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Volume 40, 2000

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lalina.muir@publish.csiro.au

Published by
CSIRO PUBLISHING
in co-operation with the
Standing Committee on Agriculture and Resource Management (SCARM)

Australian Journal of Experimental Agriculture, 2000, **40**, 631–642

The sustainability indicator industry: where to from here? A focus group study to explore the potential of farmer participation in the development of indicators

C. King[AC], *J. Gunton*[B], *D. Freebairn*[D], *J. Coutts*[CE] *and I. Webb*[F]

[A]Department of Primary Industries, PO Box 102, Toowoomba, Qld 4405, Australia.
[B]Department of Primary Industries, PO Box 27, Kairi, Qld 4872, Australia.
[C]Department of Natural and Rural Systems Management, The University of Queensland, Lawes, Qld 4343, Australia.
[D]Department of Natural Resources, PO Box 318, Toowoomba, Qld 4350, Australia.
[E]Rural Extension Centre, The University of Queensland, Lawes, Qld 4343, Australia.
[F]Department of Natural Resources, PO Box 1054, Mareeba, Qld 4880, Australia.
[F]Department of Natural Resources, PO Box 1054, Mareeba, Qld 4880, Australia.

Abstract. In Australia, the work being carried out on sustainability indicators has become an industry on its own. This paper firstly provides an introduction that reviews the literature on indicator development and use, particularly in relation to agricultural production systems. A number of reasons for the limited use of indicators by farmers are mentioned. Secondly, a focus group study involving farmers from two dryland cropping areas in Queensland to investigate sustainability indicators and sustainable farming systems is presented. The indicators the participants identified during focus groups included indicators that reflect (i) farming system components, (ii) the management of these components, (iii) the management of all components and their interrelationships at the systems level, and (iv) the external factors that influence and interact with this systems level. Focus group analysis also showed that the participants perceived sustainability as an on-going process and a sustainable farming system as dynamic and emergent in nature. The implications of these findings are discussed. Three key issues were raised (i) the value of farmer knowledge with respect to the development of indicators has often been ignored; (ii) there are links between indicators developed through traditional science and those being used by farmers; and (iii) off-farm indicators used by farmers may be very useful in policy development at a variety of levels (e.g. catchment, regional, national, global). The focus group method involving farmers provided a useful way to gain insights about farmer perceptions and for farmers to learn from each other during the research process.

Additional keywords: sustainability, farming systems, farmer perceptions, indicators, focus groups, resource management.

Introduction

Agricultural and resource management research, development and extension (RD&E) organisations have been trying to implement the use of sustainability indicators in rural areas in Australia during the past decade. A total of 150 projects focusing on sustainability indicators was identified nationwide by delegates from the National Workshop on Indicators of Catchment Health held in Adelaide in 1996 (Reuter 1997). In a recent consultancy to develop sustainability indicators for cropping systems in central Queensland, one consultant stated, with much support from colleagues, that: "developing indicators has become an industry on its own".

The reasons why indicators of sustainability have been and still are being developed are plentiful. Indicators have been developed for overall policy reform (OECD 1997), assessing the socio-economic status of rural areas (Copus and Crabtree 1996), evaluating and monitoring of land resource changes due to human induced land use pressures (Pieri 1996), monitoring catchment health (Irons and Walker 1996), planning and monitoring improved

10.1071/EA99148

cropping strategies, creating farmer awareness of land degradation (Wylie *et al*. 1993) and sustainable agriculture in general (SCARM 1993). Other general rationales include benchmarking, the justification of public expenditure in resource management, support for the land 'stewardship' ethic of farmers, economic health and inter-generational equity.

A number of frameworks have also been developed to identify indicators. These include the driving force-state-response framework (OECD 1997), the 5-level framework for evaluation of sustainable land management (Gameda and Dumanski 1994), a framework based on farm economics, physical aspects of the farm, human/social issues and off-farm impacts (McGuckian 1997), a cobweb based framework that takes into account farmer satisfaction and resource conservation (Gomez *et al*. 1996), a framework for evaluating soil quality using the sequence of process, attribute, indicator and methodology (Carter 1996) and a framework based on decision theory to guide thinking about the values of potential indicators (Glenn and Pannell 1998).

A variety of criteria have been suggested to develop and select indicators. Selection criteria have included policy relevance, analytical soundness, measurability (OECD 1997), satisfying valid sampling and statistical and consistent methodologies (SCARM 1996), being scientifically and technologically credible, robust and simple, showing direct relationship to the factor being evaluated and being highly sensitive to reflect change over short time frames while having relevance over long time frames (Dalal 1997). In most cases indicators are static measures (Williams 1997), although some researchers have recognised a need for indicators to be monitored in a dynamic context (Lawrence 1997) and measured in relative rather than absolute terms (Copus and Crabtree 1996). In contrast with the idea that indicators should be directly related to biophysical 'health', an alternative approach has been proposed (Freebairn 1999) that some measure of behaviour (e.g. implement sales) or land condition description (e.g. soil cover) may be more stable and measurable than observed environmental conditions such as erosion rates, water quality or soil organic matter.

