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Identifying and ranking attributes that determine sustainability in Dutch dairy farming

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Abstract. Recent developments in agriculture have stirred up interest in the concept of "sustainable" farming systems. Still it is difficult to determine the extent to which certain agricultural practices can be considered sustainable or not. Aiming at identifying the necessary attributes with respect to sustainability in Dutch dairy farming in the beginning of the third millennium, we first compiled a list of attributes referring to all farming activities with their related side effects with respect to economic, internal social, external social, and ecological sustainability. A wide range of people (i.e., experts and stakeholders) were consulted to contribute to our list of attributes. Our consultation showed that only one attribute was selected for economic and internal social sustainability: profitability and working conditions, respectively. The list for external social sustainability contained 19 attributes and the list for ecological sustainability contained 15 attributes. To assess their relative importance, the same experts and stakeholders ranked the attributes for external social and ecological sustainability by using a questionnaire. The most important attributes for external social sustainability were food safety, animal health, animal welfare, landscape quality, and cattle grazing. For ecological sustainability they were eutrophication, groundwater pollution, dehydration of the soil, acidification, and biodiversity. The present method for identifying and ranking attributes is universal and, therefore, can be used for other agricultural sectors, for other countries, and for other time periods.

Key words: Dairy farming, Expert perceptions, Stakeholder perceptions, Sustainability aspects, Sustainability attributes, The Netherlands

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Introduction

Interest in the concept of "sustainable" farming systems has grown as a result of the continuous pressure on farm incomes, occurrence of animal diseases with a major impact (e.g., foot-and-mouth disease and BSE), concerns about animal welfare, and environmental problems caused by agriculture. Alternative farming systems, which include integrated farming, biodynamic farming, and organic farming are often equated with sustainable agriculture (Hansen, 1996; Rigby and Caceres, 2001). Others, however, see sustainable farming as encompassing a wider range of systems. It is nevertheless difficult to determine the extent to which certain agricultural practices can be considered sustainable or not (Rigby and Caceres, 2001).

To characterize agricultural systems as sustainable, the concept of sustainability has to be made operational and appropriate methods need to be designed for its long-term measurement (Heinen, 1994). A method developed for assessing sustainability in agriculture should take into account all possible farming activities and all their side effects (de Graaf et al., 1996). Sustainability should be assessed on the basis of three aspects: economic, social, and ecological sustainability (Shearman, 1990; Heinen, 1994; Hansen, 1996). So far, several methods have been developed for identifying sustainability in agriculture (de Wit et al., 1995; Chandre Gowda and Jayaramaiah, 1998; Hanegraaf et al., 1998; Callens and Tyteca, 1999; Webster, 1999; Rigby et al., 2001; Sands and Podmore, 2000; Sulser et al., 2001). Most of these approaches, however, do not focus on farming activities and related side effects with respect to all (i.e., economic, social, and ecological) aspects. In addition, none of them are aimed particularly at assessing sustainability in dairy farming. Dairy farming is different from other sectors of agriculture, as it is a combination of two types of production processes (i.e., animal production and plant production). An assessment of sustainability in dairy farming requires four steps: (1) description of the (problem) situation; (2) identification and definition of relevant economic, social, and ecological attributes or issues; (3) selection and quantification of suitable sustainability indicators; and (4) aggregation of indicator information into an overall contribution to sustainable development (Bell and Morse, 1999; de Boer and Cornelissen, 2002).

The aim of this paper is to develop a methodology for step 2 of this assessment, which means providing an overview of sustainability attributes within the context of Dutch dairy farming. Therefore, a comprehensive list of attributes concerning economic, social, and ecological sustainability is first identified and then ranked using the perceptions of different stakeholders and experts.

Definitions of sustainability are discussed in the second section of the paper. In the third section, the method used for identifying and ranking attributes for assessing sustainability in dairy farming is explained step by step. The results are discussed in the fourth section. The final section contains the discussion and major conclusions.

Definition of sustainability

During the past decade, sustainability has been on the agenda of government, agricultural organizations, and society-at-large. Much of the debate about the nature and potential of sustainable agriculture focuses on definitions (Francis and Youngberg, 1990). Two popular and widely used definitions of sustainable development are given in *Our Common Future* (Brundtland, 1987) and in *Caring for the Earth* (Munro and Holdgate, 1991). 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 (Callens and Tyteca, 1999). The result is that at least 70 more definitions have been constructed, each different in subtle ways, each emphasizing different values, priorities, and goals (Pretty, 1995). An overview of definitions of sustainability in agriculture can be found in Francis et al. (1990), Bell and Morse (1999), and Hansen (1996).

