencies in assessing resource management issues. Some commentators have highlighted the importance of this data, and decried the lack of farmer monitoring. However, a more pragmatic position is to accept that if the data is important enough to the agencies, they need to take steps to ensure that it is collected, rather than relying on voluntary cooperation from public-spirited farmers.

Finally, a comment on the common practice of including standard socio-economic variables in lists of suggested sustainability indicators (e.g. farm profit, farm debt). Such variables are already routinely collected by a range of statistical and economic agencies. While they are, no doubt, related in various ways to the resource management issues of interest, including them in indicator programs appears to be mainly a needless distraction from the core issues. A better role for the economics discipline would be to evaluate the economic viability of available resource management practices, and to assist in assessing the economic benefits of monitoring.

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