Indicators have been developed for a variety of end users. These include farmers (Hunt and Gilkes 1992), local councils (White 1997), catchment and land protection boards (Hill and Forbes 1997), policy makers (OECD 1997) and other decision makers at community (SIP 2000), regional, national (SCARM 1996) and global levels (Doran 1996; Pieri 1996). In some instances, however, end users have been encouraged to develop their own indicators. For example, the ISO 14000 concept has introduced the notion of continuous improvement to farmers, as a way of developing their own sustainability indicators and self-audits. A totally bottom-up approach, however, is now being questioned in the same way as traditionally top-down approaches have been questioned in the past, that is, with respect to the validity of different knowledge systems. A bottom-up approach (i) assumes that traditional scientific knowledge is less valid than indigenous or farmer knowledge and (ii) denies the input of other stakeholders in the development process with regard to the ecological sustainability endeavour at a system level, wider than that of a farm or catchment (King 1998).

One concern in the management of soil and water resources is the impact of agricultural practices on those resources. Although many indicators of sustainability have been developed for use in agricultural systems, there is still debate on how to set them into a legislative or social context. In terms of this implementation, indicators have been presented as thresholds, standards, targets, indexes, performances and benchmarks, and are often based on scoring systems. Indicator decision trees (Lawrence 1997; McCord 1997) and sustainability matrices (Copus and Crabtree 1996) have even been developed as tools for assisting implementation. Indicators developed have gone as far as to inform end users whether their system is highly sustainable, moderately sustainable, not sustainable or marginally sustainable (McGuckian 1997). Although indicators have been developed for a number of purposes and a variety of users in the agricultural and resource management arena, the emphasis now seems to be placed on developing indicators that can be used by farmers in the paddock where change is occurring.

A number of reasons have been put forward as to why indicators are not being effectively used for the purposes they have been developed. In agricultural production systems, reasons have been primarily focused around farmers not adopting sustainability indicators that have been developed through scientific research. Reasons include measurements being meaningless for farmers, production agriculture being viewed as separate from conservation agriculture by farmers, indicators being regarded as theoretical and not useful, lack of enthusiasm by farmers for measuring land degradation on their own farms (Wiley *et al*. 1993), the threatening nature of the land conservation subject, monitoring being perceived as a negative process by farmers (McCord 1997) and a feeling by farmers of being 'assessed' (Williams 1997). In a recent review of the sustainability indicator literature, Glenn and Pannell (1998) note that the criteria used to select indicators appear to have no link to the application of the indicators in management and decision making.

Dover (1994) suggests that the long-term observation and monitoring required to show trends in natural systems involve 'permanence of resourcing or function' that is not a desirable process for community groups. Walker (1997) suggests that problems with the implementation of indicators are more likely to do with (i) [not] identifying and involving the user base in indicator selection and collection, (ii) poor articulation to the target users of the benefits from documenting data (e.g. the use of a report card), (iii) poor definition of the spatial coverage needed for statistical purposes, and (iv) limitations on the interpretation that users can place on indicators.

It has been suggested that 'adoption rates' can be improved by enhancing the meaning of indicators and integrating indicators into other programs (Wiley *et al.* 1993) or under different banners such as Property Management Planning (PMP), TOPCROP or Farmwise (McGuckian 1997). The acceptance of indicators by farmers and the community has also been recognised as a way forward. An increasing understanding of the need for ownership in the collection of data by end users has resulted in suggestions to have participatory processes within these projects (Irons and Walker 1996). Three essential components for creating and maintaining a successful natural systems monitoring tool-kit are suggested by Irons and Walker (1996). These are (i) the political will of Federal and State Cabinets, (ii) a coordinated commitment from government agencies, and (iii) community support for the necessary responses. It is for some of these reasons that participatory approaches have been strongly recommended for the 'indicator industry'.

In the Proceedings of the National Workshop on Indicators of Catchment Health, the workshop summary by Williams (1997) provides an overview of the issues raised and emerging principles that reflect a current 'indicator school of thought'. Major points illustrated in this report concerned with the use of indicators at a community and on-farm level were: (i) indicators must have meaning to land users, to local and regional catchment committees and to policy development; (ii) for any indicator program to be of value, it must be driven by the community of interest, not the academics or the research institutions; (iii) there is a need to be careful in assuming any given value system in judging response to catchment indicators; (iv) the research on indicators and the development of tools for monitoring must be conducted within a social context and in a participatory manner if we are to gain progress, ownership and innovation.

Summary of the review

The authors' review on sustainability indicators enables some general concepts and conclusions to be drawn about indicator development and use. They are: (i) indicators have been predominantly discipline based, point sourced, monitored in a static context, and measured in absolute terms; (ii) indicator development has been predominantly reductionist in nature, focused at regional, state and national levels, carried out by the scientific community, and neglected end users in the development process; (iii) indicator use has been predominantly based on an adoption by end users, content orientated, ignorant of farmer knowledge, and a 1-way transfer of technology; and (iv) current thoughts of RD&E for indicator development and use include: development of indicators in a dynamic and social context, participatory processes with land managers in implementation, the inclusion of trend as an indicator as well as condition, and indicators having meaning to end users.

In light of this review, it is proposed that there has been limited research undertaken to explore the value of farmer knowledge in relation to sustainability and sustainability indicators. Farmer knowledge (sometimes referred to as indigenous knowledge or rural peoples' knowledge) has been shown to be an important contributor to the development process, particularly with regard to the relevance and applicability of technology innovation. The following focus group study illustrates farmer knowledge in this area.

Methods

In an effort to understand the nature and types of indicators that farmers use to assess their farming systems and make management decisions, a preliminary study using a focus group technique was conducted for the Australian Centre for International Agricultural Research (ACIAR) Project 9435: Tools and Indicators for Planning Sustainable Soil Management on Semi-Arid Farms and Watersheds. This research was based on 3 premises. Firstly, an improved understanding of farmer perceptions in this area would contribute to project direction during its initial development stage and provide some insight into instigating and facilitating future participatory processes with scientists and farmers. Secondly, farmer knowledge must play an important role in developing indicators that are more appropriate and applicable for use at a variety of levels in resource management. Thirdly, this method would provide a mechanism for farmers in the research process to also learn from each other about farming systems management and decision making.

