# Method for measuring sustainability in dairy farming

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## Abstract

The aim of this paper is to present a method for use in measuring sustainability in dairy farming. In this paper the methodological aspects are discussed in stepwise fashion. The first step is to introduce an outline for an analysis scheme of sustainability in dairy farming. The second step is to extend the analysis scheme to consider a wide range of possible attributes relating to sustainability of dairy farming. This is done using experts and/or interest groups for each specific aspect of sustainability. To prevent the method from becoming too complex and data intensive, in step 3 the same experts and interest groups as in step 2 are asked to select the most relevant attributes. The method for measuring sustainability will be applied to experimental farms. If attributes cannot be measured directly, indicators are determined. The appropriate indicators are derived in step 4. In the fifth step attributes levels are expressed on a standardised scale by using utility functions derived for each attribute. Estimating importance weights for each attribute, which results in a sustainability index per aspect, is also part of step 5. Sixth step is to weight sustainability indices into an overall sustainability index. Both utility functions and importance weights are dependent on preferences of experts or interest groups. Conjoint analysis is the method chosen for measuring preferences and is therefore used in step 5 and 6 for measuring utility functions and importance weights.

## 1 Introduction

The prospects for agriculture are not clear. Factors from within agriculture as well as factors from outside the sector influence its future. A key issue, in assessments of the future prospects for agriculture by government, agricultural organisations and society is sustainability.

If dairy farming is to be sustainable, there must be an effective way of monitoring trends in sustainability [16]. Therefore the concept of sustainability has to be made operational and appropriate methods need to be designed for its long-term measurement [12]. The method developed for assessing sustainability in dairy farming should be able to account for all possible farming activities and all their side effects [10].

In this paper we describe a proposed method for measuring sustainability in dairy farming. The method should allow the sustainability of different dairy-farming systems (conventional, organic, mixed conventional and mixed organic) to be compared. The method, when operational, will be tested on experimental farms of these various types. In this paper the methodological part for the development of the method is discussed.

Following this introduction, section 2 clarifies several definitions on sustainability. In sections 3 and 4 the proposed method for measuring sustainability in dairy farming is explained step by step. Finally in section 5 the methodology for designing the method and the possibilities of the method are discussed.

## 2 Definition of sustainability

During the past decade, sustainability has been on the agenda of government, agricultural organisations and society. Two popular and widely used definitions of sustainability [16] are given in Our Common Future [5] and in Caring for the Earth [17]. These are respectively: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs"; and "development that improves the quality of human life while living within the carrying capacity of supporting ecosystems". Such broad definitions are likely to give rise to various different interpretations [6].

This diversity in interpretation of sustainability is mainly due to:

a) The position and opinion of the user
b) The time period over which sustainability is judged or expected to persist
c) The scale of the system for which sustainability is considered

Each of these aspects is addressed in turn:

a) The above mentioned definitions are respectively anthropocentric and ecocentric or biocentric. In anthropocentric views the focus is on the sustainable welfare of humans, whereas in biocentric view humanity is no more, but also no less, important than all other things on earth [15]. In this paper the anthropocentric view is assumed. Even within this view sustainability means different things to different people [12, 18].

People tend to underestimate things that are not in their own direct, immediate interest, and so ignore some of the most pressing global problems related to sustainable development [18]. The term sustainability has therefore a different meaning for a farmer considering the possibilities to continue his farm than for an environmentalist looking at the farm from outside [13].

b) Views of sustainability by different interest groups change over time. As a consequence sustainability does not represent the endpoint of a process; rather it represents the process itself [18]. Sustainability implies an ongoing dynamic development, driven by changing human expectations about future opportunities. Sustainability is "sustainable development". A method for measuring sustainability in dairy farming will have to be revised over time. In this way new scientific understandings and policies can be included in the method.

c) The importance of sustainability varies with the scale of the system for which it is assessed [18]. Different scales can be distinguished: farm, village, town or city, region, country and so on until the whole planet is considered. The sustainability of a system does however not depend on the sustainability of all its sub-systems [14]. The method for measuring sustainability that is developed in this paper, is designed to compare different dairy farming systems, therefore sustainability is considered at farm level in this paper.

## 3 Methods

As mentioned above, there are different interpretations of sustainability. In this paper we aim to develop a method for measuring sustainability which takes this variation into account as fully as possible. Six steps in the method are proposed.

