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Modelling worker physical health and societal sustainability at farm level: An application to conventional and organic dairy farming

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Abstract

Farm-level modelling can be used to determine how farming systems and individual farm-management measures influence different sustainability indicators. Until now however, worker physical health and societal sustainability have been lacking in farm models. For this paper, we first selected attributes of physical health (working conditions) and societal sustainability (food safety, animal welfare and health, and landscape quality). Second, possible sustainability indicators for these attributes were identified, and those selected were included in an existing dairy farm LP-model that was subsequently used to analyse possible differences in societal sustainability within and between a conventional and organic dairy farming system. Results for physical health and societal sustainability were similar for conventional and organic dairy farming systems in the basis situation, as well as in the situation where additional management measures were applied to improve societal sustainability, but improved animal welfare did result in the organic system due to prescribed grazing, and due to assumed summer feeding in the conventional system. Results show that additional management measures considerably improved societal sustainability of the conventional as well as the organic system. LP-modelling appeared to be a suitable method for comparing farming systems and determining the effect of management measures on physical health and societal sustainability. The level of societal sustainability is determined mainly by applied management measures, and is related to the particular farming system in only a very limited way. This implies that societal sustainability is mainly dependent on the cost-effectiveness of management measures and on the attitude of the dairy farmer.

Keywords: Dairy farming; Sustainability; Modelling; Economic sustainability; Societal sustainability; Physical health

1. Introduction

Sustainability is an important topic in Dutch dairy farming (Wijffels, 2001). Sustainability indicators can be very effective in making the concept operational and monitoring changes in the level of sustainability (Heinen, 1994; Rigby et al., 2001). To improve the level of sustainability of dairy farming, we need insight into the effects of farm management on sustainability indicators. Farm-level modelling can be used to determine how changes in farm-management affect them (Berentsen and Giesen, 1995).

Generally, it is agreed that sustainability consists of three interrelated aspects (e.g. Hansen, 1996; Heinen, 1994; Shearman, 1990): (1) economic sustainability (the profit dimension); (2) social sustainability (the people dimension or equity); and (3) ecological sustainability (the planet dimension or environmental sustainability). Considerably more literature is available on the quantification of economic and ecological than of social sustainability. This is due to the supposed impracticability of social sustainability (Dessein and Nevens, 2005a) and to differences in perception of social sustainability between farmers and other societal groups. In Dessein and Nevens (2005a,b) the perception of the farmer

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is used as point of departure for measuring social sustainability. They distinguish four elements of social sustainability: (1) social justice, (2) social capital, (3) culture, and (4) physical and psychological health (Dessein and Nevens, 2005a,b). For societal groups, nevertheless, different elements are important for social sustainability. The effects of dairy farming systems on animal health, animal welfare, and food safety, for example, have become primarily societal concerns (Noordhuizen and Metz, 2005). This paper focuses on worker physical health and societal sustainability, as these elements of social sustainability are measurable and highly relevant for dairy farming in a densely populated country such as the Netherlands.

Several dairy farm models deal with economic and/or ecological sustainability (Berentsen et al., 1998; Bos and Van De Ven, 1999; Herrero et al., 1999; Kristensen and Kristensen, 1998; Pacini et al., 2003; Rotz et al., 1999; Van Calker et al., 2004; Van Huylenbroek et al., 2000). Generally however, issues related to physical health and societal sustainability are lacking in dairy farm models.

The objectives of this paper were to: (1) select relevant attributes for worker physical health and societal sustainability with respect to the Dutch dairy farm level; (2) determine which indicators measure these selected attributes; and (3) apply the selected indicators by analysing differences within and between a conventional and an organic dairy farming system. For this objective, the indicators of physical health and societal sustainability were included in an existing LP-model (Van Calker et al., 2004).

2. Selection of attributes and indicators for worker physical health and societal sustainability

2.1. Selection of attributes

Identification of attributes for worker physical health and societal sustainability was based on Van Calker et al. (2005).[1] The method for identifying the attributes was based on the expertise, experience, and knowledge of a group of respondents. Two types of respondents were involved: experts and stakeholders. Experts were asked to identify attributes for physical health, whereas stakeholders were asked to identify attributes for societal sustainability. Selection of experts was based upon the competence of the expert as revealed mainly by their scientific papers. To ensure diversity, experts from different scientific institutions and organisations were selected. The stakeholders (e.g. consumers and policy-makers) were individuals who previously showed concern about the impact of agriculture on the well-being of people and animals. This was judged by looking at their participation in the public debate on future developments in dairy farming. By consulting seven experts on physical health and nine stakeholders on societal sustainability, a comprehensive list of attributes was made for each. Experts and stakeholders were consulted again to rank the list of attributes on a Likert scale from 1 to 5 (see Van Calker et al., 2005).

Arguing that insufficient worker physical health, i.e. disability, in dairy farming is caused by poor working conditions, most respondents suggested that working conditions should be included as an attribute for physical health. Working conditions was selected as the only attribute for physical health since it subsumed all the subjects the respondents identified. For societal sustainability, 12 attributes were identified (Van Calker et al., 2005), and this list was used as a starting point in this paper. A further and final selection of attributes for societal sustainability was based on (see Table 1):

(1) the relative importance of these attributes as determined by stakeholders;
(2) the quantification of these attributes in an objective way;
(3) the effect of farm-system and/or farm-management measures on the level of these attributes, i.e. sensitivity.