Data collection

Qualitative data were collected using a focus group method (Krueger 1988). As the purpose of the study was to explore the diversity of indicators used by farmers, focus groups were seen as an appropriate sampling method to maximise a range of responses. Focus groups have developed out of market research techniques and are designed to obtain a range of perceptions, feelings, opinions and thoughts in a given grouping of people. Analysis of information gained through focus groups seeks patterns and trends that develop among participants within and across the groups. Focus groups have their own internal rigour which provides validity of findings. This includes the method for choosing and inviting participants, developing and undertaking the questioning route and in analysing the data. The test for the optimum number of focus groups is when there is little new information being gained with each subsequent group.

In this study, 2 focus groups (1 group with 6 male participants and one group with 7 female participants) were carried out with farmers from the Atherton Tablelands, North Queensland, and 1 focus group (6 male participants) with farmers from the Darling Downs, South Queensland. All participants were involved in managing dryland mixed-cropping systems. Participants were selected to represent a cross-section of farmers in these areas using a variety of criteria (e.g. age, socio-economic status, personality, previous involvement in groups). By including people from many categories, the researcher maximises the range of responses. These responses are not an equal representation of the frequency (e.g. outcomes from random sampling) of people in a community belonging to these categories. Random sampling techniques were discarded as options for data collection as these techniques require more time and resources to gain the same maximum diversity. As such, the results in this paper are not intended to depict a representative frequency of a community (and therefore not intended to provide specific indicators for use by all farmers in dryland cropping). Rather, the results are a depiction of the diversity of indicators used by the participants in the focus group to aid in the management of their farming system.

Data analysis

The data from 2 of the key questions asked during the focus group are explored in this paper. The first question: 'What does a sustainable farming system mean to you?' was used so that the data from the second question could be placed in context. That is, the interpretation and analysis of the key question would be based on the response of the first question. The second key question was 'What are the things that tell you that you are farming more sustainably?' The focus group sessions were recorded and general themes and participant reactions were noted. Focus group data were analysed using a qualitative data analysis package, QSR NUD*IST (Non-numerical unstructured data indexing, searching and theorising) (Gahan and Hannibal 1998). This package is useful for handling textual data and enables a rigorous analysis of qualitative data. Emergent themes and linkages were identified using this package, through a series of coding participants' own responses.

Although there has been delineation between 'scientists' and 'farmers' in this paper, the authors acknowledge the scientific nature of farmers' roles in farming systems management. When the term 'scientists' is used in this paper, it refers to scientists working in formalised scientific organisational structures.

Results

There were several themes that emerged about the nature of sustainable farming systems and the types of indicators that are being used by the land manager.

Theme 1: what is a sustainable farming system?

The focus group study showed that the participants perceived that a sustainable farming system was not a specific goal or end point to be reached, but rather a dynamic system where it is possible to influence the properties of that system for it to be more sustainable over time. All participants were aiming to be more sustainable, although they expressed that system properties can be influenced so that a farming system over time can be more or less sustainable.

A farming system encompasses several components, and those emphasised included the farm family unit, natural resource base, finances, capital items and cropping system. Each of these components are (i) interrelated within the farming system (i.e. the dynamic activity that goes on within the property boundary that the participant manages), and (ii) constantly influenced by the external system (i.e. the dynamic activity that goes on outside the property boundary that influences a participant's management decisions).

Participants perceived their individual farming system as unique from other farming systems. A sustainable farming system is based on individual preferences (e.g. quality of life) and it is therefore difficult to have benchmarks that can be used across the board to assess sustainability. Since farming systems are individual and site specific, the rate of change in relation to a more sustainable system may vary between farming systems in a catchment, district and region. It is difficult to compare rates of change as the changes are embedded within an economic, social and resource environment.

Theme 2: the nature of indicators

System properties were not seen as indicators of more or less sustainable systems, but rather, they can be monitored over time, either qualitatively or quantitatively or both, to reflect any change in the farming system. Data showed that a sustainability indicator as perceived by the participants is a trend that occurs over time, not a measurement at a particular point in time. These measurements can only be used to develop an indicator. A trend is monitored through continuous measurement and observation of a variety of farming system properties. Data also showed that indicators of unsustainability are used just as much as indicators of sustainability.

Indicators reflect the variety of components within the farming system. Indicators do not exist in isolation. They are impacted upon, influenced by and may depend on other internal and external farming system factors. Indicators are trialed and tested (by the farmer) through experience over time and are continually being evaluated

Table 1. Indicators for farming system components and corresponding attributes identified by farmers

Farm family unit	Natural resource base	Finance base	Capital items	Cropping system
Quality of life	Soil quality and quantity	Margins	Machinery costs	Chemical costs
Health	Water availability	Net farm income stability	Land price	Fertiliser costs
Aesthetic qualities	Natural vegetation	Investment opportunity	Land area	
Available time	Wildlife			

for their usefulness in assessing the sustainability of a farming system. Indicators may be replaced with other more applicable indicators at any time, reflecting the dynamic and emergent nature of farming systems.