1. Develop an outline of the analysis scheme of sustainability in dairy farming
2. Make a comprehensive list of the attributes which determine sustainability in dairy farming
3. Select a sub-set of the most relevant sustainability attributes
4. If possible, find indicators to represent those attributes that cannot be measured directly
5. Weighting all relevant attributes into a sustainability-index per aspect
6. Determine weights to combine the sustainability indices for each aspect to derive an overall sustainability index

### 3.1 Develop an outline of the analysis scheme of sustainability in dairy farming

Figure 1 is an outline of an analysis scheme of sustainability in dairy farming. This outline has been developed after consulting experts from the same fields of research related to agricultural sustainability. In literature sustainability of a farm is assessed with respect to three aspects: economic, social and ecological sustainability [8]. However, we have subdivided the assessment into four

aspects: economic, internal social, external social and ecological sustainability. Economic sustainability is defined as ability of the dairy farmer to continue his farm (economic viability). Internal social sustainability relates to working conditions for the farm owners and employees. External social sustainability relates to societal concern about the impact of agriculture on the well being of people and animals [4]. In other words, internal social sustainability is farmer oriented while external social sustainability is society oriented. Ecological sustainability concerns threats or benefits to the flora, fauna, soil, water and climate. The Brundtland report [5] underlines the fact that sustainable development requires a production system in which there is a commitment to preserve the ecological basis for development.

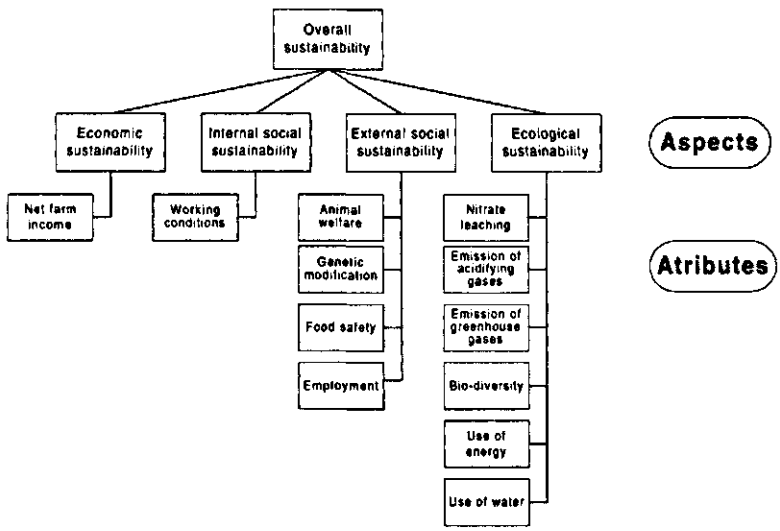


Figure 1 Outline of an analysis scheme of sustainability in dairy farming with aspects and attributes

The four aspects of sustainability, showing also some of the attributes that might be selected within each aspect, are outlined in Figure 1. Attributes can contribute or detract from the attainment of sustainability. In this stage of the method attributes are just general verbal descriptions, which can be measured directly or indirectly. The listed attributes are intended to be illustrative and are neither comprehensive nor final.

For economic sustainability, net farm income is chosen as an attribute. Working conditions are distinguished as an attribute within internal social sustainability. Inadequate working conditions are likely to mean that farmers cannot continue to operate in the long term. Animal welfare, genetic modification, food safety and employment are some of the aspects likely to farm part of external social sustainability. Animal welfare will need to be included, as consumers are increasingly demanding livestock products that are produced with consideration to animals' needs. In the Netherlands a public debate is taking

place about genetic modification. Consumers' acceptance of genetic modification of crops and farm animals remains uncertain, so genetic modification will be included as attribute. Food safety is included as an attribute within external social sustainability because there appears to be great societal concern about food safety - witness the BSE crisis. Dairy farming provides employment both on farms and in such areas as the agro-food sector. Therefore employment with respect to dairy farming is included as attribute within external social sustainability.

Within ecological sustainability a wide range of attributes can be distinguished. Examples include nitrate leaching, emission of acidifying and green house gases, use of water and energy and bio-diversity. Levels of nitrate leaching, emission of acidifying and greenhouse gases are included as these attributes reflect the environmental pollution that is caused by dairy farming systems. Water and energy use relates to the depletion of natural resources and are therefore included within ecological sustainability. Bio-diversity is included as high bio-diversity is seen as essential in the future [11]. It should be clear that figure 1 is an outline. The final analysis scheme with all sustainability attributes is one of the outcomes of the processes described in this paper.

### 3.2 Make a comprehensive list of the attributes which determine sustainability in dairy farming

In the previous section an outline of an analysis scheme with aspects and some possible attributes was introduced. However, this outline is only provisional as we have yet to consult a wide range of experts. The plan is to use a questionnaire survey to develop a gross list with attributes within each aspect of sustainability. In these questionnaires the outline of Figure 1 will be used as a starting-point and respondents will have the option of adding or skipping attributes.

