Agricultural Systems 115 (2013) 51–62

Contents lists available at SciVerse ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

A guide for choosing the most appropriate method for multi-criteria assessment of agricultural systems according to decision-makers' expectations

M. Carof [a,b,c,*], B. Colomb [d,e], A. Aveline [f]

[a] AGROCAMPUS OUEST, UMR1069, Sol Agro et hydrosystème Spatialisation, F-35000 Rennes, France
[b] INRA, UMR1069, Sol Agro et hydrosystème Spatialisation, F-35000 Rennes, France
[c] Université Européenne de Bretagne, France
[d] INRA, UMR1248, Agrosystèmes et agricultures Gestion des ressources Innovations Ruralités, F-31320 Castanet-Tolosan, France
[e] INP-ENSAT, UMR1248, Agrosystèmes et agricultures Gestion des ressources Innovations Ruralités, F-31320 Castanet-Tolosan, France
[f] Groupe ESA, LEVA, F-49000 Angers, France

ARTICLE INFO

Article history:
Received 7 February 2012
Received in revised form 25 September 2012
Accepted 30 September 2012
Available online 2 November 2012

Keywords:
Cropping system
Farming system
Evaluation methods
Multi-criteria decision aid
Sustainability assessment
Decision-makers' expectations

ABSTRACT

Modern agriculture must meet new challenges such as production of healthy food, adaptation to climate change, protection of natural resources, and conservation of landscape. These challenges require changes in current agricultural systems and therefore, environmentally-friendly agricultural systems must be designed and their sustainability assessed. Over the past several years, various methods have been developed for making such assessments (e.g. the Balancing and Ranking Method, MEACROS, MODAM, the modelling framework of Pacini et al., ROTAT + Farm Images, MASC, and ROTOR) but few studies put forward simple solutions for selecting one method over another. In this paper, we propose a simple guide to distinguish methods one from another. Categories of the guide include the type of systems to assess, the spatial and temporal scales at which systems are assessed, the dimensions of sustainability for which systems are assessed, the type of visualisation for comparing options, the target users, and the ability to generate alternative systems. The guide was developed and tested with a group of farm advisors involved in a three-year project called RotAB, which aimed to assess the sustainability of organic arable farming systems: the advisors looked for a method for sustainability assessment of cropping systems. We presented seven recent assessment methods as well as the guide to advisors. The guide's key points allowed them to clearly express their requirements: the method they looked for had to evaluate cropping systems and helped advisors to propose new ones; it had to evaluate multiple sustainability criteria that are easily understandable by farmers; indicators had to be scientifically based, without the need for many input data; the method had to be easy to use and produced graphical output that can be discussed with farmers. Finally, the guide helped advisors to choose one of the seven methods (in that case they chose MASC). This guide can help decision-makers distinguish assessment tools from one another using simple categories and choose the one best adapted to their expectations.

1. Introduction

Agricultural decision-makers (e.g. farmers and their advisors, stakeholders) must ensure that agricultural development meets requirements of sustainable agriculture, such as production of healthy food for an increasing world population, competition on the global market, adaptation to on-going climate change, protection of natural resources, and landscape conservation (Godfray et al., 2010; Foley et al., 2011). This requires changes in agricultural systems and abandonment of unsustainable practices (Kirchmann and Thorvaldsson, 2000; Lichtfouse et al., 2009). New agricultural systems should use fewer inputs and non-renewable resources without drastically reducing system productivity and profitability over the long-term. These changes may concern animal-production systems, cropping systems, or farming systems; in this paper we focus on the latter two. A cropping system is a set of crop management practices applied to a parcel (Sebillotte cited by Sadok et al., 2008) whereas a farming system is the combination of productive activities at the farm level (Le Gal et al., 2010).

Alternative cropping/farming systems can be designed using a four-step approach (Vereijken, 1997; Loyce and Wery, 2006):

1. Define goals and constraints for new cropping/farming systems.

* Corresponding author. Address: AGROCAMPUS OUEST, 65 rue de Saint-Brieuc, CS 84215, F-35042 Rennes cedex, France. Tel.: +33 (0)2 23 48 54 77.
E-mail address: matthieu.carof@agrocampus-ouest.fr (M. Carof).

0308-521X/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.agsy.2012.09.011

2. Generate systems compatible with the constraints and able to meet the goals.
3. Assess the systems.
4. Test and disseminate the most innovative systems to operators (e.g. farmers).

Step 1 generally involves diagnosis, which allows designers to identify and analyse issues in current systems. Issues may be due to soil, climatic, technical, economic, environmental, or social concerns. The generation of cropping/farming systems (Step 2) is achieved with methods such as prototyping (see, e.g. Rapidel et al., 2009) and computational modelling (see, e.g. Le Gal et al., 2010). The latter is of primary interest since such models are able to rapidly generate a large number of alternative[1] systems (Pandey and Hardaker, 1995; Rossing et al., 1997; Bergez et al., 2010) that are locally adapted to diverse contexts (Boiffin et al., 2001). Step 3 is essential, since analysis and interpretation of assessment results allow designers to select systems that can be tested and transferred to operators. According to assessment results, designers may modify system components and re-assess improved systems. Step 4 allows designers to recommend the adoption of innovative systems. Using participatory-action research for innovative system design facilitates steps 1, 3, and 4, since operators are directly involved in the design process (see, e.g. Dorward et al., 2003; Le Bellec et al., 2012).