Theme 3: types of indicators used by participants

The indicators the participants identified during the focus group study could be grouped into 4 main categories: (i) farming system components, (ii) management of these components, (iii) management and decision making within the farming system (i.e. the interrelationships between components and the sum of these components), and (iv) external factors that influence and interact with the farming system.

The first 3 of these categories included indicators that participants use that tell them that they are being more sustainable. For the purposes of this paper, these indicators are referred to as the on-farm indicators and they reflect participant's own farming system. The fourth category includes indicators that participants use that tell them whether they have the ability to be more sustainable. These reflect external factors that influence the farming system. The indicators in this category are referred to as the off-farm indicators and reflect the environment external to the farming system. In each of these 4 main categories an indicator and attribute have an underlying assumption of change. For example, in Table 1, soil quantity can be read as 'a change in soil quantity'.

Indicators that reflect the farming system components. Five main indicators were identified (and paralleled the perceived components of a farming system) including the farm family unit, natural resource base, finance base, capital items and cropping system. These are listed in Table 1 along with the corresponding attributes also identified in the focus group study.

Indicators that reflect the management of farming system components. Other indicators related to the management of the identified farming system components. These are illustrated in Table 2.

Indicators that reflect the management of the farming system (i.e. all components and their interrelationships). At a systems level, the 2 indicators used reflected changes in the management and decision making involved in the entire farming system, that is, the management of all components and their interrelationship. For example, implementation as an attribute can be read as 'a change in the way the farmer implements the management process (or all components and their interrelationships)'. Table 3 depicts these with the corresponding attributes.

Indicators that reflect the external factors that influence and interact with the farming system. The participants indicated that there were a number of indicators they used that tell them whether or not they have the ability to carry out decisions they have made toward

Table 3. Indicators and attributes for the management and decision making within the farming system

Management	Decision making
Whole farm planning	Critical thinking
Implementation	Reflection about experience
Monitoring	Use of experience
Timeliness of operations	Experimentation

Table 2. Indicators for the management of farming system components and corresponding attributes

Farm family management	Natural resource management	Financial management	Capital items management	Croppings management
Time management	Soil management	Risk management	Machinery management	Chemical management
Stress management	Water management	Business management	Property management	Fertiliser management
	Natural vegetation management			Operations management
	Wildlife management			

Table 4. Off-farm indicators and attributes identified by farmers in the focus group study

Off-farm indicator	Attributes
Information	Access to information, consistency of information, farmer input into information generation
Farming community	Community cohesiveness, social contact, suicide levels, stress levels
Market forces	Consumer preferences, market control, market price, market stability, distance to markets, freight costs, alternative markets, access to export markets, middleperson cost
Catchment characteristics	Soil and water movement across property boundaries, catchment planning, catchment coordination, location in the catchment
Government support	Tax deductions, rebates, policy, regulation
Public relations	Media reporting, consumer preferences, urban perceptions
Industry requirements	Quality of product, quantity of product, deregulation, industry input, industry control
Research and technology	Awareness of research and technology, access to research and technology, farmer input into research and technology, relevance of research and technology, ability to use technology
Global trends	Level playing fields, current issues and concerns globally, global supply and demand

Table 5. A subset of farmer descriptions of measurements for less sustainable and more sustainable farming systems for four (from a total of 83) attributes identified in the focus group study

Indicator	Attribute	Example descriptions
Natural resource base	Soil quality and quantity	***Less sustainable*****:** compacted soil, salty soil, chemical build-up, clods, smear pans, loss of fertility, loss of organic carbon, residue problems, wheel tracks, water erosion, wind erosion, soil washing down the creek, soil erosion, topsoil is gone. *More sustainable*: soil more friable, soil easier to work, improved soil structure, improved soil texture, improved root penetration, increased organic carbon levels, balanced nutrient levels, presence of ground cover, mulch.
Natural resource management	Soil management	***Less sustainable*****:** spoiling your soil structure below, using larger and larger tractors to pull the ground, excess passes of machinery, pouring chemicals on, applying a quick fix, ripping up the paddock cropping on a slope that is too steep for anything but pasture. *More sustainable*: using less soil depth, putting in contour banks, using appropriate rotations, using mixed farming, adding mulch, planting crops that are in the ground longer, working your ground less, monitoring of fertiliser, being nitrogen aware, keeping nutrient levels up, grassing of contours, applying minimum or zero till practices, holding your ground together, appropriate distance between contour banks.
Decision making	Critical thinking	***Less sustainable*****:** doing things just because the generations before you did it that way, doing what everyone else is doing, making decisions in isolation of the big picture, no ability to change programs or schedules when situations change, not learning from mistakes and being able to then do it better next time. ***More sustainable*****:** ability to critically think about advice and its application rather than just accepting it, knowing why you are doing something, having options available and being able to choose the most appropriate one, being able to make decisions in relation to the whole system.
Research and technology	Farmer input into research and technology	***Less sustainable*****:** farming community doesn't have a say in what research gets done, government departments dreaming up projects, no money for relevant research, not having enough time to be involved in research activities, not being considered in the development of research and technology, curtailing of funding to organisations that work with farmers on research projects. ***More sustainable*****:** having us involved in the research, finding out from us ideas about what research and technology might be useful, letting farmers try out some of the technology along the way, working with farmer groups to look at potential research activities and then trying something out together.

more sustainable management options. These are seen in Table 4.

Description examples by focus group participants

To provide some examples of less sustainable and more sustainable farming systems in relation to indicators and corresponding attributes, one attribute has been chosen from each of the Tables 1–4 and example descriptions used by participants in the focus groups are illustrated in Table 5.