Contribution to the rural economy (including employment), degree of industrialisation, land use in developing countries, and use of by-products were all judged less relevant by stakeholders (Van Calker et al., 2005, i.e. scored lower than 3 on a 1–5 Likert scale) and were therefore not selected. Further, multi-functionality, use of undisputed products, and use of genetically modified organisms (GMO) were not selected, as different opinions exist in assessing the most sustainable level of these attributes, i.e., they cannot be quantified in an objective way. Cattle grazing is an important attribute for societal sustainability, but was covered by animal welfare and therefore not selected. Food safety, animal welfare, animal health, and landscape quality were selected since they complied with each of the above-mentioned selection criteria. In the following sections the selected attributes are defined.

2.1.1. Working conditions

Insufficient physical health or disability in dairy farming is considered to be caused by inadequate working conditions. The main causes of disability in Dutch agriculture are musculoskeletal-related disorders (back, neck/upper-extremity and lower-extremity) and injuries (Hartman et al., 2003). In general, risk factors for disability due to injuries and disorders can be subdivided into farm characteristics, psychosocial variables and personal characteristics of the farmer (Hartman, 2004). In this research only farm characteristics were included. Psychosocial variables and personal characteristics were not included as these risk factors are mainly related to the individual, rather than to farm-management measures and farming systems. Furthermore, psychosocial risk factors were not significantly associated with disability (Hartman et al., 2004).

[1] In Van Calker et al. (2005) societal sustainability is referred to as external social sustainability and physical health is referred to as internal social sustainability.

Table 1
Selection criteria for societal sustainability attributes

Attribute	Selection criteria			
	Relative importance[a,b]		Objectively quantifiable[b]	Sensitivity[b]
Food safety	4.9	✓	✓	✓
Animal welfare	4.6	✓	✓	✓
Animal health	4.4	✓	✓	✓
Landscape quality	4.3	✓	✓	✓
Cattle grazing	4.2	✓	×	–
Use of GMO	3.5	✓	×	–
Use of undisputed products	3.3	✓	×	–
Multi-functionality	3.0	✓	×	–
Contribution to rural economy	2.7	×	–	–
Degree of industrialisation	2.4	×	–	–
Use of by-products	2.4	×	–	–
Land-use in developing countries	2.1	×	–	–

[a] Relevance scored by experts on a Likert scale from 1 to 5, where 1 = not relevant and 5 = very relevant (Van Calker et al., 2005).
[b] ✓ = selection criteria has been met; × = selection criteria has not been met; – = selection criterion has not been considered.

2.1.2. Food safety

Food safety is defined as the assurance that food will not cause harm to the consumer when prepared and/or eaten according to its intended use (Codex-Alimentarius-Commission, 2001). Within food safety three elements can be distinguished (De Groote et al., 2002; Valeeva et al., 2004): (1) chemical food safety, (2) microbiological food safety, and (3) physical food safety. Physical food safety is of minor importance (Valeeva et al., 2004), as all milk is filtered on the dairy farm as well as during processing. The most important risk factors are antibiotics and dioxin for chemical food safety, and Salmonella, *Escherichia coli*, *Staphylococcus aureus* and *Mycobacterlur paratuberculosis* for microbiological food safety (Valeeva et al., 2005).

2.1.3. Animal welfare

Animal welfare is an often-used but much-debated concept. While the complexities of defining animal welfare and the limitations of any definition are recognised, the 'five freedoms' (Webster, 1995) are considered an adequate and appropriate working basis for measuring it (Winter et al., 1998). They are (Webster, 1995): (1) freedom from thirst, hunger and malnutrition, (2) freedom from discomfort, (3) freedom from pain, injury and disease, (4) freedom to express normal behaviour, and (5) freedom from fear and distress. In this research it was assumed that freedom from thirst, hunger and malnutrition is assured by the economic incentives of the farmers. Freedom from pain, injury and disease is subsumed within animal health (third attribute for societal sustainability). Thus in this research animal welfare was defined as freedom from discomfort, freedom to express normal behaviour, and freedom from fear and distress.

2.1.4. Animal health

In this research, animal health mainly concerned the third freedom: freedom from pain, injury and disease. Diseases can be subdivided into List-A diseases, List-B diseases and production diseases. List A-diseases, e.g. foot-and-mouth disease, are transmissible diseases with the potential for very serious and rapid spread (Van Schaik, 2000). List-A diseases are not included in this research as the Netherlands is certified free of List-A diseases by the Office International des Epizooties. List-B diseases, e.g. bovine rhinotracheitis and paratuberculosis, are transmissible diseases considered to be of socio-economic and/or public health importance within countries, and significant in international trade of animals and animal products (Van Schaik, 2000). Production diseases, e.g. milk fever, ketosis, mastitis and lameness (see for an overview Kelton et al., 1998), are associated mostly with a decline in production (Wensing, 1999).

2.1.5. Landscape quality

The landscape quality of a farm is primarily the result of interaction between natural features of the region, and the decisions and attitude of the farmer (Hendriks et al., 2000; Piorr, 2003; Weinstoerffer and Girardin, 2000). This interaction has resulted in a wide variety of (agri)cultural landscapes in the Netherlands (Hendriks et al., 2000).

Landscape quality can be evaluated from an objective point of view, i.e. its material substance, made up of forms and actual objects present within a particular physical area, and from a subjective point of view, i.e. the appreciation and interpretation of these concrete forms by different stakeholders (Weinstoerffer and Girardin, 2000). Although the subjective point of view is of considerable importance in the evaluation of landscape quality, only the objective point of view for measuring landscape quality was included in this study.

In all regions, landscape consists of buildings, fields, trees, bundles, pools, roads, paths, dams, dikes etc. The way these landscape elements are ordered depends on the region (Hendriks and Stobbelaar, 2003; Piorr, 2003). In this research the Netherlands was assumed to be one region with respect to the measurement of landscape quality.

