

# Indicators - A Method to Describe Sustainability of Farming Systems

*Jens Peter Hansen & Vagn Østergaard*

## Abstract

In order to assess the sustainability of agricultural production, indicators are needed. These indicators should be formulated to have the following features or attributes: a) be representative for the chosen system and have a scientific basis b) be quantifiable, c) be part of the cause-effect chain, and d) offer implications for policy making. A method for formulation of indicators is described. This method starts with the goal setting of sustainability, i.e. ecological, economic and social sustainability. These goals are resolved into a number of objectives, for which causing factors of the individual objectives are chosen and divided until the last ones can be described as indicators with the above mentioned attributes. The use of a methodological approach assures that different views of sustainability expressed through use of indicators can be communicated between stakeholders.

## Background / Problem identification

The United Nations Conference on the Environment and Development in 1992 (Agenda 21, 1992) underlined that present and planned national agricultural systems, may not be sustainable because they deplete the natural resource base and impose unacceptably high environmental costs (Crosson and Andersson, 1993). Therefore, both the international and national agricultural research institutes have to develop technologies (systems and knowledge) that are sustainable from both an economic, ecological and social point of view.

But by whom and how shall sustainability be given an operational definition? It can be argued that the problem of sustainability is owned by society (Rasmussen, 1995) and that the concept of sustainability (= sustainable development) is ambiguous (Dunlap et al., 1992) including both political, administrative and scientific elements. Scientific elements constitutes the knowledge foundation on which political decisions and administrative instruments are based. The quality of these depends not only on the scientific knowledge itself, but also on the awareness and actual use of this knowledge.

A methodological approach is needed to help operationalise and communicate concepts of sustainability. Such a method must be founded on scientific knowledge, but must also acknowledge that an evaluation of sustainability includes pooling of conflicting objectives according to goals and values held by the actors involved - namely farmers and family members (primary actors), advisers and users of nature (secondary actors) as well as politicians and consumers (tertiary actors). We propose the use of indicators as an instrument

in such a method and discuss in this paper characteristics of indicators, methods of indicator formulation and the use of indicators.

### Characteristics of indicators

We adopt the following definition of the term *indicator*: "In measurement theory the term "indicator" is used for the empirical specification of concepts that cannot be (fully) operationalised on the basis of generally accepted rules", Vos et al. (1985) cited by Gilbert and Feenstra (1993). The function of indicators lies primarily in simplification, in the sense that they are a compromise between scientific accuracy and the demand for concise information. From the literature, Gilbert and Feenstra (1993) have identified four desired features of indicators:

- a. The indicator must be representative of the system chosen and must have a scientific basis.
- b. The indicator must be quantifiable.
- c. A part of the cause-effect chain should be clearly represented by the indicator.
- d. The indicator should offer implications for policy.

More detailed characteristics, or criteria, for desirable global sustainability indicators are given by Liverman et al. (1988).

### Method of indicator formulation

The formulation of indicators should be done through a **method** resulting in the above mentioned four features or attributes. The reason being that it is necessary to document and communicate the research method and results. A method to describe goals by objectives and indicators is formulated by Vemuri (1978) and adopted by Rasmussen and Dalsgaard (1994).

This method starts with the goal of the decision maker. In order to measure how well this goal is fulfilled, we often need to resolve the goal into a number of objectives, necessary for fulfilling the goal. These objectives (B1, B2,... in Figure 1) can be subdivided into causing factors (C1, C2,...) and finally into indicators (D1, D2,...), which can be measured and are quantifiable (see above), as shown schematically in Figure 1. It should be noticed, that in complex situations, the resolving of different objectives can result in some common indicators.

A few examples are given below. We have chosen to focus on the ecological aspect of sustainability, although economic and social sustainability are of similar importance.

### Indicators to evaluate ecological sustainability of farming systems

According to the review paper by Yunlong and Smit (1994), the ecological definition of sustainability focuses on biophysical processes and the continued productivity and functioning of ecosystems. In this section examples of indicators, related to mixed crop-livestock farming systems producing primarily food and fibre, are given.