Links between farmer and scientist indicators

Some links between the natural resource base indicator identified by farmers in the focus group study and some of the soil and other bio-physical measurements being made by the project scientists on the krasnozem (Ferrosol) sites in north Queensland are shown in Table 6. These are also illustrated with respect to the general issue for sustainability they predominantly aim to address. Measures given in italics are fundamental properties of the land resource and are seen to be unchangeable through changes in management. Indicators shown in bold are of particular importance to one of the studies being carried out for the ACIAR Project on Red Ferrosols (krasnozems) of the Atherton Tablelands that are perceived to be easily determined by scientists. This suite of scientist and farmer measurements is not intended to be fully comprehensive or to be appropriate for all land resource sustainability issues. That is, the measurements in the Table: (i) do not attempt to address other components within the farming system (and their interrelationships), and (ii) are context bound (e.g. particular soil types and farming practices).

Some of the scientists' measurements listed in Table 6 are also input parameters for the simulation models and other tools which are being used by ACIAR Project 9435 to predict crop yields and soil responses over time and with management or environmental changes. For example, the Perfect model (Freebairn *et al*. 1996) is being calibrated to predict soil loss over time and may help identify critical thresholds for rapid decline of crop yields and sustainability.

It should be noted that the indicators and attributes illustrated above are those that were identified through 3 focus groups (all participants involved in dryland cropping systems management). If another focus group

Table 6. Links between the indicators identified by the farmers in the focus groups (i.e. natural resource base indicator and corresponding soil quality and quantity attribute) and soil and bio-physical measurements being used by the ACIAR project scientists

Issue for sustainability	Farmer measurements to inform indicator	Scientist measurements to inform indicator
Soil erosion	Slope	Slope
	Distance between contours	Slope length
	Ground cover, mulch or stubble	Soil surface cover
	Soil erosion	Canopy cover
	Moisture retention, excess run-off	Run-off
	Soil more friable, easier to work	Soil strength, morphology or consistence
	Erosion	Soil loss
Available soil water	Root penetration	Rooting depth
	Root penetration	Barrier layer (for roots)
	Root penetration (erosion, topsoil gone)	Gravel or rock content
	Groundcover, mulch or stubble	Soil surface cover
	Moisture retention, timing of planting	PAWC[A], DUL[B]
Soil quality	Improved soil structure, compacted soil, wheel tracks, pans, earth worms	Bulk density, soil fauna
	Keeping organic carbon level up	Total organic carbon
	Keeping organic carbon level up	Levels of labile carbon[C]
	Organic carbon levels	Levels of labile carbon
	Nutrient levels balanced	pH, extractable calcium, and aluminium
	Salty soil	Electrical conductivity
	Nutrient levels balanced, fertility loss	Extractable soil nutrients
	Nutrient levels balanced	Total soil nitrogen
	Improved soil texture	Organic matter, hand soil texture
	Chemical build up	Electrical conductivity

[A] PAWC, plant available water capacity. [B] DUL, drained upper limit.
[C] Labile carbon, especially C1 easily oxidised fraction (by 0.33 mmol/L $KMnO_4$).

was held with farmers from another location or managing a different type of farming system (e.g. irrigated systems), alternative or additional attributes may be identified. This study was not undertaken to gain a comprehensive list of indicators to suit all farming systems and all locations and should not be read as such. The study was carried out primarily to explore: (i) farmer's perceptions about sustainability, (ii) farmer's knowledge about and use of sustainability indicators, and (iii) whether there are any commonalities between farmer and scientist perceptions.

Discussion

Referring to the array of indicators and attributes listed above, it is proposed that the farming community have much to offer in terms of both on-farm and off-farm indicators. Not only do they have much to offer, but it may be argued that if scientists do not make a link with farmers in relation to developing indicators, the relevance and appropriateness of the indicators that they develop must be questioned. Perhaps indicators being used by farmers may provide insight into (i) indicators that may be useful at different levels of scale (e.g. catchment, regional, global scales), (ii) how to develop mechanisms between scales, and (iii) the interrelated nature of systems components and external influences. The literature seems to suggest that farmers should be using on-farm indicators to monitor resource condition, but this research shows the extensive variety of indicators already being used both on-farm and off-farm. One of the main points that the authors of this paper would like to put across is the extent of farmer knowledge about sustainability indicators in relation to diversity and scale.

Similarities and differences in the perceptions of farmers and scientists

An important point to note from this study is that indicators used by farmers may be similar to those suggested by the scientific community. This is particularly apparent with the natural resource base indicator and subsequent attributes. At first glance some of the indicators may appear different (i.e. different terminology or degree of specificity) however, the fundamental principles are often the same. For example, some farmers use steel rods to assess soil strength whereas a scientist might use a shear vane and simultaneous measurement of soil moisture. As another example, many farmers monitor soil friability and surface structure by feel, however science at this stage has not been able to quantify 'friability' or 'tilth'. In this case, farmers' measurements of feel are just as valid (if not more valid in a 'traditional scientific' sense) as any measurements developed by scientists that have at best shown limited correlation with 'friability'. Given these examples, an alternative process for the development of indicators could be a participatory one, where farmers and scientists work from basic principles to develop more specific and appropriate measurements that are based on a common language and meaning and are relevant to particular situations.