2.2. Selection of indicators

Defining indicators for sustainability attributes is a two-step process (De Boer and Cornelissen, 2002). The first step identifies possible sustainability indicators. The second step selects final sustainability indicators (SI) based on various selection criteria (SC). The SC used in this research are:

- SIs must be objectively quantifiable and influenceable at farm level (SC1). Since in this study a farm model (Van Calker et al., 2004) was used, direct indicators, i.e. animal or product-based indicators, did not qualify, and therefore only indirect indicators of farm-management measures and features of the environment could be included in the model.
- SIs should be proved valid (SC2). This can be judged by using output and design validation (Van der Werf and Petit, 2002). Output validation compares indicator output with directly-measured data. Design validation involves submission of the design of the indicators to a panel of experts and is used when no other method of validation is possible (Bockstaller and Girardin, 2003).
- Utility values can be determined for the possible SI (SC3). By determining ideal (utility = 1) and anti-ideal (utility = 0) values for indicators it is possible to benchmark the performance of indicators with different units of measurement (De Boer and Cornelissen, 2002). The ideal value represents a maximum value if the indicator is of the type 'more is better' or a minimum value when the indicator is of the type 'less is better'.

In the next subsection all possible SIs from the literature are listed per attribute, and then are judged on whether or not they meet the selection criteria. Consideration of a SC for a certain SI is stopped the moment the SI does not comply with an SC. Table 2 presents the selection of the indicators for the social sustainability attributes.

2.2.1. Working conditions

2.2.1.1. Indicators for working conditions. Not many indicators for working conditions can be found in the literature that are suitable for Dutch agriculture (see Table 2). For this research the physical load index (PLI) or 'Agrowerk' (Hartman et al., 2005) was selected to measure the level/quality of working conditions because it is: (1) the only indicator designed to measure working conditions of Dutch dairy farmers; (2) based on farm structure and management and can be included in the farm model; and (3) valid, as it is strongly associated with sick leave (Hartman et al., 2005).

2.2.1.2. Physical load index. The PLI was developed to explain sick leave due to back, neck, shoulder or upper-extremity disorders. The PLI is calculated on the basis of work methods, descriptions of how particular activities are normally carried out (e.g. 'milking in a cowshed without automatic removal') (Hartman et al., 2005). The physical load of each work method is based on eight risk variables for back disorders (e.g. lifting and carrying) and 26 risk variables for neck, shoulder or upper extremities (e.g. highly repetitive neck flexion). For the calculation of the PLI the relative duration (%) of a risk variable per work method

Table 2
Selection criteria for Sustainability indicators (SI) related to worker physical health and societal sustainabilty

Attribute	Indicator	Reference	Selection criterion[a] (SC)		
			SC1 Quantifiable	SC2 Valid	SC3 Utility
Working conditions	Concise exposure index	Grieco et al. (1998)	×	–	–
	Physical load index	Hartman et al. (2005)	✓	✓	✓
Food safety	HACCP	Noordhuizen and Frankena (1999)	✓	✓/×[b]	✓
	Food safety index	Jorna (2004)	✓	✓/×[b]	✓
	KKM	Noordhuizen and Metz (2005)	✓	✓/×[b]	✓
	Chain food safety index	Valeeva et al. (2005)	✓	✓/×[b]	✓
Animal welfare	TGI200	Sundrum et al. (1994)	✓	✓	✓
	TGI35L	Bartussek (1999)	✓	✓	✓
	Extended green label	Van Zeijts et al. (1999)	✓	✓/×[b]	✓
	Ethical accounting	Sörensen et al. (2001)	×	–	–
	Italian approach	Tosi et al. (2001)	×	–	–
Animal health	HACCP	Noordhuizen and Frankena (1999)	✓	✓/×[b]	✓
	Animal health index	Van Zeijts et al. (1999)	✓	✓/×[b]	✓
Landscape quality	Checklist contribution landscape quality	Kuiper (2000)	×	–	–
	Checklist for landscape management	Rossi and Nota (2000)	×	–	–
	Landscape indicator	Weinstoerffer and Girardin (2000)	×	–	–
	Agricultural nature value (ANNA)	Guijt (2002)	✓	✓/×[b]	✓
	Legibility concept	Hendriks and Stobbelaar (2003)	×	–	–
	EU landscape indicators	Piorr (2003)	×	–	–

[a] ✓ = selection criteria has been met; × = selection criteria has not been met; – = selection criterion has not been considered.
[b] The SI is design-validated but not output-validated.

was multiplied by the number of hours per year spent at it. A score for low (0), medium (1) and high exposure (2) was set for each risk variable for back disorders (derived from Hartman et al., 2005), and a score of 0 (for low exposure) or 1 (for high exposure) for each risk variable for neck, shoulder or upper-extremity disorders (Hartman et al., 2005). In this way the PLI can be calculated for back disorders and for neck, shoulder or upper-extremity disorders. The 'overall' PLI is calculated by equally weighting the PLI for back disorders and for neck, shoulder or upper extremities. Consequently the minimum of 0 points is used as the ideal value (utility = 1), and the maximum of 42 points as the anti-ideal value (utility = 0). A detailed description of the PLI can be found in Hartman et al. (2005).