The diversity of the definition of sustainability is largely explained by the position and the opinion of the user. Generally, two different ethical perspectives can be distinguished – biocentrism (or ecocentrism) and anthropocentrism (Thompson, 1992). The most prominent features of biocentrism are that humans are not inherently superior to other living beings (Barret and Grizzle, 1999), and that various beings or entities, from individual organisms to the biosphere, have intrinsic value (Shearman, 1990). The anthropocentric view focuses on the sustainable welfare of humans (Barret and Grizzle, 1999). The definition of sustainable development in the Brundtland report (1987), for example, is explicitly anthropocentric (Rennings and Wiggering, 1997; Hardaker, 1997). Without a doubt, the anthropocentric perspective dominates the paradigm of sustainable development (Shearman, 1990).

People from different disciplinary backgrounds also can view sustainability quite differently (Lowrance et al., 1986; Shearman, 1990; Heinen, 1994; Jaeger, 1995; Hardaker, 1997; Bell and Morse, 1999; Rigby et al., 2001). An important difference between economists and ecologists is the scope of substitution, particularly of human capital for increasingly scarce natural resources and environmental services. Economists are generally optimistic about substitution while ecologists have a pessimistic view of it (Hardaker, 1997).

Finally, the variety of definitions with respect to sustainability in agriculture has been classified also on the basis of a specific economic, social, or ecological concern (Douglass, 1984) and its historical and ideological roots (Kidd, 1992). This emphasizes again that defining sustainability depends on the individual. The meaning of sustainability varies along spatial and temporal scales (Fresco and Kroonenberg, 1992).

Different spatial scales can be distinguished (e.g., field, farm, village, city, region, country and so on until the whole planet is considered) (Bell and Morse, 1999). Lynam and Herdt (1989) have pointed out that the sustainability of a system is not necessarily dependent on the sustainability of all its sub-systems. Invoking the Lynam and Herdt principle implies that individual subsystems need not all be sustainable for global sustainability to be achieved (Hardaker, 1997). Although sustainability is an important concern on several spatial scales (Lowrance et al., 1986; Lynam and Herdt, 1989), it is particularly relevant at farm level (Hansen and Jones, 1996).

Societal views of sustainability change over time. In other words, definitions of sustainability are time-specific (Pretty, 1995). Sustainability implies an ongoing dynamic development, driven by human expectations about future opportunities based on economic, social, and ecological information (Cornelissen et al., 2001). Planning horizons of ten or fifteen years are usually about as long as it is plausible to consider (Lynam and Herdt, 1989; Hardaker, 1997). Even over such lengths of time, the ability to account for upcoming changes in technological, social, political, and economic situation is very limited (Hardaker, 1997).

The perceptions of different stakeholders and experts are included in this research as a way to identify and rank sustainability attributes. By choosing this approach, we attempt to take into account different ethical perspectives. The farm level is regarded as the most important starting point because economic, ecological, and social attributes come together at farm level (de Koeijer et al., 1999). This research focuses, therefore, at the farm level. The research was and will continue to be conducted at the very beginning of the third millennium. Consequently, the results reflect the knowledge and the views of this period in time with respect to sustainability on Dutch dairy farms.

Methods

Step 2 for the assessment of sustainability in dairy farming concerns the identification and ranking of attributes. The method for identification and ranking of attributes for sustainability in dairy farming was performed in 2001 and consisted of three steps:

1. Developing a preliminary outline for determining sustainability
2. Making a list of attributes that determine sustainability
3. Assessing the relative importance of sustainability attributes

Developing a preliminary outline for determining sustainability

A preliminary outline of sustainability in dairy farming was developed based on literature research, and after consulting experts in the field of sustainability. Our assessment in this research focused on four aspects – economic, internal social, external social, and ecological sustainability.

Economic sustainability is defined as the ability of the dairy farmer to continue his farming business (i.e., economic viability). Internal social sustainability relates to working conditions for the farm operator and employees. External social sustainability has to do with societal concern about the impact of agriculture on the well being of people and animals. Ecological sustainability concerns threats or benefits to the flora, fauna, soil, water, and climate.

