How can farmers and researchers measure sustainability?

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Abstract

Measuring 'sustainability' is a challenge that needs be met if the globe is to survive increasing environmental challenges over the long-term. There is a need to move beyond comparisons using relatively few ‘benchmarks’ which are inadequate to describe sustainability.

Whilst quantifying sustainability has been attempted for experiments, some of these measures, or suitable surrogates, need to be simplified into a form which can be readily adopted by land managers. This is needed so that farmers can continue to be profitable over the long-term as well as meet increasingly stringent auditing standards which will assure the consumer and regulator that sustainable farming methods have been employed.

A description is given of a producer-led initiative to measure whole-farm sustainability of three different farming systems. Some of the methods used to measure sustainability reported in the international and Australian literature are also discussed, and suggestions made regarding some ways in which farmers might compile various measurements to attest to the sustainability of their farming system.

Key Words

Sustainability, natural capital, whole-farm

Introduction

The concept of sustainability is a broad human construct which is difficult to measure. Nevertheless, the world needs food and fibre production systems to feed an increasing global population and this must be achieved without damaging the planet’s natural resources (1). It is likely that this will involve environmental auditing of farm performance as consumers and governments increase their expectations and demand environmentally sustainable production systems. Hence there is a growing need to be able to measure these attributes of farming systems.

There is widespread agreement among the many definitions of ‘sustainability’ that the term implies an ability to continue to feed and clothe ourselves between generations in such a way that we do not deplete our natural resources. Many would also state that sustainable systems also need to be profitable over the long-term. Thus, measures of sustainability must, by definition, include trends over time in those natural resources which support production (such as soils, pastures, crops and animals), together with the resulting production and economic outcomes. We need improved methods if they are to be adopted and have relevance at the farm level (2).

Measures of sustainability

The literature abounds with partial measures of sustainability and benchmarks. However, few authors report comprehensive measurements of sustainability over an entire farm.

As soil is the most fundamental natural resource, it is not surprising that many sustainability indicators relate to soil properties. Some of these include soil health (3), nutrient and carbon balances (4), and the capacity to use stored water (5) and thereby minimise deep drainage and acidification.

Soil structure is another important soil attribute which needs to be measured as it can lead to improved infiltration, increased plant available water and reduced run-off (6). Other measures related to soil structure are measures of soil organic matter, carbon and its lability, all of which are key indicators of sustainability. Carbon has important influences on soil aggregate stability, hydraulic conductivity and soil strength and hence has a large influence on sustainability.

Relevant plants measurements include the proportion of perennial grasses which allow for deeper rooting and water uptake and legumes which assist in recycling nitrogen (5). Stubble retention is also a desirable management practice because of its influence on soil structure; it is important that the speed of breakdown of such organic matter residues is only moderate if soil structure is to be improved (7). Whilst there is a need to measure the health of entire catchments (3), we also need better systems for monitoring whole-farm nutrient flows and the potential for nutrient losses.

In order to measure sustainability more completely, it needs to be assessed over space and time, using multiple criteria including the 'triple bottom line' measures relating to ecology, economic and social indicators (8). More research and consultation with stakeholders will be needed before there is a convenient method of combining these different vectors of sustainablity.

Measuring sustainability

Scott *et al*. (5) assessed the relative sustainability of grazed pastures on the Northern Tablelands of NSW by focusing on the water and nitrogen economy of three pasture communities with different botanical compositions. By measuring 37 variables associated with soil, pasture, animal and production 'layers' contributing to sustainability, including trends over time, an index of relative sustainability was calculated and presented as a 'sustainability matrix'. This experiment was carried out on a small scale on a land area less than 6 ha. If widespread adoption is to be achieved, there is a need for measurements to be taken over larger areas which are seen as more credible by farmers. However, the larger the area, the more expensive and difficult it is to develop measurements which are practical and inexpensive.

One means of measuring whole-farm sustainability is being attempted on whole farmlets within the Cicerone Project on the Northern Tablelands of NSW (9). This project has involved setting up three comparable farmlets to assess the sustainability and profitability of each. The land was allocated without bias to paddocks of each farmlet using a range of criteria recorded within a geographic information system (GIS) including soil conductivity (assessed by electromagnetic inductance survey), fertiliser history (using paddock records) and slope and elevation (from digital elevation map). A total of 6 iterations were carried out to ensure that the starting conditions of each farmlet were as even as possible. Work is underway to assess pasture herbage mass and quality using remotely sensed satellite data.

A list of some of the measurements taken by researchers in research and what might be possible to measure on the Cicerone farmlets is shown in Table 1 below.

Discussion and Conclusions

It is hoped that eventually, the individual members of farmer groups (such as the Cicerone Project) will be able to adopt a process of assessing whole-farm sustainability on their own farms in a manner similar to that being carried out on the Cicerone farmlets. It can be seen from Table 1 that farmers (perhaps with the help of consultants) will need to become increasingly sophisticated in their data collection and analysis if they are to assemble data representing all layers of sustainability.