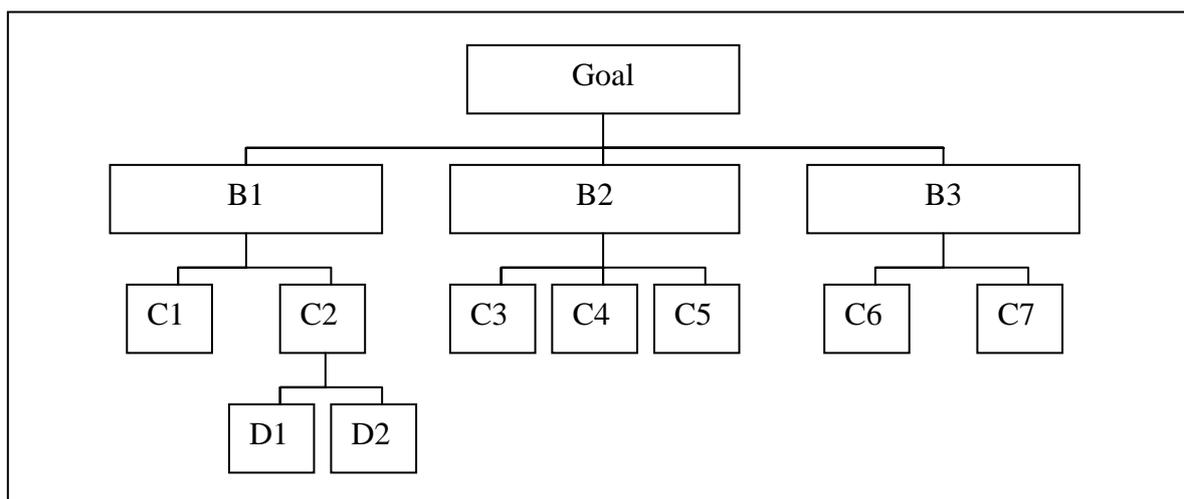


Figure 1: A schematic model for description of a goal by its objectives, causing factors, and indicators. (Mod. a. Vemuri, 1978).

### Biological diversity

The objective maintenance of biodiversity or biological variation and quantity is prerequisite for future generations to fulfil their needs for livestock products. The fulfilment of the objective depends on the number of livestock species and breeds, flora and fauna and the wealth of species - further determined by causing factors such as biotopes, permanent pastures, windbreaks etc. and crop composition within cultivated land. Figure 2 shows the goal of ecological sustainability, the objectives, the causing factors and the related indicators.

### Reduced resource use

On a global level, much concern is focused on the use of energy, particularly of fossil origin. The goal to reduce the use of energy is driven by the want to put less pressure on the environment and to use less fossil resources. Indicators can be consumption or input of Mega Joule energy and kgs of CO<sub>2</sub> produced per kg of product from farming.

### Fertile soil

Fulfilment of the objective to maintain or build up fertile soil depends on erosion, amount of organic matter, biomass and nutrients (e.g. N, P and K) in the soil as well as possible storage of pesticides and unwanted minerals (Figure 2).

### Constant climate over years

An overall goal is to have a constant climate over the years. The greenhouse effect - possibly caused by emission of CO<sub>2</sub> and CH<sub>4</sub> - has been much discussed without a clear picture of its long term effects. Indicators can be the production of CO<sub>2</sub> and CH<sub>4</sub> per kg product from farming.

## Using indicators

The desired features of indicators means that they in several ways can support quantitative model based analyses in relation to sustainability. The process of building indicator trees, as in Figure 2, helps with problem identification and formalisation of knowledge. Having constructed indicator trees, these can serve as a guide in model building. And further, when such models are used, they are an excellent way of communicating the model's assumptions and coverage to model users. With an indicator based model, a political or administrative decision maker can simulate how alternative instruments will influence sustainability. Assuming that the model leaves it to the user to decide which indicators to include and how to pool these, the user can base his/her judgement on a personal perception of sustainability. And again. this personal perception can be communicated be means of (pruned) indicator trees as a framework..

## Conclusion

In order to assess the sustainability of agricultural production, indicators are needed. Such indicators validity is closely coupled with perceptions of sustainability hold by these responsible for their formulation. Therefore, the reasoning leading to concrete indicators should be clearly stated. This can be accomplished by using the described method, which starts with the goal setting of sustainability, i.e. ecological, economic and social aspects of sustainability. These goals are subsequently resolved into a number of objectives, for which causing factors of each individual objective are identified and further subdivided until the point where indicators with the above mentioned attributes can be identified.