For each aspect, attributes were selected that contributed to or detracted from sustainability. An attribute, for this research, was defined as a particular feature of an aspect of sustainability (derived from Hardaker et al., 1997). Attributes equate with "issues" as used in other studies (e.g., de Boer and Cornelissen, 2002).

Making a list of attributes that determine sustainability

The method to identify and rank attributes is based on the expertise, experience, and knowledge of a group of respondents. The respondents (i.e., experts vs. stakeholders) who were chosen to identify attributes differed with respect to aspects of sustainability (Table 1). Four different questionnaires were used – economic, internal social, external social, and ecological questionnaires. The questionnaires on economic, internal social, and ecological sustainability were sent to scientific experts, as the assessment of attributes with respect to these aspects of sustainability is a matter of expert knowledge. The supervising committee of this research project proposed experts for the different aspects of sustainability. Selection took place through discussion in which the competence of the expert was the main criterion. Competence was judged mainly by looking at scientific papers written by the proposed experts. To ensure diversity, experts from different scientific institutions and environmental, labor, and farmers' organizations were selected.

Identification of external social sustainability attributes depends strongly on the preferences of stakeholders, as societal concerns differ between stakeholders. Based on Grimble and Wellard (1997), we define the term stakeholder as "any group of people, organized or unorganized who share a common interest or stake in a particular issue or system" (p. 175). In this research, four stakeholders or interest groups are included – consumer and farmer organizations, industrial producers, and policy makers. These stakeholders, proposed by

Table 1. Type and number of respondents per aspect of sustainability.

Aspect of sustainability	Type of respondents			
	Experts	*N*[a]	Stakeholders	*N*
Economic	Yes	9	No	–
Internal social	Yes	7	No	–
External social	No	–	Yes	9
Ecological	Yes	10	No	–

[a] Number.

the supervising committee of the research project, were individuals who had shown social concern for the impact of agriculture on the well-being of people and animals. This was judged by looking at the participation of the stakeholder in the public debate on future developments in dairy farming. The questionnaires on external social sustainability were sent to nine representatives within the stakeholder category.

After sending the questionnaires, an appointment was made with each responding expert or stakeholder, to talk things over. This served as a way to minimize the chances of misunderstanding or misinterpretation. Each questionnaire identified suggestions for attributes with respect to a particular aspect of sustainability. Respondents had the option of adding and removing attributes. This step resulted in a list of all attributes within each aspect of sustainability in dairy farming.

Assessing the relative importance of sustainability attributes

As a result of the chosen approach in the previous section, many sustainability attributes were likely to be listed. It was recognized that some attributes might overlap and that those attributes that appeared to be dependent on others should be excluded as far as possible to avoid redundancy. In cooperation with experts on the concerning aspect of sustainability, seemingly dependent and independent attributes were indicated. In the second questionnaire sent to the same set of experts and stakeholders, respondents were asked first whether seemingly dependent attributes should be omitted or be used as separate attributes.

Next, the respondents were asked to rank the listed sustainability attributes. Two ranking methods were used – interval ranking and ordinal ranking (Churchill, 1999). In interval ranking, the respondents were asked to rank each attribute relevant to a particular aspect according to its perceived importance. A Likert scale of 1 to 5 was used, with 1 being not important for sustainability and 5 being very important. In ordinal ranking the respondents were asked to put the list of attributes in order of importance.

To compare the final ranking, the average and standard deviation of the relative importance weights of attributes were calculated for each respondent and ranking method. The relative importance weight *Wijk*, for attribute *i*, respondent *j*, and ranking method *k*, was calculated as follows:

$$W_{ijk} = \frac{X_{ijk}}{\overline{X_{jk}}},$$

where X_{ijk} is the value of attribute *i* for respondent *j* and ranking method *k*, $\overline{X_{jk}}$ is the average ranking of all attributes for respondent *j* and ranking method *k*.

By using the relative importance weights of both ranking methods, each respondent was tested for internal consistency by using the Spearman Rank Correlation Coefficient. The results of non-consistent respondents were omitted from the analysis.

Results

First we will present the comprehensive list of attributes that determine sustainability in dairy farming, followed by the results of assessing the relative importance of sustainability attributes. These results are presented according to each aspect of sustainability.