2.2.2. Food safety

2.2.2.1. Indicators for food safety. All indicators for food safety complied equally with the selection criteria (see Table 2). The disadvantage of using the HACCP (Hazard Analysis and Critical Control Point; Noordhuizen and Frankena, 1999), and KKM (Chain Quality Program for Dutch dairy farms; Noordhuizen and Metz, 2005) is that with these certification systems there is either compliance or non-compliance—no intermediate values are possible (i.e., the SI is dichotomous). This implies that compensation for a less-than-sufficient performance in one specific element of food safety is not possible, and that comparisons of food-safety levels between and within farming systems are very limited. Therefore the chain food safety index of Valeeva et al. (2005) was selected instead. The advantages of this methodology are that it (1) has the potential to be used in the whole dairy chain and (2) is scientifically grounded and design-validated.

2.2.2.2. Chain food safety index. Valeeva et al. (2005) assessed management measures for improving food safety at all levels of the dairy production chain. The focus in our paper is at farm level and concerns chemical food safety (antibiotics and dioxin) and microbiological food safety (Salmonella, E.coli, M. paratuberculosis, and S.aureus). In Valeeva et al. (2005) experts assessed the relative importance of 30 preventive measures for chemical and microbiological food safety at farm level. On the basis of these assessments indices for chemical and microbiological food safety can be calculated. The most important preventive measures included in the farm model are presented in Appendix A and can be found in Valeeva et al. (2005).

The final chain food safety index (CFSI) is calculated by equally weighting the index for chemical and microbiological food safety. The ideal value (utility = 1) is achieved when all preventive measures for chemical and microbiological food safety are taken, and the anti-ideal value (utility = 0) is obtained if no preventive measures are taken at all.

2.2.3. Animal welfare

2.2.3.1. Indicators for animal welfare. A great number of indicators for animal welfare in dairy farming was found in the literature (see Table 2). Ethical accounting (Sörensen et al., 2001) and the Italian approach (Tosi et al., 2001) were not selected, as they are based not only on indirect but also on direct variables. The extended green label indicator for animal welfare (Van Zeijts et al., 1999) was not selected; although design-validated, it is not output-validated. The validation of the TGI (TierGerechtheitsIndex)-200 (Sundrum et al., 1994) with animal health data, gave satisfying results (Alban et al., 2001). The TGI-35L (Bartussek, 1999) was selected, however, to measure animal welfare, as it is validated for animal health and animal behaviour (Ofner et al., 2003). Furthermore the TGI-35L (animal needs index in english) is scientifically grounded (Bartussek, 1999, 2001).

2.2.3.2. TierGerechtheitsIndex-35L. The TGI-35L was developed in Austria to certify the level of animal welfare on farms. In it, points are assigned to characteristics of five areas of the housing system and management: (1) locomotion, (2) social interaction, (3) flooring, (4) light and air, and (5) craftsmanship (Bartussek, 1999). A detailed description of the TGI-35L can be found in Bartussek (1999), and related management measures can be found in Appendix A. The maximum score for TGI-35L is 45.5 points (utility = 1), whereas a score of less than 11 points defines the level of welfare as 'not suitable' (utility = 0; Bartussek, 1999). The score for TGI-35L is calculated for dairy cows, heifers (1–2 years) and calves (0–1 years). The final score for animal welfare is determined by weighting scores per category according to the number of animals per category.

2.2.4. Animal health

2.2.4.1. Indicators for animal health. Only two indirect animal health indicators were found in the literature (see Table 2), as the most-used indicators for animal health are direct indicators (e.g. the incidence of several diseases). The HACCP concept is well suited for animal health management at farm level, involving scientifically-based risk identification and management (Noordhuizen and Frankena, 1999). The HACCP methodology was not selected however, because of its dichotomous nature.

The animal health index (AHI) is based on farm-management measures and is assessed by experts in the field of animal health in Dutch dairy farming (Van Zeijts et al., 1999). No comparison of AHI output with directly-measured animal health data is available. The AHI complies, nonetheless, with design validation, as it is assessed by experts. The AHI was therefore selected for measuring animal health.

2.2.4.2. Animal health index. The AHI is part of the 'extended green label' (in Dutch: *Verbreed Groen Label*), which encourages individual farmers to produce according to more strict 'sustainable' standards (Van Zeijts et al., 1999). The AHI assesses how dairy farmers eradicate and control diseases. Management measures included in AHI are aimed mainly at eradicating List-B diseases and controlling production diseases.

A closed farming system is the basis for the eradication of diseases in the AHI as it prevents introduction of, for example, Bovine, Salnonella Dublin, Herpus virus (Van Schaik et al., 2001). With respect to control of diseases, several management measures are included that maintain the balance between resistance (e.g. feeding and vaccination strategies) and herd environment (e.g. hygiene and climate). The most important preventive measures included in the farm model are presented in Appendix A and can be found in Van Zeijts et al. (1999). The ideal value (utility = 1) is achieved when all management measures are taken (100 points). A minimum of 16 points is used as the anti-ideal value (utility = 0).

2.2.5. Landscape quality

2.2.5.1. Indicators for landscape quality. Many indicators for landscape quality can be found in the literature (Piorr, 2003; Stobbelaar and Van Mansvelt, 2000). Most of these indicators however do not measure landscape quality at farm level. The agricultural nature norm analysis (ANNA, Guijt, 2002) was included, as it is based on management measures affecting landscape quality and has been already tested in practice. The disadvantage of ANNA is that its output validity has not yet been tested. Its design validity is guaranteed however, as ANNA was developed on the basis of scientific literature and by consulting experts.

