Organic farming and multi-criteria decisions: An economic survey

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Keywords: Multi-Criteria Analysis, Cost-Benefit Analysis, Decision Making, Organic Farming

Abstract:

Organic food production is a sphere where decision making is multi-facetted and complex. This applies to producers, political decision makers and consumers alike. This paper provides an overview of the economic methods that can aid such multi criteria decision making. We first provide an outline of the many different Multi-Criteria Analysis (MCA) techniques available and their relative advantages and disadvantages. In addition, theoretical and practical problems related to the use of Cost-Benefit Analysis (CBA) and MCA respectively are briefly discussed. We then review the MCA literature on case studies on organic farming. Based on this review we provide directional markers for future research where MCA may possibly be applied and adapted in order to provide useful knowledge and support for decision makers in the context of organic farming.

1 Introduction

Shifting from conventional to organic farming and food consumption will impact a long range of important variables such as biodiversity, pollution levels, agricultural productivity, animal welfare, food quality and possibly human health. In order to determine whether such a change is favourable for an individual consumer or producer or society as a whole, all aspects of the change need to be included.

Economists have worked with such multidimensional decision problems for decades and a number of methods have been developed. The traditional method is the Cost-Benefit Analysis (CBA) which is based on the idea that all impacts of a project, costs as well as benefits to all members in a society, are measured in monetary terms and added up in a single number indicating whether and to what extent the benefits of the project outweigh the costs to the society. However, CBA is based on a considerable number of restrictive assumptions and the method has received substantial criticism on ethical grounds (see e.g. Sagoff 1994) as well as methodological (see e.g. Sugden 2005). One particular challenge in CBA is that of assigning monetary values to impacts that are non-market, e.g. impacts on nature and the environment in general. A number of so-called economic valuation methods have been developed for this purpose (see e.g. Garrod and Willis (1999) or Champ et al. (2003) for an overview of stated and revealed preference methods). Nevertheless, there may still be non-market impacts where the required monetization is not feasible, either because it is not possible to obtain data due to insufficient information on impacts or because people are unable or unwilling to make reliable trade-offs against money. As the latter is a core assumption underlying the economic valuation methods, the inclusion of non-market values in CBAs depends critically on whether people are able and willing to make trade-offs in the addressed problems.

Multi-Criteria Analysis (MCA) methods offer a methodologically less restrictive alternative to CBA. Both methods have advantages and disadvantages. MCA lacks some of the strengths of CBA such as its communicative simplicity and the economically consistent way that all included aspects are treated. However, MCA offers more flexibility than CBA and MCA is potentially more comprehensive in the coverage of impacts. The primary distinguishing feature between CBA and MCA is that in MCA it is not necessary to measure all impacts in monetary terms[1]. MCA may be particularly helpful when impacts that are considered to be important by decision makers cannot be included in a CBA because monetary value estimates are not available.

In this paper we focus on decision making in relation to organic farming. Production and consumption of organic products entail decision problems characterized by multiple objectives – whether the decision maker is a consumer, a producer or a politician. As such, organic farming poses a decision making context where the CBA and MCA methods could provide useful inputs to decision makers. We have chosen to focus mainly on MCA because interest in these methods has grown rapidly in recent years (Dolan 2010) and because a lack of monetary value estimates for relevant non-market impacts of organic food production limits the practical use of CBA. Our aim is to provide directional markers for future research where MCA may possibly be applied and adapted in order to provide useful knowledge and support for decision makers in the context of organic farming. In the following section we will briefly describe the MCA approach and give an overview of the different MCA methods. Section 3 provides a literature review of studies using MCA in an organic farming context while Section 4 provides a discussion and some preliminary conclusions concerning the usefulness of MCA for decision making in the organic farming context.