List of attributes

Economic sustainability

Suggested attributes for economic sustainability were liquidity, profitability, and solvability of the dairy farm. Liquidity refers to the farm's capacity to generate sufficient cash to meet its financial commitments as they become due. Profitability is the difference between the value of goods and services produced by the farm and the costs of resources used in their production. Solvability is concerned with the relationship between the current market value of assets and the claims others have on the farm (Barry et al., 2000).

All of the proposed attributes are highly interrelated. Indirectly, solvency and liquidity are linked to profitability. In deliberation with the respondents, therefore, it was decided that profitability would be selected as the only attribute for assessing economic sustainability in dairy farming. Profitability can be measured by using net farm income as an indicator.

Internal social sustainability

The respondents rejected the suggested attributes in the questionnaire (i.e., leisure time and disability). Arguing that disability in dairy farming is considered to be caused by poor working conditions, most respondents suggested that disability and leisure time should be replaced by "working conditions on a dairy farm." Working conditions, which can be measured by constructing an index, consisted of a quantitative dimension (i.e., time aspects) and a qualitative dimension (i.e., physical and mental burden). Working conditions on a dairy farm were selected as the only attribute within internal social aspect of sustainability, since this attribute subsumed all of the subjects that the respondents identified.

External social sustainability

Most respondents included the suggested attributes (i.e., food safety, animal welfare, and employment) in their list of attributes. The respondents added a further sixteen attributes covering a very wide range of concerns to the list of external social sustainability (Table 2). The reasons for including these attributes are presented in Appendix A.

It is clear that not all of these attributes are independent. For example, cattle grazing was mentioned as a separate attribute, but it is also part of animal welfare and landscape quality. Attributes in the first column of Table 2 are considered to be independent attributes, while those in the second column are considered to be dependent attributes. Associations shown in the table were provided by the respondents (e.g., "use of new technologies" with "degree of industrialization") and judged by the authors.

Ecological sustainability

Most respondents included the suggested attributes in the questionnaire (i.e., acidification, biodiversity, and use of energy) in their list of attributes. Respondents added 12 attributes to the list for ecological sustainability (Table 3). The reasons are presented in Appendix B.

Again, not all attributes are independent. Biodiversity, for example, was mentioned as a separate attribute, whereas it is affected (especially on grassland) by emission of acidifying gases and nitrate and phosphate concentration in surface water (i.e., eutrophication), among other things. Attributes in the first column of Table 3 are considered to be independent attributes; those in the second column are considered to be dependent attributes.

Table 2. List of attributes of external social sustainability.

No.	Independent attributes	No.	Dependent attributes
1	Food safety	10	Cattle grazing (2 and 5)[a]
2	Animal welfare	11	Use of pesticides (1 and 4)
3	Contribution to urban economy	12	Use of new technologies (4)
4	Degree of industrialization	13	Use of Genetic Modified Organisms (4)
5	Landscape quality	14	Use of artificial fertilizer (4)
6	Multifunctionality	15	Intensity (4)
7	Use of by-products	16	Animal health (1 and 2)
8	Use of undisputed products	17	Level of milk production (4)
9	Land use in developing countries	18	Farm size (4)
		19	Employment (3)

[a] Numbers between parentheses refer to the independent attributes in the first column.

Table 3. List of attributes with respect to ecological sustainability.

No.	Independent attributes	No.	Dependent attributes
1	Use of pesticides	12	Use of energy (3)[a]
2	Use of antibiotics	13	Use of water (6)
3	Global warming	14	Biodiversity (1, 2, 5, 6, 7, 8, 9 and 10)
4	Use of ozone depleting gases	15	Soil fertility (2 and 5)
5	Use of heavy metals		
6	Dehydration of the soil		
7	Acidification		
8	Wastewater disposal		
9	Groundwater pollution		
10	Eutrophication		
11	Genetic diversity of livestock		

[a] Numbers between parentheses refer to the independent attributes in the first column.

Relative importance of sustainability attributes

For economic and internal social sustainability, only one attribute (i.e., profitability and working conditions, respectively) was identified and relative importance could be ignored. By contrast, in the case of external social and ecological sustainability, 19 and 15 attributes were identified, respectively and assessment of relative importance was necessary.

Next, we will discuss the consistency of the respondents and then present the results for external social and ecological sustainability.

Consistency of respondents

Each respondent was checked for internal consistency by using interval and ordinal ranking (Table 4). With

Table 4. Consistency of respondents.