The literature on indicators seems to emphasise that many indicators developed by scientists are indicators to monitor particular properties of farming system 'components', and not the 'system' as a whole. However, the study illustrated that farmers use indicators at both a 'components' level and a 'systems' level. At present, there is limited information on indicators at a systems level, even though a systems approach has been shown to be useful because it takes on a holistic view of the world and allows for interactions to be discovered (Roling and Jiggins 1998). The development of indicators has been predominantly reductionist, and interactions are neglected as research focuses around exploring and analysing separate parts of the system. Using participatory approaches enables scientists to work with farmers to develop indicators at a systems level to fill this gap.

What also needs to be considered is how the nature of sustainability and a sustainable farming system is perceived by different individuals in the indicator development process. If some participants view sustainability as a process and others perceive it as an end point, then it may be difficult to reach a consensus on a set of common and appropriate indicators. For this reason, one of the first stages in developing indicators is to create an environment where all participants can be informed about each other's perspectives, providing a foundation for negotiation. This could also deal with some of the issues associated with what constitutes 'validity' with respect to attributes and measurements. In many cases, the validity of traditional scientific (often quantitative) measurements have outweighed other types of measurements (often qualitative) even though these types of measurements may be more contextually based and provide more in-depth understandings of the complexity of interrelationships between system components and the system as a whole.

Benefits of farmers' indicators of sustainability

There are a number of benefits to understanding the indicators that farmers use, how they use them and why they use them. King (1997) promotes the value of farmer process knowledge as well as farmer technical knowledge in gaining insight in farming systems management, particularly in taking a multi-disciplinary approach to decision making and management. With respect to the development and use of sustainability indicators, farmer knowledge, both content (i.e. the types of indicators) and process (i.e. how to implement indicators) must be seen as valuable and valid. It is proposed that indicators used by farmers are valuable through: (i) contributing to our wider knowledge of indicators and how they may be used to improve decision making and resource management action, (ii) the development of indicators where issues may be raised by farmers or the community but there are no existing indicators to address these issues, (iii) developing ways of improving the measurement and monitoring of indicators already being used by farmers and scientists, (iv) understanding the interrelated nature of indicators at a systems level, (v) devising learning tools to work with farmers in understanding more about the relationships occurring in their system; (vi) learning about resource manager preferences and perceptions, (vii) linking scientifically generated indicators with those already being used by farmers that have been developed through experience and are in a real world context, (viii) creating new indicators that reflect both farmer knowledge and scientific knowledge, (ix) providing input into government policy and regulation, (x) identifying inconsistencies between indicators that are to be implemented and the environment in which they are being implemented, (xi) providing input into the decision making of those working with sustainability issues, and (xii) understanding why farmers are using some indicators and not others and why some indicators are not appropriate in particular situations.

The issue of scale of measurement is important to mention at this stage. Previous assumptions in the 'indicator industry' have suggested that farmers, communities and government differ in the type of indicator in which they are interested, particularly in relation to scale. For example, it is assumed that farmers are more interested in on-farm and paddock condition indicators, and rural communities are interested in catchment assessments. In contrast, it is assumed that governments are more interested in (and require) integrated regional assessments, which take into account land use and its spatial and temporal impact on natural resource condition, regional wealth generation and social well-being and their associated policy implications. While these assumptions seem pertinent in relation to the different roles of farmers, communities and government, this study suggests that the participant farmers, were in fact, interested in indicators at a variety of levels, greater than that of the farm and catchment.

Participatory processes and the development of indicators

The value of farmer knowledge and experience has been recognised as a complementary source of knowledge to traditional science (Scoones and Thompson 1994). In recent 'sustainability indicators literature', there is an emphasis on the involvement of farmers and other community members in the use of indicators to collect data on and monitor local resource condition to gain community ownership and awareness (Anon. 1997; Irons and Walker 1996). This paper however, illustrates that the development of indicators for monitoring and assessing resource condition has been predominantly carried out by the scientific community and suggests that farmers and scientists need to be involved together in both the development and use of these indicators. Participatory processes involving farmers and scientists in the development of indicators ensures that local knowledge will be incorporated into the development process and farmers may have some ownership for the indicators that they are 'expected' to implement. Participatory processes have been suggested as a means of more sustainable, equitable and viable resource management (Jiggins 1993; Pretty and Chambers 1993).

The challenge for the 'indicator industry' now does not seem to be the implementation of existing indicators, but rather, what processes can be facilitated between researchers and farmers so that the development and implementation of indicators is participatory, applicable and provides ownership to those managing the natural resources. Table 7 illustrates a variety of criteria of indicator development and use and lists subsequent approaches that (i) have been used traditionally (and are predominant) in RD&E, (ii) are current innovative approaches suggested within RD&E at present, and (iii) are being suggested by the authors of this paper as elements for future development.

The current trend of agricultural extension is to facilitate and use more participatory learning processes with farmers (Roling and Jiggins 1994; Hamilton 1995) so that an equal distribution of impacts and benefits of technology (Roling *et al*. 1976), the value of farmer knowledge and experience (Scoones and Thompson 1994) and different individual perceptions of reality (Long and Long, 1992) can be more accountable. Using a participatory learning approach involving scientists and farmers will enable more effective and efficient development and use of sustainability indicators in the future. Although this paper focuses on the role of scientists and farmers, it is not intended to exclude other stakeholders from the research and development process.