2 Classification of MCA methods

Belton and Stewart (2002: 2) broadly define MCA as: *"… an umbrella term to describe a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter".* Also it is worth mentioning the following description of MCA by Dodgson et al. (2009: 47): "*In practice, MCA is applied to help decision makers develop coherent preferences. In other words, coherent preferences are not assumed to start with, but the approach helps individuals and groups to achieve reasonably coherent preferences within the frame of the problem at hand..*" This statement highlights that MCA is not only a framework for how to include existing preferences for multiple criteria in a decision process. It is also a tool that can help decision makers to make up their mind about what is important in the specific decision problem. Thus, the fundamental idea behind MCA is that it helps to structure a decision problem by taking multiple potentially conflicting criteria explicitly into account in a formal model which can serve as basis for considerations, which can hopefully lead to decisions that are rational, justifiable and explainable (Mendoza and Martins 2006). The typical MCA process involves a majority of the following stages (Ananda and Herath 2009; Dodgson et al. 2009):

1. Establishing the decision context, i.e. explicating the aim for the MCA and identifying the decision maker(s) and stakeholders,
2. identifying decision alternatives,
3. defining objectives,
4. choosing criteria to measure the objectives,
5. assigning weights to the criteria that reflect their relative importance,
6. assigning scores to the criteria which reflect the value associated with the consequences of each decision alternative,

[1] Notwithstanding the fact that this may be considered an advantage of MCA over CBA, it should be noted that the issue of aggregating the impacts on individual criteria in order to provide an indicator of the overall performance of a project or policy decision is not avoided in MCA. While CBA accomplishes this through the monetization of all impacts MCA rests on subjective scores and relative importance weights associated with specific objectives and criteria in order to assess the overall performance.

7. applying a mathematical algorithm that combines weights and scores to derive an overall measure of each decision alternative, thus enabling a ranking of alternatives,
8. examine results, and finally
9. conduct analyses of the sensitivity of results to changes in scores and weights.

A standard feature of MCA is a performance matrix or consequence table in which each row describes an option and each column describes the performance of the options against each criterion. The individual performance assessments are often numerical, but may also be expressed as 'bullet point' scores or colour coding (Dodgson et al. 2009). In some decision contexts the analysis only goes as far as identifying the performance matrix (steps 1-6), which involves obtaining a systematic picture of the precise ways in which perspectives differ on the issues and options in question. This is a so-called Multi-Criteria Mapping (MCM) exercise.

One way of formalizing the approach is to say that the purpose of an MCA is to simultaneously maximize a collection[2] of objective functions, U_m, each associated with one or more criteria[3], m=1,…,M. If the criteria are independent then the M different criteria are related to each other through weights, α_m, that reflect the decision maker's relative prioritization of each criterion and possibly the criteria functions are also linked through competing use of N common input factors, $(X_1,..., X_N)$ (Dodgson et al. 2009: 25):

$$(1) \qquad Max\ \alpha_1 U_1(X_1,..., X_N),..., \alpha_m U_m(X_1,..., X_N),……, \alpha_M U_M(X_1,..., X_N)$$

Equation (1) illustrates that in MCA the decision maker needs to determine the the weight that he wants to assign to each criterion α_m as well as the combination of input factors $(X_1,..., X_n)$ in order to identify his most preferred alternative.

A range of MCA methods have been developed in the recent decades. Belton and Stewart (2002) provide a classification of MCA methods into three general categories, namely *value function methods*, *goal and reference point methods*, and *outranking methods*. Below, we give a brief introduction to these categories of methods and to some of the main methods belonging to them. An in-depth treatment is found in Belton and Stewart (2002).

2.1 Value function methods

The value function methods rest on the assumptions that decision makers are willing to make trade-offs between criteria (also denoted as compensatory behaviour) and that a true value or utility based ranking of decision options exists – it just needs to be discovered (Ananda and Herath 2009). For each criterion, quantitative scores are developed that describe how well the option fulfils the specific criterion. The individual criterion scores are then aggregated across

[2] This shows an important contrast to the CBA approach where the main purpose is to maximize one overall utility function encompassing all aspects of the decision problem: $Max\ U(X_1, …,X_N)$. This is possible in a CBA since all aspects are measured using a common denominator, money. This difference in the basic optimization problem also shows one of the limitations of MCA compared to CBA: It cannot show whether a decision adds more to societal welfare than it subtracts. Unlike CBAs, where the basic decision rule is that total benefits should exceed total costs, there is no similar explicit necessity for such a potential Pareto improvement rule in MCAs. Hence, the 'best' decision identified using an MCA method may actually lead to a decrease in social welfare (Dodgson et al. 2009: 20).