It is envisaged that the data derived from the Cicerone farmlets will be published regularly on the website of the Cicerone Project (9) and that this may encourage more farmers to anonymously enter their own data for comparison. As shown in Table 1, the principle data sources needed by farmers can be collected using the following tools: meteorological measurements (expensive), soil moisture probe (expensive), piezometer (cheap), soil tests (cheap), visual assessment of pastures (cheap), direct measurements of animals and crops (cheap), good record keeping (cheap) and market information (cheap). Further work is needed to determine how these assembled data can be used to form a robust index of sustainability.

Eventually, farms may need to have an automatic weather station providing real-time accumulation of climatic data events. This can be supplemented with data on soil moisture in a range of paddocks similar to the way in which today's cotton farmers or viticulturists monitor soil moisture. Also, it is possible that the needed economic and production data could be extracted readily from other paddock management, machinery and financial software and soil test data direct from the testing laboratory. If data concerning off-farm effects are eventually needed for auditing purposes, it may be necessary to install standard catchment flumes which are capable of automatic sampling of run-off water. It is also possible that some form of audited record keeping of inputs and outputs, including energy consumption, may be desirable.

Of course, all of this data collection and management will come at a significant cost. It is to be hoped that consumers and markets, both local and international, will recognise the value of production systems which meet agreed audited sustainable production standards.

Table 1. List of various components of sustainability and the methods by which they can be measured by researchers and farmers (✓ = feasible to measure).

Factor	Research	Research method	Farm	Farm method
Climate:				
Temperature	✓	Meteorological station	✓	Max-min thermometer or data logger
Rainfall	✓	Meteorological station	✓	Rain gauge or meteorological station
Soil layer:				
Soil water deficit	✓	Neutron probe	✓	Soil moisture probe
Water run-off	✓	Run-off plot		
Depth to water-table	✓	Piezometer	✓	Piezometer
Soil strength	✓	Penetrometer	**?**	
Soil erosion loss	✓	Run-off plot		
Soil structure	✓	Laboratory test		
Microbial biomass	✓	Laboratory test		

Organic matter/carbon	✓	Soil test	✓	Soil test
Labile carbon	✓	Laboratory test		
N in run-off water	✓	Laboratory test		
Mineral N at surface	✓	Soil test	✓	Soil test
Mineral N at depth	✓	Soil test	✓	Soil test
Soil pH	✓	Soil test	✓	Soil test
Phosphorus and sulfur	✓	Soil test	✓	Soil test
Pasture layer:				
Ground cover	✓	Botanal	✓	Visual assessment
Adequate legume	✓	Botanal	✓	Visual assessment
Perennial grasses	✓	Botanal	✓	Visual assessment
Weeds	✓	Botanal	✓	Visual assessment
Herbage mass	✓	Median quadrat	✓	Visual assessment
Digestibility	✓	NIR spectroscopy	?	
Animal layer:				
Pasture and nitrogen intake	✓	Alkanes		
Wool growth (per sheep)	✓	Direct measurement	✓	Direct measurement
Fibre diam./tensile strength	✓	Direct measurement	✓	Direct measurement
Live weight (per sheep)	✓	Direct measurement	✓	Direct measurement

Fat score	✓	Direct measurement	✓	Direct measurement
Cropping layer:				
Grain yield	✓	Record keeping	✓	Record keeping
Grain quality	✓	Record keeping	✓	Record keeping
Production and profit				
Stocking rate	✓	Record keeping	✓	Record keeping
Live weight gain/ha	✓	Calculated	✓	Calculated
Wool produced/ha	✓	Calculated	✓	Calculated
Grain yield/ha	✓	Record keeping	✓	Record keeping
Product prices	✓	Market reports	✓	Market reports
Labour	✓	Management records	✓	Management records
Inputs and outputs	✓	Management records	✓	Management records

The most valuable assessments of sustainability will be achieved when they incorporate parameters relating to the biophysical, economic and social components of sustainability.

Gathering data on animal reproduction, growth and wool production and quality is especially important as animals are the best integrators of the capacity of soils and pastures to sustain production over the long-term. It is already feasible to obtain remotely sensed data on herbage mass and quality and this will be a useful addition to sustainability measurements. Similarly, it is necessary to gather data from crop yield measures and quality assessments. Links also need to be established between the farmer's financial software and measurements of sustainability if economic factors are to be taken into account.

Because of the number of measurements needed of all parts of the production system, it will be a difficult task to get farmers to adopt sustainability measurements. Even technology as widely available as soil testing is currently used by relatively few farmers. Thus, it may be necessary for governments to enhance adoption of the measurement of sustainability by subsidising the cost. Whilst such subsidies will be a cost the community, it is likely to lead to better environmental outcomes which will hopefully more than offset the subsidy. Adoption is likely to be highest when farmers see an economic incentive and thus, the search for profitable systems which provide quality ecosystem services is of great importance.

The adoption of the types of measurements proposed will not necessarily lead to a short-term benefit. Above all, trends over time need to be incorporated into any assessment. These measures will provide an assessment of relative sustainability. Absolute measures will require far more detailed accounting of the level of inputs and outputs, of energy use and of the capacity of the system to avoid leakage of nutrients and soil losses.

The data could eventually be summarised from a range of sources into a “dashboard” displayed on a farm’s computer screen in such a way that trends over time in all crucial factors are readily apparent. There is a need for researchers to work with extension agencies and farmers to develop workable solutions to the challenge of integrating this diverse array of information.

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