2.2.5.2. Agricultural nature norm analysis. The ANNA was developed to list management measures affecting nature and landscape quality (Guijt, 2002) and is based on the farm-nature plan as described by Smeding and Joenje (1999). It was developed initially for organic agriculture and applied on 90 organic farms. It is also suitable for conventional agriculture (Guijt, pers. comm.). In ANNA, management measures with respect to three types of nature are identified: wet nature, herbaceous nature, and woody nature, and some additional management measures are distinguished (Guijt, 2002). Points are achieved when these measures are applied. In Appendix A an overview is given of the selected management measures and the corresponding points. For a more detailed description see Guijt (2002). If <15 points are achieved, then landscape quality is considered low (utility = 0), while for farms with scores >36 landscape quality is considered high (utility = 1) (Guijt, 2002).

3. Materials and methods

3.1. Model description

The basic structure of the economic-environmental LP-model (Berentsen and Giesen, 1995) has the form of a standard linear programming model:

$$\begin{aligned} &\text{Maximise} && (Z = c\prime x) \\ &\text{Subject to} && Ax \leqslant b \\ &\text{and} && x \geqslant 0 \end{aligned}$$

where x = vector of activities; c = vector of gross margins per unit of activity; A = matrix of technical coefficients; and b = vector of right-hand-side values. The objective function maximises net farm income.

The model contains activities for common production processes on Dutch dairy farms (e.g. grass, maize and milk production). Constraints are included for available fixed assets (e.g. land area and milk quota), as well as for links between different activities (e.g. feeding requirements versus feed production and purchase). Environmental policy is included as a constraint on the basis of the mineral accounting system (MINAS; Ondersteijn et al., 2002). For a more detailed description of the basic LP-model, see Berentsen and Giesen (1995) and Van Calker et al. (2004).

Appendix A presents the effects of the most important management measures on costs, physical health and societal indicators. Comparing cost effects with indicator effects gives an impression of the trade-off involved with a particular measure between income on the one hand, and physical health and societal sustainability on the other.

3.2. Organisation of the analyses

The above-mentioned model was demonstrated by using characteristics of two experimental dairy farms in the Netherlands that can be considered extreme exponents of farming systems (see Table 3). Calculations were done for the year 2004.

The main objectives of the experimental farm "High Tech" are to minimise the cost price per kg of milk and to improve working conditions. It represents relatively large family farms (800.000 kg milk quota) on fertile clay soil. At "High-Tech" a low cost-price per kg milk and improved working conditions are pursued by high production per ha (±23.000 kg milk per ha), high production per

Table 3
Farm structure and farm characteristics of "High-Tech" and "Aver-Heino"

	"High-Tech"	"Aver Heino"
Type	Conventional	Organic
Soil type	Clay	Sand
Area (ha)	35	67.5
Milk quota ($\times 10^3$ kg)	800	682
Milk production (kg per cow)	9600	7400
Fat (%)	4.35	4.65
Protein (%)	3.34	3.38
Replacement rate (%)	34	36
Use chemical fertiliser	Yes	No
Use of chemical-synthetic crop protection	Yes	No
Grazing	Non-obligatory	Obligatory
Purchase of concentrates and roughage	Conventional	Organic
Application of animal manure	No restriction	170 kg N per ha
Maximum amount of concentrates (kg)	No maximum amount	40% of daily ration
Milk for calves	Artificial milk	Raw milk

cow (9600 kg milk per cow) and high production per man-hour. High production per man-hour is realised by, among other thing, automatic milking systems, automatic feeding, and keeping the herd indoors throughout the year by means of summer feeding.

"Aver Heino" was converted to organic dairy farming in 1998 and is located on semi-dry sandy soil. "Aver Heino" is, like most organic dairy farms, characterised by lower intensity of the farm (±10.000 kg milk per ha) and a lower milk production per cow (7400 kg milk per cow). The most important standards and requirements for organic dairy farming are presented in Table 3. To show the possible ranges of societal sustainability within and between the two farming systems, four situations were analysed:

1. "*High-Tech*": standard conventional management as already applied at "High-Tech";
2. "*High-Tech*$^{+}$": improved level of societal sustainability by applying additional management measures to the "High-Tech" situation;
3. "*Aver Heino*": standard organic management as already applied at "Aver Heino" farm;
4. "*Aver Heino*$^{+}$": improved level of societal sustainability by applying additional management measures to the "Aver Heino" situation.

Differences between "High-Tech" and "High-Tech^{+}", and between "Aver Heino" and "Aver Heino^{+}" indicate possibilities for improvement with respect to societal sustainability. Table 4 presents all the management measures related to societal sustainability applied in the four situations. No management measures were included that specifically aim to improve working conditions. This implies that performance for working conditions is a result of the model optimisation.

4. Results

4.1. Technical results

Table 5 presents numbers of livestock, land use and purchased feed. The numbers of dairy cows are determined by the available milk quota and the milk production per cow. The number of young stock for "High-Tech" is lower mainly because replacement is partly based on purchased cows. In the "High-Tech^{+}" situation the purchase of dairy cows is not allowed and the number of young stock therefore increases.

In the "High-Tech" situation no grazing is applied and a constant ration is supplied year-round to the dairy cows and young stock. The area for maize silage is maximised, as energy production per ha is cheaper for maize in comparison to grassland. MINAS (Ondersteijn et al., 2002) limits the area of maize, as phosphate losses per ha are higher for maize in comparison to grassland. Furthermore grass silage is used as protein source for dairy cows and young stock. By-products (beet pulp and undegradable extracted soy meal) and concentrates are included as an additional source of energy, rumen degradable protein, and intestine digestible protein.