[3] Sometimes the notation is used that a decision maker seeks to maximize his *values* that each might be operationalized through maximization of several *objectives* which again might consist of several *criteria* (Bogetoft & Pruzan, 1991).

criteria in order to assess a total value[4] of the particular option in terms of achieving the goal of the decision. This enables a ranking of the available decision options according to their values. All methods within this group rely on a hierarchical decision model (a decision tree) explicitly defining the goal of the decision, the different decision options and the different criteria that will be used to evaluate how well the decision options meet the overall goal (Dolan 2010). Multi-Attribute Value Theory (MAVT) and Multi-Attribute Utility Theory (MAUT) and the Analytical Hierarchy Process (AHP) are the most commonly used methods within this group. Several modifications and variations of the AHP, such as the Analytical Network Processing (ANP), have been developed for instance to incorporate risk and uncertainty about outcomes (Ananda and Herath 2009).

2.2 Goal and reference point methods

Methods in this category are particularly suited for cases where decision makers find it very difficult or impossible to assign relative weights to criteria a priority, i.e. express trade-offs between them, but they are nevertheless able to describe desired outcomes in terms of satisfying goals for each criterion. It is against this backdrop that the goal and reference point methods have been developed. In contrast to the utility paradigm underlying the value function methods, they rely on the concept of satisficing in the sense that satisfactory levels of achievement are defined for each criterion, and when this is reached for the most important criterion attention is shifted to the second-most important criterion. This process is then repeated for the next criteria and so on, until eventually the decision options reaching the desirable levels for as many criteria as possible are identified. In other words, elimination of decision options are systematically carried out until a satisfactory level of performance for the given criteria is reached. This process is of course dynamic as the criteria are typically not completely independent and sometimes conflicting. Therefore, it may be necessary to go back in the elimination process and cycle through it again (Mendoza and Martin 2006).

The Goal programming method is the most frequently applied and studied of all the MCA methods (Mendoza and Martins 2006). Other methods in this group are Modelling to Generate Alternatives (MGA) and the Step Method (STEM). A few methods focusing on the idea of a learning systems approach have been developed. The Visual Interactive Method for Discrete Alternatives (VIMDA) and the Aspiration-level Interactive Method (AIM) are two such methods.

2.3 Outranking methods

The outranking methods relax the assumptions of compensatory behaviour and existence of a true ranking of options underlying the value based methods by assuming only a partial comparability axiom. This means that preferences can be modelled by means of four binary relations: 1) indifference, 2) strict preference, 3) large preference, and 4) incomparability. The basic idea is that decision options are compared pairwise within each criterion in order to establish whether preferences for one option over the other can be asserted. Aggregating information about preferences, indifferences and incomparabilities over the full set of criteria the model aims to establish the strength of evidence in favour of selecting one option to another. The MCA process itself facilitates development and evolving of preferences within the context of the choices to be made (Mendoza and Martins 2006). The most frequently used outranking methods are (different versions of) the ELECTRE and PROMETHEE methods (Ananda and Herath 2009).

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[4] While the value-based approaches do share much of their underlying theoretical framework with CBA, the ”total value” mentioned here is not to be confused with the concept of total economic value (measured in monetary terms) commonly used in CBA.

2.4 Other methods

Fuzzy set theory can in principle be applied to any of the MCA methods when some of the parameters are imprecise rather than known with perfect certainty. Instead of assigning weights and scores, the fuzzy set approach introduces a way to assess the imprecision inherently present in the available information. One example is when a person cannot decide whether a particular option should be categorized as attractive or unattractive but prefers the term 'rather attractive' – then it is not clear which group of attractiveness the option should be placed in and the fuzzy set theory suggests working with degrees of membership (Dodgeson et al. 2009: 28). Considering the role played by fuzziness in human cognition, this approach is often considered relevant when dealing with real world issues of high complexity (Ananda and Herath 2009). If uncertainty is not caused by imprecision but rather randomness, probability-based approaches have been proposed to deal with the uncertainty (Mendoza and Martins 2006).