Currently, a large body of scientific literature exists on methods that assess all or part of agricultural sustainability (see, e.g. Sadok et al., 2008; Bockstaller et al., 2009). These methods are useful in the assessment step by helping decision-makers simultaneously and rapidly assess the economic, environmental, and social dimensions of sustainability of multiple cropping/farming systems. However, a lack of guides makes it difficult for designers to determine the method most appropriate for their requirements and expectations.

This paper presents a simple guide allowing agricultural decision-makers to distinguish assessment methods one from another. As part of a French project called RotAB (Fontaine, 2012), the guide was developed based on the active participation of farm advisors and on seven recent assessment methods. Section 2 describes the RotAB participatory project as well as the procedure followed to select the assessment methods, and Section 3 briefly presents these methods. In Section 4, the guide is introduced and its categories (i.e. the key points used to distinguish the methods from one another) are described in detail. A final section discusses on advantages and disadvantages of the guide.

2. Material and methods

The guide was developed as part of the RotAB project, involving three scientists (the authors of the paper) and four advisors from the Chambers of Agriculture of five French regions (Fontaine, 2012). This three-year project launched in 2008 aimed to assess the sustainability of organic arable farming systems. Due to a lack of animal manure, management of these stockless farming systems may be difficult (e.g. soil fertility may decline); therefore, they can be seen as unsustainable. In this context, advisors, who are often questioned by farmers willing to adopt new, lower-impact systems, needed a method to help organic farmers modify management practices in systems deemed unsustainable. This method needed to assess the sustainability of current systems as well as potential innovative ones. During an initial meeting, the four advisors pointed out a lack of information about recent assessment methods and reasons for selecting a particular one.

Consequently, we searched (March 2009) the ScienceDirect (www.sciencedirect.com) and CAB Abstracts (www.cabi.org) bibliographic databases to find recent assessment methods. We defined a query to identify original scientific papers whose topic dealt with assessment methods of agricultural systems: (tool* OR indicator* OR decision* OR "support* system*") AND (evaluat* OR assess*) AND ("crop* system*" OR "crop* rotation*" OR "farm* system*" OR "farm* scal*" OR "farm* level*"). The asterisk (*) represented any group of characters, including no character.

From the query results, we selected 445 recent peer-reviewed articles less than ten years old published in leading scientific journals dealing with agronomy and ecology. From the abstracts of these articles, we identified seven assessment methods addressing cropping/farming systems (Section 3).

We then held two workshops with the four advisors. The first one gathered information about advisors' expectations and led to the development of the guide (Section 4). In the second participatory workshop, we presented the guide to the advisors, who applied it to the seven assessments methods selected (Section 4).

3. Description of the seven assessment methods – a review

The seven methods selected from the literature research are the Balancing and Ranking Method (Strassert and Prato, 2002), MEACROS (Mazzetto and Bonera, 2003), MODAM (Zander and Kächele, 1999), the modelling framework of Pacini et al. (Pacini et al., 2004a), ROTAT + Farm Images (Dogliotti et al., 2003, 2004, 2005), MASC (Sadok et al., 2009), and ROTOR (Bachinger and Zander, 2007) (Table 1). They are described in the following paragraphs.

3.1. BRM: Balancing and Ranking Method

BRM is a "three-step procedure to derive an overall complete final order of options" (Strassert and Prato, 2002). This step-wise ordering procedure requires that a set of options (such as cropping/farming systems) be proposed and a consistent family of criteria be defined (i.e. name, description, scale, and indicator of any defined criterion). It also requires a committee of decision-makers (Vahdani et al., 2008). First, for each option, criteria scores are assembled in a data table which is used to produce an outranking matrix. Entries of the latter are absolute frequencies derived from pair-wise comparisons of options (see, e.g. Roy, 1991 for definition of pair-wise comparisons). For example, if one compares A cropping systems based on n criteria, the outranking matrix is an $A \times A$ matrix, where each entry indicates the frequency with which an option is superior to another, based on the n criteria (e.g. system 1 is superior to system 2 on i criteria and worse than or equal to system 2 on the other $(n - i)$ criteria). Second, triangulation of the outranking matrix is performed to obtain an implicit provisional ordering of options. According to Strassert and Prato (2002), the triangular matrix "reorders the options such that … the sum of the values above the main diagonal is a maximum in the matrix of the final order". Third, the balancing principle is applied to the provisional ordering of options: decision-makers balance the advantages and disadvantages of any pair of options until a complete ordering of options is obtained.

3.2. MEACROS: Multi-criteria Evaluation of Alternative CROpping Systems

MEACROS is a multi-criteria evaluation tool to compare and select alternative farming systems. It is based on concordance analysis derived from the ELECTRE method (Nijkamp cited by Mazzetto and Bonera, 2003). First, an "impact matrix" is constructed which indicates the performance of each alternative according to each of the chosen criteria. Rows are the alternative farming systems, columns are the evaluation criteria (up to 88 default criteria),

[1] In this paper, the term "alternatives" is used as synonymous with "options".