Four different questionnaires will be used: an economic, internal social, external social and ecological questionnaire. In each case the aim is to elicit from those consulted a gross list of attributes with respect to the aspect of concern. As described in table 1, the type of respondents to be consulted differs between aspects of sustainability.

Table 1 Type of respondent per aspect of sustainability

| Aspect of sustainability | Respondents | |
|---|---|---|
| | Experts | Interest groups |
| Economic | Yes | No |
| Internal social | Yes | Yes |
| External social | No | Yes |
| Ecological | Yes | No |

The questionnaires on economic sustainability will be send to economic experts as evaluation of economic viability of a dairy farm is not dependent on preferences of different interest groups. Selection of attributes within internal social sustainability is dependent on preference of one interest groups, the dairy

farmers. A questionnaire on internal social sustainability will be send to representatives of farmers and to experts working on the field of working conditions in dairy farming. Selection of attributes within external social sustainability depends on preference of interest groups, as the meaning of ethical sound producing differs between interest groups. The questionnaire on external social sustainability will be send to representatives of consumer and farmer organisations, retailers and policy makers. The selection of attributes to evaluate the ecological sustainability of a dairy system is not a matter for different interest groups. Rather the choices should be made drawing on expert knowledge. Therefore questionnaires with respect to ecological sustainability will be send to experts.

The questionnaire will be send to approximately 10 experts or representatives of different interest groups for each aspect of sustainability. After sending the questionnaire an appointment will be made with each responding expert or representative. At the interviews the questionnaires will be talked over to minimise the chances of any misunderstandings about interpretations of attributes. After visiting all the experts and representatives of different interest groups, a gross list including all the attributes within each aspect of sustainability in dairy farming will be obtained.

### 3.3 Select a sub-set of the most relevant sustainability attributes

As a result of the chosen approach in section 3.2, many sustainability attributes may have been listed. However, it will not be possible to include very many sustainability attributes into the method for assessing sustainability since to do so would probably make the measurement task too complex and data intensive [8]. A restricted number of attributes (15-25) will be selected for measuring sustainability on dairy farms. To select the most important attributes, the relevance of the listed sustainability attributes will be rated by the same experts and representatives as in step 1. In Churchill [9] a method, called summated ratings, is proposed to select a subset of attributes. In this method experts are asked to evaluate a attribute on its relevance with respect to the concerned aspect of sustainability. The attributes are placed on a Likert scale varying from extremely relevant to totally irrelevant in 11 classes. After the evaluation of all attributes by all experts or representatives, for each attribute an average score (scale value) is calculated. If two attributes have approximately equal averages, the one with the smallest variation is selected [9].

### 3.4 Assessment of indicators if attributes cannot be measured directly

As mentioned before the method for measuring sustainability is to be used to compare the sustainability of different dairy farming systems. These dairy farming systems (conventional, organic, mixed conventional and mixed organic) are represented by experimental farms. It is possible that it will not be technically feasible to measure some of the selected attributes on these farms. In other cases, it may simply be too expensive to make the required measurements. In such

cases the chosen attributes will be measured using one or more indicators, at least where this is possible. The aim will be to choose a sustainability indicator (or set of indicators) believed to have high correlation with the unmeasured sustainability attribute. For example, if nitrate concentration in groundwater is chosen as a attribute for ecological sustainability of dairy farming, then nitrogen surplus, rainfall, grazing management and ground water table might be used as indicators. For each unmeasured attribute, an estimation function can be specified using existing models, published information or expert knowledge.

If it is not possible to make a good direct or indirect (by using indicators) measurement of a attribute, then the specific attribute cannot be included in the method. In such a case it will then be possible to select another attribute from the same aspect for inclusion in the method (figure 1 and section 3.2).

### 3.5 Weighting all relevant attributes into a sustainability-index per aspect

Agricultural production systems cannot be valued either sustainable or unsustainable. This means that sustainability is a continuous concept [11] and must be expressed as an index. For weighting all relevant attributes into an sustainability-index per aspect two (sub)steps are distinguished: (1) represent all attributes on a standardised scale and (2) weight attributes intervals into a sustainability index per aspect.

Utility reflects the level of preference or enjoyment an individual attaches to a given level of a attribute. In our method we use utility to measure the degree of attainment of sustainability. By means of utility functions physical data that represent attributes are converted into utility values [2]. In this way all sustainability attributes are expressed on a standardised scale.

The shape of the utility function of attributes might vary. Figure 2 shows an inverse relationship between a sustainability attribute (concentration of pollutant) and the utility associated with it. This relationship, as figure 2 shows, is not linear, since it is assumed that the level of pollution has no significant negative effects on the environment, as long as the pollution level is limited. Therefore it is necessary to define utility functions for each sustainability attribute [2]. Each attribute is converted to a utility value between zero and one, whereas the worst level is zero and the best level is one. Respondents scale intermediate levels between zero and one.