In the "High-Tech^{+}" situation grazing is applied for dairy cows and young stock to improve societal sustainability. Consequently the total area of grassland increased. The area of 'conventional' grassland is mainly used for grazing and harvesting grass silage for dairy cows, whereas the included herbaceous grassland is used for grazing and harvesting grass silage for young stock and dry cows. Herbaceous grassland and additional nature elements are included in the "High-Tech^{+}" situation to improve landscape quality (see Table 4). The nitrogen application for "High-Tech^{+}" on conventional grassland is higher in comparison to "High-Tech", as the included herbaceous grassland requires less fertilizer. The purchase of maize increases since herbaceous grassland has a lower yield and the area of maize decreases.

In the "Aver Heino" situation no artificial fertilizer is allowed. Two types of legumes are grown with grass in Dutch organic dairy farming: red and white clover. Red clover in grass/clover production can fix 200 kg N ha^{-1} yearly, whereas white clover can fix 70 kg ha^{-1} (Baars and Van Dongen, 1993), which implies that energy and protein production is higher for grass/red clover. On the other hand, red clover is less persistent especially when grazing takes place. Therefore, costs of renewing grass/red clover are higher than of renewing grass/white clover. The uptake of fresh grass by grazing cows in the summer ration is maximised because it is a cheap source of energy and protein (no harvesting costs). The maximum is determined by the dry-matter intake capacity of the cows, and by the minimum requirement of 5 kg DM from maize silage in summer for day-grazing dairy cows. Grass/red clover and grass/white clover are grown in a ratio such that enough grass is available. Farm-grown maize and purchased maize are included as a cheap energy source in winter rations. Shortage of energy and protein is supplemented with by-products (beer pulp) and concentrates. In the "Aver Heino^{+}" situation land-use changes due to increased grazing of dairy cows (i.e. day and night grazing instead of day grazing) and inclusion of herbaceous grassland and nature elements. Herbaceous grassland is included as the lower yields of energy and protein per ha are compensated for agricultural nature-conservation subsidies. Grass/red clover is included to fulfil the need for energy and protein from grassland during grazing. Grass/red clover is preferred above grass/white clover as it yields more energy and protein. Shortage of feed is resolved by the purchase of maize (20.2 ha), by-products (brewers grains), and concentrates.

4.2. Economic results

Table 6 shows gross revenues, costs and net farm income in the four situations. The economic results follow from the

Table 4
Management measures applied for the basis situations ("High-Tech" and "Aver Heino") and for the situations where societal sustainability is improved ("High-Tech$^+$" and "Aver Heino$^+$")[a]

Measures	"High-Tech"	"High-Tech$^+$"	"Aver Heino"	"Aver Heino$^+$"
Food safety				
Purchasing non-certified feed	2	1	2	1
Purchasing dairy cows	2	1	2	1
Purchasing animal manure	2	1	2	1
Prevent contact with neighbouring cows during grazing	2	3	2	3
Maintenance of milking machine	2	3	2	3
Veterinary checks and monitoring animal health	2	3	2	3
Develop treatment plan	2	3	2	3
Housing system for dairy cows	Cubicle	Cubicle	Cubicle	Deep litter
Improve water quality for cleaning and drinking	2	3	2	3
Separate calving place	2	3	2	3
Feeding artificial milk	3	3	1	1
Animal welfare				
Grazing cows	1	Day	Day	Day-and-night
Grazing young stock	1	Day-and-night	Day-and-night	Day-and-night
Min. additional roughage during summer (kg dm per cow)	×	5	5	0
Housing system for dairy cows	Cubicle	Cubicle	Cubicle	Deep litter
Housing young stock	Cubicle	Cubicle	Cubicle	Deep litter
Animal health				
Separate housing of dairy cows and young stock	1	3	1	3
Purchasing dairy cows	2	1	2	1
Purchasing animal manure	2	1	2	1
Prevent contact with neighbouring cows during grazing	2	3	2	3
Additional housing measures	1	3	1	3
Measures to test health status	2	3	2	3
Artificial milk for calves	3	3	1	1
Landscape quality				
Cleaning ditch	2	3	2	3
Develop additional slope in ditch	2	3	2	3
Develop pool	2	3	2	3
Develop marshland	1	2	1	2
Develop herbaceous grassland	1	2	1	2
Protect meadow birds in grassland	1	2	1	2
Fallow land	1	2	1	2
Improve biodiversity of banks and borders	2	3	2	3
Develop wooded bank and/or thicket	2	3	2	3
Introduce nests for birds, bats and (bumble)bees	2	3	2	3
Develop strategic nature plans	2	3	2	3

[a] 1 = management measure is prohibited in the model, 2 = management measure is optional in the model, 3 = management measure is prescribed in the model.

technical results. The gross revenues of the farm consist of revenues from milk, animals, single-farm and subsidy payments. The single-farm payments are paid independently of the volume of production. Nevertheless single-farm payments in 2004 are mainly based on the milk quota and the area of maize. The subsidy payments are related to agricultural nature conservation.

Gross revenues are higher for "High-Tech$^+$" in comparison to "High-Tech" due to subsidies for including herbaceous grassland and other nature elements. The same applies to "Aver Heino$^+$" in comparison to "Aver Heino". The differences between "High-Tech" and "Aver Heino" revenues from milk and meat were small, as the lower milk quota (see Table 3) of "Aver Heino" is compensated for by the higher price for organic milk.