Table 7. Traditional, current innovative and suggested future approaches of research (R), development (D) and extension toward the development and use of sustainability indicators for more sustainable farming systems

Criteria	Traditional approach	Current innovative approach	Suggested future approach
Sustainability	Sustainability viewed as a goal	Sustainability viewed as a goal	Sustainability viewed as a process
Validity of indicator	Scientifically valid	Scientifically valid	Negotiated between farmer and scientist
Context of measurement	Measured in a static context	Measured in a dynamic context	Measured in a dynamic context
Monitoring approach	Monitored in absolute terms	Monitored in relative terms	Monitored in relative terms
Assessment approach	Sustainability perceived as goal orientated	Sustainability perceived as system orientated	Sustainability perceived as process orientated
Development context	External to farming system	External to farming system	Internal to farming system (i.e. on-farm)
Basis for farmer input	Content knowledge (often ignored)	Content knowledge (passive)	Content and process knowledge
Focus of R&D	Single discipline	Multi-disciplinary	Inter-disciplinary
Application in policy	Scientific objectivism	Justification of public funds	Joint ownership
Data collection approach	Collection by scientist	Collection by scientist and farmer	Collection by scientist and farmer
Development of indicators	Development by scientist	Development by scientist	Development by scientist and farmer
Paradigm of extension	Adoption	Adoption	Negotiated learning and action

The review of the literature suggests that other stakeholders (e.g. consumers, policy makers) have also been excluded. That is, a suggested future approach for the 'validity of indicator' criteria (Table 7) in a wider context is best expressed as negotiated among stakeholders, rather than negotiated between farmer and scientist.

Reflections on the focus group methodology as a research (and extension) method

The benefit of focus groups over normal discussion is that the moderator seeks to explore issues while injecting minimal personal input and influence into group discussion. Questions start at a general level, moving to more focused questions in line with the research as the process progresses. Importantly, the focus group method does not seek consensus or frequency, but rather provides an opportunity to explore a range of opinions and experiences from a group representing maximum diversity. The choice to use this method illustrates to participants that the focus of the moderator is on 'listening' rather than 'telling'. At the end of this focus group study, farmers involved in the process expressed that they had gained new insights about how other farmers manage their systems and make decisions. There were also follow up phone calls where participants stated "We really got a lot out of yesterday, we just hope that you got what you wanted too". This emphasised the usefulness of the method as a research *and* extension tool, where farmers learn from each other during a facilitated interaction focusing on particular key questions and issues. The focus group enabled a diverse range of indicators used by participants to be captured, proving a useful method for achieving the purpose of the study.

Conclusions

To ensure viable farming futures, resource monitoring and assessment has been seen as a primary objective in moving toward more sustainable farming systems. For this reason, indicators of sustainability have taken a leading role in current agricultural research and development. Perhaps indicators that are being trialed and tested over time and through experience by land managers may provide a 'gateway' into understanding ways that indicators can be developed, tested and used in decision making toward more sustainable farming systems. Numerous reasons have been put forward in the literature as to why indicators already developed by research and development organisations are not being used by farmers. There are 2 underlying premises to these ideas. The first assumption is that farmers are not using indicators at present, and secondly, if farmers are not using indicators then they do not understand them or know about them. Two points that came up in the case study presented in this paper were that (i) farmers had tested some of these indicators before through experience and there were reasons why these did not work in practice, and (ii) current knowledge of farmers about indicators had been ignored.

There are a number of major points that have been put forward in this paper. Firstly, indicators that farmers use to tell them whether or not they have the ability to be more sustainable can be useful for those developing indicators at regional, national and global levels. Secondly, farmer knowledge needs to be accepted as a complementary source of knowledge to traditional scientific knowledge. Thirdly, farmers need to be involved in not only the use of indicators, but also in the development of indicators. Finally, the facilitation of participatory processes involving farmers and scientists may lead to a better understanding of the use, appropriateness and development of indicators for monitoring and assessing resource condition. With improved monitoring and assessment, farmers may be able to make more informed choices when selecting farm management options.

References

Anon (1997) Proceedings of the National Workshop on Indicators of Catchment Health, Waite Campus, Adelaide, South Australia, 2–4 December 1996.

Carter MR (1996) Concepts of soil quality. In 'Proceedings International Symposium, Advances in Soil Quality for Land Management: Science, Practice and Policy, 1996, pp. 5–9. (Centre for Environmental Management, University of Ballarat)

Copus AK, Crabtree JR (1996) Indicators of socio-economic sustainability: an application to remote rural Scotland. *Journal of Rural Studies* **12**(1), 41–54.

Dalal R (1997) Consultancy to Design a Regional Environment Audit and Monitoring Process for the Grains Industry using Central Queensland as a Pilot Study.

Doran JW (1996) Soil health and global sustainability. In 'Proceedings International Symposium, Advances in Soil Quality for Land Management: Science, Practice and Policy, pp. 46–51. (Centre for Environmental Management, University of Ballarat)

Dover S (1994) In 'Meeting community needs for monitoring catchment health'. (Eds CD Irons and J Walker). CSIRO Technical Memorandum 96.31. Division of Water Resources, Canberra.

Freebairn D, Littleboy M, King CA (1996) A Modelling Workshop for the Semi-arid Tropics, International Crops Research Institute for the Semi-Arid Tropics. (ICRISAT: Hyderabad, India)

Gahan C, Hannibal M (1998) Doing qualitative research using QSR NUD*IST. (Mentor Consulting Pty Ltd, Sage Publications Software: London)

Gameda S, Dumanski J (1994) Framework for evaluation of sustainable land management: case studies of two rainfed cereal-livestock land use systems in Canada. In 'Proceedings 15th World Congress of Soil Science, **6a**'. pp. 410–421.