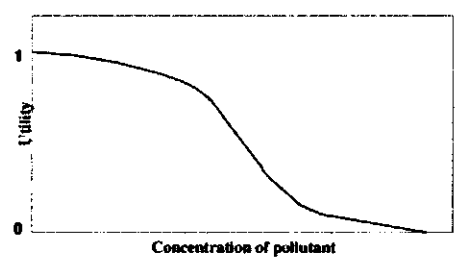


Figure 2: Example of an utility function converting physical values (with respect to concentration of pollutant) into utility values

Utility is a personal thing and inter-personal comparisons of utility are usually held to be impossible [3]. This means that no group utility function can be assessed. However in this research a group choice has to be made. However according to Anderson, Dillon and Hardaker [1] standardising utility functions though clearly in violation of Arrow's impossibility theorem, may be acceptable to some groups in some circumstances.

After representing the attributes on the same scale, attributes are weighted into a sustainability index per aspect. Therefore importance weights are determined for all attributes. In this paper utility and preferential independence is assumed, what means that the attribute intervals are combined additive into a sustainability index per aspect.

The same type of respondents as in step 1 and 2 are used to assess utility functions and importance weights. Utility functions and importance weights within external social sustainability will be assessed by different interest groups. These preferences are expected to differ considerably between interest groups. Therefore for each interest group a different external social sustainability index is calculated. Also within the three other aspects of sustainability preference between experts will differ, it is however assumed that these differences are relatively small. It is clear that for all attributes preferences of experts or representatives of interest groups should be measured. Conjoint analysis is used to measure preferences and is discussed in section 4.

### 3.6 Weighting sustainability indices per aspect into one overall sustainability index

Next step is to weight the three sustainability indices into one overall sustainability index. This last step can be seen as a political choice. Groups that have economic benefits from a polluting productive activity, may for instance give a relatively high importance to economic sustainability, especially if they do not suffer from the impact of the pollution they cause [2]. Therefore importance weights for sustainability indices per aspect are determined by interest groups. Farmers, consumers, policy makers and retailers are asked to assess importance weights. This can lead to different overall sustainability indices between interest groups. It is clear that importance weights for sustainability indices per aspect are dependent on preference of interest groups. As mentioned earlier conjoint analysis is used to measure preferences and will be discussed in the next section.

## 4 Conjoint analysis

Conjoint analysis was developed from the theoretical work of mathematical psychologists and it is commonly used in marketing research for measuring buyers' trade-offs among multi-attributed products and services [7]. Srinisavan and Park [19] developed a new approach in conjoint analysis called customised conjoint analysis (CCA), that combines a self-explicated approach with the full-profile approach. This approach has as main advantage that many attributes can be analysed. In the self-explicated approach (direct approach) the respondent

first evaluates levels by rating the desirability of the levels (on a 0-1 desirability scale). Next, the respondent is asked to indicate the relative importance of each of the included attributes. By using this self-explicated approach utility functions and importance weights for all attributes will be estimated. As however it is expected that utility functions and importance weights are estimated less accurately in this approach, the full-profile conjoint analysis is also included. In this full-profile conjoint analysis the six most important attributes, dependent on respondent, are included. In the full-profile approach respondents are asked to evaluate a set of hypothetical objects that differ from one another on two or more attributes [19]. By using this full-profile conjoint analyses, utility functions and importance weights of the selected attributes can be determined. This results in sustainability indices per aspect and an overall sustainability index, which can differ between interest groups.

## 5 Discussion

Past few years several approaches for measuring sustainability have been published [8, 11, &13]. The approach in this paper is different because preferences of different interest groups are included in this method for measuring sustainability in dairy farming. The advantage of this approach is that the designed sustainability index is broadly based, which is prerequisite for implementation [10]. Also the approach was designed specifically to assess sustainability in dairy farming whereas most other approaches are aimed at agriculture in general.

The method developed will be used to compare different dairy farming systems that are represented by experimental farms. Once the method has been tested and refined, it can be used in conjunction with mathematical programming to evaluate trade-offs between economic, social and ecological sustainability between and within different dairy farming systems attributes. Such a MCA (Multiple Criteria Analysis) can be used, for example, to explore the opportunities for and effects on sustainability of converting from dairy farming system to another. Within any given system, the models can be used to examine the effect on sustainability aspects and overall of changes in policy or management. For example, the model could be used to show the effect of obliged grazing on economic, internal social, external social and ecological sustainability.

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