External social sustainability		Ecological sustainability	
Respondent	Correlation coefficients	Respondent	Correlation coefficients
A	0.66*	1	0.73*
B	0.81*	2	0.72*
C	0.52	3	0.88*
D	0.97*	4	0.95*
E	0.68*	5	X
F	0.83*	6	0.95*
G	0.75*	7	0.95*
H	0.84*	8	0.91*
I	0.44	9	0.96*
		10	0.68*
Average	0.69*	Average	0.82*

* There is an association between both ranking methods ($P < 0.05$)

respect to external social sustainability, two respondents (i.e., C and I) were judged inconsistent. This means that the order of relevance of the attributes differed significantly between the interval and ordinal ranking for these respondents. On the subject of ecological sustainability, only one respondent (i.e., 5) was found to be inconsistent, because this respondent was not able to do the ordinal ranking. The results of these three respondents (i.e., C, I, and 5) were not included in the analysis.

Ecological respondents were more consistent than external social respondents. This was indicated by a higher average correlation coefficient (i.e., 0.82 vs. 0.69). Apparently ecological respondents (i.e., experts) were more familiar with these kinds of questionnaires than stakeholders.

External social sustainability

The following dependent attributes were selected by less than 50% of the respondents and were therefore excluded from the ranking procedure; employment, level of milk production, and farm size (not selected at all); use of artificial fertilizer, intensity, and use of new technologies (selected by 29% of the respondents); and use of pesticides (selected by 43% of the respondents). Table 5 shows that the average interval rankings and the average relative importance weights together with their standard deviations. Attributes are presented in order of average relative importance weight.

Based on the interval ranking of external social sustainability, food safety proved to be the most important attribute. The average interval ranking was 4.9 and the corresponding relative importance weight was 1.43. The standard deviation of food safety was relatively small, which means that most respondents agreed on the importance of food safety. The average interval ranking of all attributes, including those not presented, was 3.4 and the average relative importance weight was by definition equal to one.

The dependent attributes (i.e., animal health, cattle grazing, and the use of GMO) were not selected by all respondents as a separate attribute (as shown by N). Results of these dependent attributes, therefore were based on fewer opinions. However, average interval rankings of these three dependent attributes were relatively high. This means that respondents who did select these attributes as separate attributes agreed on their relevance. In Table 6, the average ordinal rankings (i.e., order of relevance) and the average relative importance weights with their standard deviations are shown. Attributes are presented in order of average relative importance weight.

Based on the ordinal ranking for external social sustainability, food safety was once again the most important attribute. The average ordinal ranking was 1.4 and the corresponding average relative importance weight was 1.78. The average ordinal ranking of all attributes was 6.9 and the average relative importance weight was by definition equal to 1.0. The difference in the order of relevance of the attributes between average ordinal rankings and corresponding average relative importance weights was hardly discernible. This was expected, as respondents all use the same levels (i.e., 1, 2, 3, etc.) in ordinal rankings.

Differences were observed between the interval and ordinal ranking order of some attributes. In particular, the order of the use of GMO (i.e., number 6 in Table 5 and number 11 in Table 6) differs considerably. This difference is attributable to the internal inconsistency of each of the respondents.

Table 5. Average and standard deviation of interval ranking and relative importance weights of attributes for external social sustainability.

No.	Attributes	*N*[a]	Average interval ranking	Std.dev.[b] interval ranking	Average importance weight	Std. dev. importance weight
1	Food safety	7	4.9	0.4	1.43	0.21
2	Animal health	5	4.6	0.9	1.35	0.25
3	Animal welfare	7	4.4	0.5	1.28	0.06
4	Landscape quality	7	4.3	0.8	1.24	0.16
5	Cattle grazing	5	4.2	0.4	1.24	0.23
6	Use of GMO	6	3.5	0.5	1.00	0.15
7	Use of undisputed products	7	3.3	1.0	0.94	0.20
8	Multifunctionality	7	3.0	1.2	0.85	0.25
9	Contribution to urban economy	7	2.7	1.0	0.80	0.31
10	Degree of industrialization	7	2.4	0.8	0.72	0.27
11	Land use in developing countries	7	2.4	1.1	0.69	0.25
12	Use of by-products	7	2.1	1.1	0.62	0.29

[a] Number.
[b] Standard deviation.

Table 6. Average and standard deviation of ordinal ranking and relative importance weights of attributes for external social sustainability.