Glenn NA, Pannell DJ (1998) The Economics and application of sustainability indicators in agriculture. Contributed Paper at the 42nd Annual Conference of the Australian Agricultural and Resource Economics Society, Armidale, NSW, 19-21 January, 1998.

Gomez AA, Swete Kelly DE, Syers KJ, Coughlan KJ (1996) Measuring sustainability of agricultural systems at the farm level. In 'Proceedings International Symposium, Advances in Soil Quality for Land Management: Science, Practice and Policy'. pp. 108–113. (Centre for Environmental Management, University of Ballarat)

Hamilton NA (1995) Learning to learn with farmers. Published Doctoral Dissertation, Wageningen Agricultural University, Wageningen, The Netherlands.

Hill S, Forbes P (1997) Monitoring to meet the needs of the Catchment and Land Protection Boards and Council in Victoria. In 'Proceedings, National Workshop on Indicators of Catchment Health'. pp. 59–61. Waite Campus, Adelaide, South Australia. 2–4 December 1996.

Hunt N, Gilkes B (1992) 'Farm monitoring handbook: a practical down-to-earth manual for farmers and other land users.' The University of Western Australia, Nedlands.

Irons CD, Walker J (1996) Meeting community needs for monitoring catchment health. Technical Memorandum 96.31. (CSIRO: Canberra)

Jiggins J (1993) From technology transfer to resource management. In 'Proceedings of the XVII International Grassland Congress'.

King CA (1998) A process-analysis approach for improving multi-disciplinary farming systems research, development and extension. Proceedings of the Third European Symposium on Rural and Farming Systems Analysis: Environmental Perspectives, 25–27 March 1998.

King CA, Jiggins J, Coutts J (1998) Beyond the practice boundaries: inter-organisational skills for ecological sustainable development (ESD). Paper presented at the Management for Ecological Sustainable Development Conference, The University of Queensland, Brisbane, September, 1998.

Krueger RA (1988) 'Focus Groups: a practical guide for applied research.' (Sage Publications: London)

Lawrence P (1997) Decision support systems. Workshop presentation. Consultancy to design a regional environment audit and monitoring process for the grains industry using central Queensland as a pilot study.

Long N, Long A (1992) 'Battlefields of knowledge: the interlocking of theory and practice in social research and development.' (Routledge: London and New York)

McCord AK (1997) An indicator decision tree for community use in land condition assessment. In 'Proceedings of the National Workshop on Indicators of Catchment Health'. pp. 49–50. Waite Campus, Adelaide, South Australia. 2–4 December 1996.

McGuckian N (1997) Sustainability indicators for cropping farmers. Report for the Grains Research and Development Corporation (GRDC) and Land and Water Research and Development Corporation (LWRDC).

OECD (1997) Environmental indicators for agriculture. Organisation for Economic Co-operation and Development. (OECD Publications: France)

Pieri C (1996) A global program to develop land quality indicators at district, national and global scales. In 'Proceedings of the International Symposium Advances in Soil Quality for Land Management: Science, Practice and Policy'. (Centre for Environmental Management, University of Ballarat) p. 101.

Pretty JN, Chambers R (1993) Towards a learning paradigm: new professionalism and institutions for sustainable agriculture. IDS Discussion Paper No. 335, Brighton, UK.

Reuter DJ (1997) Proceedings of the National Workshop on Indicators of Catchment Health. Waite Campus, Adelaide, South Australia. 2–4 December 1996.

Roling NG, Ashcroft J, Chenge F (1976) The diffusion of innovations and the issue of equity in rural development. *Communication Research* **3**(2), 155–170.

Roling NG, Jiggins JLS (1994) Policy paradigm for sustainable farming. *European Journal for Agricultural Research Education and Extension* **1**(1), 23–43.

Roling NG, Jiggins JLS (1998) In 'Facilitating sustainable agriculture: participatory learning and adaptive management in times of environmental uncertainty'. (Eds NG Roling and MAE Wagemakers) (Cambridge University Press)

SCARM (1993) Sustainable agriculture: tracking the indicators for Australia and New Zealand. Standing Committee on Agriculture and Resource Management. Report No. 51. (CSIRO: Melbourne)

SCARM (1996) Indicators for sustainable agriculture: evaluation of pilot testing. A report prepared for the Sustainable Land and Water Resources Management Committee. Standing Committee on Agricultural and Resource Management.

Scoones I, Thompson J (1994) Knowledge, power and agriculture — towards a theoretical understanding. In 'Beyond farmer first: rural people's knowledge, agricultural research and extension practice. (Ed. R Chambers) (Intermediate Technology Publications: London)

SIP (2000) The city of Austin Sustainability Communities Initiative. Sustainability Indicators Project (SIP). http://www.ci.austin.tx.us/sustainable/

Walker J (1997) Environmental indicators of catchment and farm health. In 'Farming Action Catchment Reactions'. (CSIRO Publishing: Melbourne)

White T (1997) Core State of the Environment Indicators for community and council use. In 'Proceedings of the National Workshop on Indicators of Catchment Health, 1997'. pp. 62–63.

Wiley P, Patterson R, Fievez P (1993) Indicators of sustainable cropping systems: planning and monitoring improved cropping strategies. Report for the Land and Water Research and Development Corporation (LWRDC) and Grains Research and Development Corporation (GRDC). July, 1993.

Williams J (1997) Indicators of Catchment health: workshop overview. In 'Proceedings of the National Workshop on Indicators of Catchment Health'. pp. 19–30. Waite Campus, Adelaide, South Australia. 2–4 December 1996.

Received 24 November 1999, accepted 27 February 2000