The higher costs for "High-Tech$^+$" in comparison to "High-Tech" are mainly the result of including herbaceous grassland and of improving societal sustainability. Due to the low productivity of herbaceous grassland, the cost of feed increases. Manure has to be disposed of, as hardly any manure can be applied to herbaceous grassland, and this leads to higher additional costs. The decreased area of maize leads to lower costs for contract work, seed and plant costs. Cattle costs are lower in the "High-Tech$^+$" situation, as the purchase of dairy cows is not allowed. Finally, the net farm income is ±€4400 higher for "High-Tech$^+$" compared to "High-Tech", which shows that the higher costs are compensated for by the agricultural nature-conservation subsidies. The change of income is, however, mainly the result of the change from summer feeding

Table 5
Technical results for the basis situations ("High-Tech" and "Aver Heino") and for the situations where societal sustainability is improved ("High-Tech+" and "Aver Heino+")

	"High-Tech"	"High-Tech+"	"Aver Heino"	"Aver Heino+"
Livestock				
# Dairy cows	84.8	84.8	85.6	85.6
# Young stock	25.1	30.0	32.1	32.1
# Purchased dairy cows[a]	4.8	0	0	0
Land use				
Conventional grassland (ha)	7.5	16.9	–	–
N application grassland (kg mineral N)	315	358	–	–
Grass/red clover (ha)	0	0	32.0	23.2
Grass/white clover (ha)	0		23.0	0
Herbaceous grassland (ha)	0	14.3	0	42.7
Maize (ha)	27.5	3.1	12.6	0
Additional nature elements (ha)	0	0.6	0	1.6
Roughage purchased[a] (GJ NEL[b])	0	237.5	22.6	191.2
By-products purchased[a] (GJ NEL[b])	60.8	30.1	25.0	25.0
Concentrates purchased[a] (GJ NEL[b])	184.3	179.1	114.6	144.0

[a] Per year.
[b] GJ NEL = Giga joule net energy for lactation.

Table 6
Economic results (k€) for the basis situations ("High-Tech" and "Aver Heino") and for the situations where societal sustainability is improved ("High-Tech+" and "Aver Heino+")

	"High-Tech"	"High-Tech+"	"Aver Heino"	"Aver Heino+"
Gross revenues	264.2	278.7	255.8	299.9
Milk and meat	249.6	249.2	242.8	242.8
Single-farm payments and subsidies	14.6	29.5	13.0	57.1
Costs	240.5	250.6	236.8	289.4
Purchased feed	47.5	73.5	37.4	73.9
Fertilisers	2.1	2.6	2.6[a]	1.6
Seed and plant costs	11.3	6.9	16.4	13.3
Cattle costs	31.7	26.8	22.2	41.3
Contract work	29.2	12.4	30.7	16.0
Cost of machinery	49.7	49.7	49.8	53.0
Cost of land and buildings	67.3	67.1	77.8	80.5
Food safety and animal health costs	0	5.0	0	6.3
Landscape costs	0	1.9	0	3.4
Additional costs	1.7	5.6	0	
Net farm income	23.7	28.0	19.0	10.5

[a] Types of phosphate and potassium fertilizer that are not artificially produced.

to day grazing, as grass for grazing is the cheapest energy and protein source. If no grazing had been applied in "High-Tech+", then the net farm income would have been ±€3400 lower in comparison to "High-Tech".

The effects that explain the difference in net farm income between "High-Tech" and "High-Tech+" also explain it for "Aver Heino" and "Aver Heino+". The change in the housing system is, nonetheless, the main explanation for the lower net farm income (±€8500) for "Aver Heino+" in comparison to "Aver Heino". Especially costs for cattle are higher through the high input of straw for deep-litter systems. If societal sustainability had been increased without a deep-litter system, then the net farm income of "Aver Heino+" would have been ±12,000 higher in comparison to "Aver Heino", mainly due to the agricultural nature subsidies received.

Costs differing for "High-Tech" and "Aver Heino" are mainly those of feed, cattle, land and buildings. Despite the lower price of conventional concentrates and roughages, costs for feed are higher for "High-Tech" in comparison to "Aver Heino". This is a result of the higher intensity (kg milk/ha) of "High-Tech". Cattle costs are higher for "High-Tech", as conventional dairy cows and young stock use more veterinary drugs (e.g. antibiotics) in comparison to organic dairy farming. Due to the larger area, the costs of land and buildings are higher for "Aver Heino". This finally results in ±€4700 higher net farm income for "High-tech" compared to "Aver Heino". The net farm-income difference between "High-Tech^{+}" and "Aver Heino^{+}" increases mainly due to the grazing applied at "High-Tech^{+}" and the deep-litter system applied at "Aver Heino^{+}".

4.3. Results for worker physical health

Table 7 presents the results for worker physical health for the four situations. A lower score for the physical load index is related to worse working conditions. The increased work load for "High-Tech^{+}" (3750 h per year and 72 h per week) in comparison with "High-Tech" (3640 h per year and 70 h per week) is mainly the result of the higher need for labour in management measures to improve societal sustainability. The increased workload does not result in a worse score for PLI since in the "High-Tech" situation exposure to the most relevant risk factors for dairy farming is already exceeded. For example the limit of exposure to lifting, i.e. the risk variable for back disorders, is set at 300 h per year. In the "High-Tech" situation this limit is exceeded already and additional exposure in the "High-Tech^{+}" situation does not alter the PLI score. Instead the PLI score for "High-Tech^{+}" is improved as a result of the applied grazing, which causes a lower exposure to risk variables.

In the "Aver Heino^{+}" situation working weeks are longer (93 h) in comparison with "Aver Heino" (82 h). These changes are mainly the result of: (1) deep-litter housing system, (2) day-and-night grazing for dairy cows and, (3) additional management measures to improve societal sustainability. The deep-litter housing system increases labour in the care of dairy cows, heifers and animal welfare, because spreading straw and cleaning out the barn require more labour in comparison to conventional cubicle systems. Day-and-night grazing increases the need for labour during milking, as the cows have to be brought inside for milking twice a day. Again, the increased workload does not lead to a worse score for PLI. Instead, an improved score is obtained for "Aver Heino^{+}". The spreading of straw in the barn has, in comparison to spreading sawdust in cubicles, a negative influence on back disorders, but a positive influence on neck, shoulder and upper-extremity disorders.