No.	Attributes	N[a]	Ordinal ranking		Importance weight	
			Average	Std.dev.[b]	Average	Std.dev.
1	Food safety	7	1.4	1.1	1.78	0.18
2	Animal welfare	7	2.6	1.1	1.61	0.19
3	Animal health	5	3.8	0.8	1.46	0.15
4	Landscape quality	7	5.0	2.4	1.25	0.36
5	Use of undisputed products	7	5.1	2.8	1.22	0.47
6	Cattle grazing	5	5.7	1.2	1.20	0.19
7	Degree of industrialization	7	8.4	3.0	0.75	0.46
8	Multifunctionality	7	8.6	2.4	0.72	0.38
9	Contribution to urban economy	7	9.1	4.0	0.69	0.50
10	Use of by-products	7	9.1	3.0	0.66	0.36
11	Use of GMO	6	10.0	1.9	0.59	0.18
12	Land use in developing countries	7	10.1	4.0	0.53	0.45

[a] Number.
[b] Standard deviation.

Ecological sustainability

The following dependent attributes were selected by less than 50% of the respondents and were therefore not included in the ranking procedure: use of water (selected by 11% of the respondents), soil fertility (selected by 33% of the respondents); and use of energy (selected by 44% of the respondents).

Here too, there was scarcely a difference in the order of attributes in ecological sustainability between interval rankings and corresponding relative importance weights. Moreover, there was scarcely a difference in the order of relevance of the attributes between ordinal rankings and corresponding relative importance weights. Therefore, Table 7 only presents averages and standard deviations of relative importance weights.

The interval ranking for ecological sustainability revealed that eutrophication and biodiversity were the most important attributes, with both having an average relative importance weight of 1.28. Despite biodiversity's dependence on many attributes (see Table 3), it was selected by all respondents as a separate attribute. The reason why respondents insisted on having biodiversity as a separate attribute is probably that other factors (e.g., land use and cropping practice) govern the level of biodiversity more than the attributes mentioned

Table 7. Average and standard deviation of relative importance weights for interval and ordinal rankings of ecological sustainability attributes.

Attributes	N[a]	Interval ranking		Ordinal ranking	
		Average	Std.dev.[b]	Average	Std.dev.
Eutrophication	9	1.28	0.15	1.54	0.35
Groundwater pollution	9	1.09	0.26	1.43	0.42
Dehydration of the soil	9	1.19	0.19	1.38	0.24
Acidification	9	1.19	0.32	1.33	0.52
Biodiversity	9	1.28	0.19	1.30	0.36
Global warming	9	1.02	0.23	1.04	0.42
Use of pesticides	9	0.99	0.27	1.02	0.44
Use of heavy metals	9	0.93	0.27	0.83	0.44
Wastewater disposal	9	0.82	0.28	0.64	0.38
Genetic diversity of livestock	9	0.71	0.29	0.51	0.34
Use of antibiotics	9	0.74	0.23	0.48	0.31
Use of ozone depleting gases	9	0.73	0.27	0.47	0.33

[a] Number.
[b] Standard deviation.

in Table 3. The ordinal ranking showed eutrophication as being the most important attribute (average relative importance weight of 1.54). The order of some attributes (e.g., groundwater pollution) showed a difference between interval and ordinal ranking. This is the result of the inconsistency of the respondents.

Discussion and conclusions

In this paper, we introduced and applied a method to identify and rank attributes using a diverse set of respondents. Priorities could be set for aspects that relate to a high number of attributes. In this way, a workable number of attributes remains for further application. Lists of attributes pertaining to external social and ecological sustainability were identified and ranked. Results of the ranking were based on seven (i.e., external social sustainability) and nine (i.e., ecological sustainability) questionnaires. The low standard deviations indicated that respondents highly agreed on the importance of attributes and that no harm was done by combining the perceptions of different stakeholders or experts. This also means that the low number of respondents was justified with respect to the ranking of the attributes. Furthermore, the number of respondents was sufficient to identify a comprehensive list of attributes.

Almost every article, paper, or book on sustainability bemoans the fact that the concept is broad and lacks consensus. This is usually followed by the authors' own preferred definitions which, in turn, add to the lack of consensus (Bell and Morse, 1999). In our research, we asked experts and stakeholders, and not the authors, to identify sustainability attributes. This ensured that the identified attributes were based broadly, and that most farming activities and all their side effects were taken into account. Stakeholders, however, were asked to identify only attributes with respect to external social sustainability. Asking them to identify attributes of economic, internal social, and ecological sustainability probably would not have affected the results of the research to any large extent. It is even likely that stakeholders would have identified the same main attributes. Nonetheless, stakeholders, in general, have insufficient knowledge on these specific aspects of sustainability to rank the attributes.