Also, the so-called descriptive approaches are useful in MCA. These methods focus on inferring decision makers' preferences from past choices and using them as input in linear statistical models – either in terms of analysis of variance or multiple regression. Principal component analysis, factor analysis and other types of latent class approaches have been used to identify trade-offs between different decision criteria in this way (Ananda and Herath 2009).

Data Envelopment Analysis (DEA) is a non-parametric approach based on linear programming aimed at identifying a production frontier. DEA is especially useful when a production process has multiple inputs and outputs, and the basic idea is that production efficiency of the different organizational decision making units can be measured and benchmarked against the efficient frontier. DEA is often included in multi-criteria decision making (Diaz-Balteiro and Romero 2008).

Conjoint Analysis (CA) or discrete choice analysis is commonly used to deal with multi-criteria decision making, though most often seen from a consumer-perspective. CA observes respondents' choices between hypothetical alternatives that differ by the levels that their describing attributes[5] take. Based on these choices, CA indirectly derives relative preference weights for the describing attributes. These preference weights are essentially similar to those assigned in the value function MCA approaches. However, a main difference is that the weights are derived indirectly in CA but elicited directly in MCA (Dolan 2010).

3 Empirical studies using MCA in an organic farming context

There are on-going discussions of how to determine which MCA method is the best. This is possibly because multi-criteria decision problems are on the borderline between economic science and policy making. Even though more than 6500 studies using MCA methods in one form or another have been published so far (Dolan 2010), there is no general consensus on which method should be preferred in a given context (Mendoza and Martins 2006). In order to shed more light on whether some MCA methods might be more appropriate than others in the context of organic farming, we have reviewed studies that have applied MCA methods in an organic farming context.

A number of reviews concerning MCA in natural resource management are available in the literature (Mendoza and Martins 2006). It is apparent from these reviews that the vast majority of MCA applications concerning natural resources concern forest management and planning (Diaz-Balteiro and Romero 2008), while there are very few applications focusing on land use in relation

[5] Attributes could be considered as criteria.

to sustainable farming and in particular organic farming. Nevertheless, these few empirical applications demonstrate that MCA techniques can indeed be very useful in relation to evaluating the sustainability of different production systems such as organic vs. integrated vs. conventional farming. Hayashi (2000) notes that as the relationship between agricultural production and the environment has recently gained increasing attention, MCA becomes increasingly relevant as a means for supporting decision making, especially when multiple stakeholders are involved.

Andreoli and Tellarini (2000) are among the first to suggest MCA as an appropriate tool to address sustainability in agriculture, though they do not provide an empirical application as such. They emphasize the need for methods that are able to simultaneously deal with all the impacts of agriculture on environment, economy, sociology, psychology and physiognomy/cultural geography – these are all criteria for sustainable landscape management according to the European Concerted Action on 'Landscape and Nature Production Capacity of Sustainable/Organic Farms' (van Mansvelt and van der Lubbe 1999). They further note that some form of overall judgment that summarizes over all criteria is necessary in order to rank farm performance, either in absolute or relative terms. To accomplish this in a setting where the full range of impacts is likely to be highly diverse and heterogeneous in many aspects (e.g. some data might be qualitative while other data is quantitative, different measurement units may apply to different impacts, some impacts may be known with certainty while others are not, etc.) they suggest that MCA methods would be highly relevant. In particular, they suggest using the so-called "weighted-sum" ranking method which relies on summing the values over all criteria where each criterion has been assigned a weight, i.e. a value function approach. If it is not possible to reach agreement concerning the (subjective) weights[6], they suggest using the "best-worst-case" ranking method instead which belongs to the group of goal and reference point methods.