There is an urgent need to describe sustainability of farming - also by means of livestock systems research. In the identification and formulation of research issues, we should pay attention to the identification of appropriate indicators as well as their measurement in order to be able to assess the sustainability of different production systems. Through this assessment, we can avoid repeating some of the past mistakes made within research and management in developed countries.

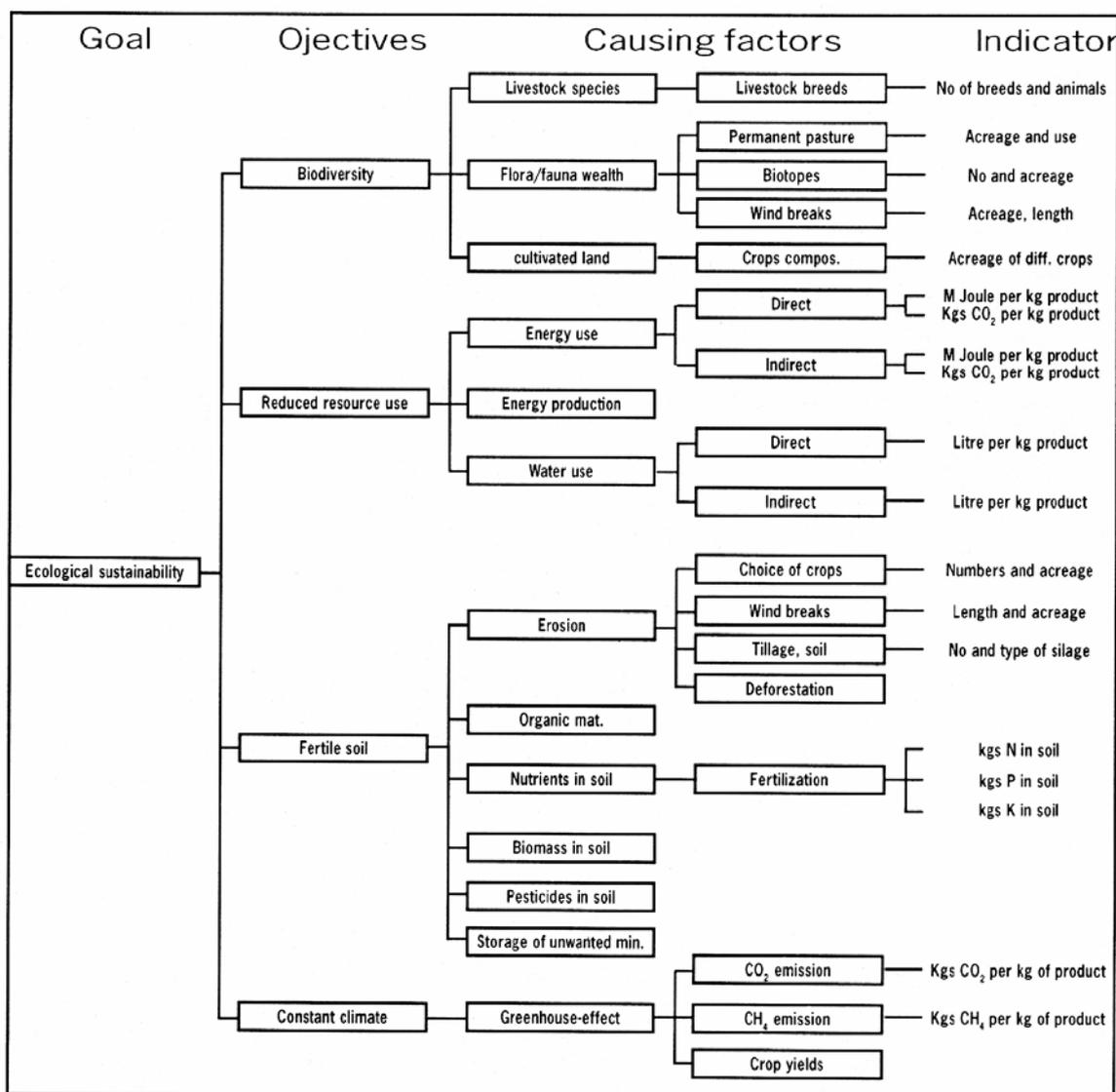


Figure 2: Goal, objectives, causing factors and indicators of ecological sustainability

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