All aspects and the most important attributes per aspect are presented in Figure 1. Only one attribute was selected for economic and for internal social sustainability – profitability and working conditions, respectively. External social and ecological sustainability could not be measured by one attribute alone. The attributes found most important for external social sustainability were food safety, animal health, animal welfare, landscape quality, and cattle grazing, while those for ecological sustainability were eutrophication, groundwater pollution (especially nitrate), dehydration of the soil, acidification, and biodiversity.

Several studies have been aimed at identifying attributes (or issues, or indicators, etc.) for measuring sustainability in agriculture (Rennings and Wiggering,

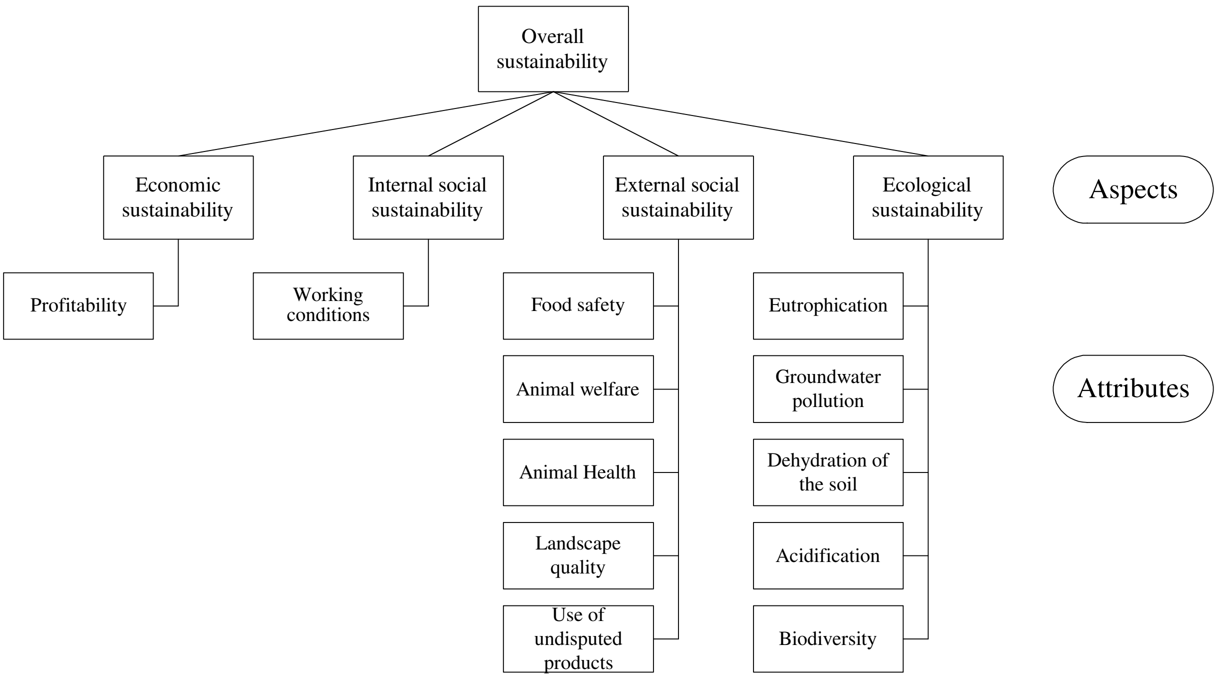

Figure 1. Analysis scheme of sustainability in Dutch dairy farming with aspects and the most important attributes.

1997; Chandre Gowda and Jayaramaiah, 1998; Callens and Tyteca, 1999; Nijkamp and Vreeker, 2000; Rigby et al., 2001). Differences in the attributes of economic and ecological sustainability found in this paper and those in other studies are mainly a result of the chosen sector (i.e., dairy farming) and differences in spatial scale (i.e., farm level vs. region level). In two studies (Callens and Tyteca, 1999; Nijkamp and Vreeker, 2000), the attribute, working conditions, is included. In some studies in the US, social sustainability refers to the structure of agriculture and the ability to sustain independent business (e.g., Bultena et al., 1995). Therefore, in general, differences in attributes for social sustainability relate to external social sustainability. External social sustainability in this study pertains to societal concern about the impact of dairy farming on the well-being of people and animals. This part of social sustainability has not been included so extensively before. External social sustainability, however, is so important for the public-image of dairy farming and for policy making that it should be included.