Stirling and Mayer (2001) seems to be the first paper that presents what may be considered an empirical MCA considering organic production as an alternative to conventional agricultural production, though their main interest is on GM technologies in food production. They use the Multi-Criteria Mapping (MCM) method to obtain a systematic picture of the different views on the issues and options in question, i.e. the competing ways of agricultural production. They identify six relevant overall criteria which in varying degrees relate to the concept of sustainability: Biodiversity, agriculture, health, economic, social, and other. Also, a number of stakeholders are included: Agriculture, food industry, scientists, government advisers, public interest groups. Stirling and Mayer (2001), somewhat unsurprisingly, find that different stakeholders assign very different criteria weights and scores to the available options. Using the MCM method implies that the analysis does not involve assessing how weights and scores could be combined across stakeholders to provide a ranking of the different types of production.

With a more direct interest in comparing environmental performance of organic and conventional farming, Parra-López et al. (2007) appear to be the first to apply an empirical full-blown MCA to value competing olive-growing systems in Spain. The following environment-oriented criteria are included: Soil erosion, soil fertility, rational use of irrigation water, water contamination, atmospheric pollution and biodiversity. They use a value function MCA where an AHP method is used to identify scores and weights (based on expert knowledge). Aggregating over criteria enables them to conclude (not surprisingly) that organic olive farming obtains a higher

[6] As an aside, Andreoli and Tellarini (2001) note that choosing to not weigh criteria implies using an equal weight for all criteria, and if only using what is considered to be the most important criteria in the decision making is equivalent to assigning a weight of 1 to this criteria and 0 to the others, thus adopting a unidimensional approach.

multifunctional environmental performance that both integrated and conventional farming. In a follow-up paper Parra-López et al. (2008a) extend the AHP analysis to include not only environmental criteria, but also sociocultural, technical and economic criteria. Widening the scope of their analysis in this way does, however, not change the main conclusion that organic farming is the best performing olive-growing system.

In a similar vein, Siciliano (2009) compares the financial, environmental and social sustainability of organic, integrated and conventional durum wheat cultivation practices in Italy. Using a goal and reference point methods denoted as a Social Multi-Criteria Evaluation (SMCE) method, the author suggests that organic farming represents a suitable compromise solution for the chosen environmental and socio-economic evaluation criteria. The findings that organic farming only performs best for the environmental criteria while being outperformed when considering financial (economic) criteria, highlights the importance of weighing criteria against each other.

Also comparing organic and conventional farming, Masuda et al. (2010) incorporate Stochastic Production Frontiers in Compromise Programming (CP), an MCA method belonging to the Goal and reference point methods. Based on the two objective functions: 1) maximizing net returns, and 2) minimizing chemical inputs, they show that the socially optimal situation would be to grow organic coffee on 26.5 % of the fields in the Kona Coffee belt on Hawaii – a much higher percentage than the actual 5 % at the time of data collection.

Focusing less on the actual type of farming, Latinopoulos (2007) takes a societal welfare maximization view on the use of water in agricultural irrigation in an area where this activity is often causing overexploitation of the water resource, i.e. the irrigation causes a negative externality to society. Multi-Objective Goal Programming (MOP) is used in order to take sustainable use of the water resource into account in the decision making alongside the usual criteria considered by the farmer in terms of economic viability. Using this goal based method to depict all feasible and all efficient resource allocations, as well as the various trade-offs between rural development and environmental protection criteria in a representative area in Greece, Latinopoulos (2007) concludes that the current policy in the area is indeed greatly favouring farmers' welfare at the expense of the water resource's quality and availability – suggesting that the conventional farming approaches currently used in the area should be reconsidered.

Another study considering the sustainability of current farming practices in an area is Carmona-Torres et al. (2011). They hypothesize that production choices of farmers in Andalusia in northern Spain are not optimal from a joint economic, environmental and social point of view. Using an Analytical Network Process (ANP) to deal with the issues of complexity, lack of information and risk that is inherently associated with the multifunctional character of agriculture – as described by 11 selected criteria and 22 different farming practices – they show that the current farming practices in the area are far below optimal in the environmental dimension.