Results of the method presented are only valid in Dutch dairy farming in the beginning of the third millennium. The method, however, can be used for other agricultural sectors, for other countries and for other time periods. The main benefit of the method used is that it gives insight into the sustainability attributes that are important for a particular agricultural sector. This knowledge can be applied by farmers and policy makers to develop new farming systems and farm policies.

The next step in this research consists of determining final sets of attributes for external social and ecological sustainability. These final sets are based on the rankings as well as on the possibilities of measuring each attribute on the farm and on the possibility that a farmer can influence the level of the attribute. The selected attributes will be measured by using indicators. These indicators can be used for developing policy with respect to dairy farming. Usually policy making focuses on only one attribute at a time (e.g., groundwater pollution), and the effect of the policy on other attributes is not taken into account. By using a multiple criteria, decision-making model that includes all sustainability attributes, the effect of new policy on the economic, internal social, external social, and ecological sustainability can be improved. An optimal policy is dependent on the weights of the many attributes, which can differ among stakeholders.

Appendix A. Reasons for including attributes pertaining to external social sustainability.

No.	Attribute	Description
1	Food safety	Food safety is included because products can contain components that can harm human health
2	Animal welfare	Society is increasingly concerned about animal welfare
3	Contribution to urban economy	Dairy farming contributes to the urban economy by providing employment and producing drinking water, among other things
4	Degree of industrialization	An industrialized dairy farm is associated with factory farming and unsustainable dairy farming systems
5	Landscape quality	Because dairy farming takes place in the rural environment, it affects landscape quality
6	Multifunctionality	Dairy farms are more appreciated when involved in additional activities
7	Use of by-products	Using by-products of the food industry helps to solve a waste problem
8	Use of undisputed products	Producers (dairy farmers) are responsible for the use of materials that can have an impact on child labor and the environment
9	Land use in developing countries	A vast area of cultivated land in developing countries is claimed for production of concentrates. This decreases the area of nature in these countries and disrupts the nutrient balance on a global level
10	Cattle grazing	During grazing, dairy cows are able to behave naturally, while giving the landscape added value
11	Use of pesticides	Pesticides are synthetic and application is associated with factory farming
12	Use of new technologies	Use of new technologies is associated by some people with factory farming
13	Use of Genetic Modified Organisms	Use of GMOs is associated with factory farming
14	Use of artificial fertilizer	High use of artificial fertilizer is associated with factory farming
15	Intensity	Intensive agriculture is associated with less environmentally friendly agriculture
16	Animal Health	The health of dairy cattle is felt to be above average
17	Level of milk production	Increasing milk yields per cow is not judged as natural
18	Farm size	Extremely large farms are associated with factory farming
19	Employment	Dairy farms contribute to employment in urban areas

Appendix B. Reasons for including attributes pertaining to ecological sustainability.

No.	Attribute	Description
1	Use of pesticides	Through leaching and run-off, pesticides negatively affect the quality of ground and surface water
2	Use of antibiotics	Accumulation of antibiotics affects soil biodiversity and soil fertility
3	Global warming	Increased concentrations of greenhouse gases in the atmosphere affects climate
4	Use of ozone depleting gases	Ozone depleting gases allow more UV-radiation to reach the earth
5	Use of heavy metals	Accumulation of heavy metals affects biodiversity and soil fertility
6	Dehydration of the soil	Quality of wildlife is affected by dehydration of the soil
7	Acidification	Emission of acidifying gases is harmful to nature
8	Wastewater disposal	Purifying wastewater increases costs for water boards. It can also affect biodiversity
9	Groundwater pollution	High concentrations of nitrate in groundwater increases costs for water boards
10	Eutrophication	High concentrations of nitrate and phosphate leads to eutrophication
11	Genetic diversity of livestock	By using only a few breeding bulls, the genetic diversity of cattle decreases
12	Use of energy	Energy is a scarce asset and should be used efficiently
13	Use of water	Water is a scarce asset and should be used efficiently
14	Biodiversity	Disappearance of species is irreversible and should be prevented
15	Soil fertility	Good soil fertility is essential for maintaining production levels

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