Turner et al. (2000) suggest that combining economic valuation, integrated modelling, stakeholder analysis, and multi-criteria evaluation can provide complementary insights into sustainable and welfare-optimizing management and policy. Inspired by these ideas, Parra-López et al. (2008b) set out to combine MCA and stated preferences. Considering the three dimensions of sustainability (social, economic, and environmental), they use a three-step approach to assess the contribution of 'agro-landscapes' to societal welfare. Firstly, social demand for multifunctional agriculture is determined. Secondly, feasible technical alternatives available from the supply part of the market are determined. Thirdly, the net utility of the alternatives is measured as the sum of changes compared to the current situation expressed in utility of market and non-market net benefits. The economic benefits are represented by their monetary values in terms of the so-called market value of landscape gross margin[7]. The non-market functions capturing social and environmental issues are described by three composite indicators: Landscape quality, nature value, and environmental health. In the estimation of the net benefits of these functions that Parra-López et al. (2008b) incorporate citizen stated preferences by combining Quality Function Deployment with ANP. This combination translates the preferences of citizens into priorities for the analysed agro-landscapes, i.e. the weights used in the utility aggregation that characterizes the value function approach. Applying this methodology to a case study of a dairy-farming based agricultural landscape in the Netherlands, they show that the current agro-landscape is actually slightly beyond the socially optimal performance levels for the non-market benefits, suggesting that it may be optimal to reduce these benefits and instead increase the market benefit, i.e. the gross margin for farmers. This is surprising as it is somewhat contrary to the findings in the other mentioned studies concerning the sustainability of current farming practices.

An interesting approach is taken by Rozman (2006) who compares the results from MCA's and a financial CBA at the individual organic farm level. A quantitative MAUT approach and a qualitative, goal-oriented DEX-i (Decision expert) approach are used. The conclusions reached using the financial CBA are different from those reached using the MCA's The author argues that even though it is due to the MAUT and DEX-i approaches being more all-encompassing than the CBA, the combination of methods provides a powerful decision-support tool.

4 Discussion and conclusion

First and foremost, we conclude that the variety of contributions of organic food production certainly appeals to the use of MCA in the decision process. Moreover, as the literature review revealed very limited experiences with valuing and even assessing the multi-dimensionality of organic food production, we suggest that the systematic approach of the MCA of identifying relevant criteria and how to measure the scores that different options obtain on each criterion might prove itself very useful - not only as building blocks for a full MCA but in its own right. Subsequent steps in the pursuit of a full MCA would involve identifying to what extent different criteria are independent[8] and identify relative weights on criteria that are independent.

The use of MCA in the context of agricultural organic food production is sparse, and the relatively few studies that have been published are quite wide-ranging – from 'narrow' applications focusing on specific products, i.e. the consumers' multidimensional preferences for specific attributes of a new type of olive oil introduced in the market, to 'wider' applications such as the comparison of conventional, environmentally friendly and organic agricultural production focusing on a number of environmental criteria. Even though these studies certainly provide insight, the number of studies is insufficient for making any general conclusions. Considering the huge number of applications in forest management and production, it seems odd that MCA methods have received much less attention and surprisingly few applications to agricultural production are seen. The multi-facetted aspects of decision making would seem as relevant in agriculture as it is in forestry. One explanation could be that the concepts of sustainability (which clearly makes decisions more complex and multi-dimensional) have taken more time to penetrate the agricultural community than was the case for the forestry community.

[7] the total revenues minus all variable costs, at the landscape scale.

[8] A simple test to identify whether two criteria are independent is to ask the following questions. Is it possible to determine how an option scores on a given criterion without knowing how it scores on another criterion? If yes, then the criteria are probably independent.

Regarding consumption of organic products, the multidimensionality has been addressed in several studies using factor analyses as well as con-joint analyses where consumers are asked to trade-off their preferences for different organic attributes with money thereby revealing their relative preferences for different attributes including the price. An exercise of letting consumers assign weights to different aspects of organic products would be an interesting addition to increase our knowledge of the organic consumer.

Hence, we conclude that MCA has much more to offer decision-making in agriculture, especially branches of agriculture where aspects of sustainability are incorporated such as in organic farming. We argue that more research is needed, focusing on holistically evaluating organic production and consumption in a way that incorporates the many aspects in a common analytic framework. In particular, combining elements of MCA and CBA seems like a fruitful venture.

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