The larger area of agricultural land and manual pest control result in a higher work load with respect to grassland and maize for "Aver Heino$^{(+)}$" in comparison with "High-Tech$^{(+)}$". The translation of working weeks into the PLI does not result in differences between the work loads of "High-Tech$^{(+)}$" and "Aver Heino$^{(+)}$".

4.4. Results for societal sustainability

Table 8 presents societal sustainability results for the four situations. The management measures to improve societal sustainability (see Table 4) for "High-Tech^{+}" result in a higher score for CFSI in comparison with "High-Tech". In animal welfare, grazing has a positive influence on locomotion, social interaction, quality of flooring and the availability of fresh air and light. Consequently, the conventional dairy farm ("High-Tech^{+}") achieves a high score for TGI-35L by applying grazing. This score is similar to that of the organic dairy farm ("Aver Heino") and considerably higher than the score of "High-Tech". The Animal Health Index of "High-Tech^{+}" is much higher in comparison with "High-Tech" because: (1) no dairy cows are purchased, (2) dairy cows, heifers and calves are housed separately, (3) animal health status is monitored, and (4) additional measures with

Table 7
Results for worker physical health for the basis situations ("High-Tech" and "Aver Heino") and for the situations where societal sustainability is improved ("High-Tech^{+}" and "Aver Heino^{+}")

Tasks	"High-Tech"	"High-Tech^{+}"	"Aver Heino"	"Aver Heino^{+}"
Work load (hours per year)				
Dairy cows				
Milking	527	641	643	757
Feeding	428	279	277	271
Care	787	765	772	1087
Heifers (10d–2y)	753	673	692	801
Calves (0–10d)	272	272	274	274
Grassland	135	349	706	792
Maize	85	9	227	0
Food safety and animal welfare	5	76	0	151
Landscape	0	17	0	32
General	650	669	678	668
Total	*3640*	*3750*	*4269*	*4834*
Physical load index (0–1)	*0.39*	*0.42*	*0.39*	*0.41*
Back disorders	0.25	0.30	0.25	0.20
Neck, shoulder and upper-extremity disorders	0.54	0.54	0.54	0.62

Table 8
Results for societal sustainability for the basis situations ("High-Tech" and "Aver Heino") and for the situations where societal sustainability is improved ("High-Tech^{+}" and "Aver Heino^{+}")

	"High-Tech"	"High-Tech^{+}"	"Aver Heino"	"Aver Heino^{+}"
CFSI (food safety)				
Chemical food safety	0.55	0.93	0.50	0.93
Microbiological food safety	0.61	0.92	0.58	0.87
Relative score (0–1)	*0.58*	*0.92*	*0.53*	*0.90*
TGI-35L (animal welfare)				
Locomotion	0.5	3.5	3.5	9
Social interaction	1	4.5	4	7.5
Flooring	3	4.5	4.5	7
Light and air	5	7.5	7.5	7.8
Craftsmanship	8	8	8	8
Total score	17.5	28	27.5	39.3
Relative score (0–1)	*0.19*	*0.50*	*0.49*	*0.84*
Animal health index				
Basis requirements	3	16	6	13
Housing and grazing	14	34	6	34
Farm management	22	35	21	35
Testing health status	0	8	0	8
Total score	39	93	33	90
Relative score (0–1)	*0.27*	*0.92*	*0.20*	*0.88*
ANNA (landscape quality)				
Wet nature	0	7	0	7
Herbaceous nature	1	11	1	9
Woody nature	0	6	0	6
Additional measures	2	9	4	10
Total score	3	34	5	34
Relative score (0–1)	*0*	*0.90*	*0*	*0.90*

respect to preventing introduction of list-B diseases and control of production diseases are applied (see Table 4). The minimum level of 15 points for ANNA is not achieved and subsequently no score for landscape quality is achieved in the basis situation. Management measures for landscape quality, e.g. including herbaceous land and improving biodiversity of banks and borders, result in a higher score on ANNA for "High-Tech^{+}".

Management measures to improve societal sustainability result in higher scores on all societal indicators for "Aver Heino^{+}" in comparison to "Aver Heino". The effects explaining differences in societal sustainability between "High-Tech" and "High-Tech^{+}" also explain differences in societal sustainability between "Aver Heino" and "Aver Heino^{+}". The introduction of a deep-litter barn is additional and further improves the score on animal welfare, TGI-35L.

In general, the results for "High-Tech" and "Aver Heino" in societal sustainability are similar. The (small) differences in the chain food safety index (CFSI) are a result of, among other things: (1) purchase of roughage by "Aver Heino", (2) purchase of animal manure by "Aver Heino", (3) feeding of raw milk to calves at "Aver Heino", (4) possible contacts with other herds during grazing at "Aver Heino" and, (5) purchase of cattle by High-Tech. The score for TGI-35L, i.e. animal welfare, is higher for "Aver Heino" in comparison to High-Tech, as in this situation grazing is applied for dairy cows and young stock. Performance on the animal health index is higher for "High-Tech" because: (1) no raw milk is fed to calves (basic requirement), (2) contacts with other herds are prevented by keeping the herd indoors throughout the year, and (3) no animal manure is purchased (part of farm management). This means that despite the purchase of dairy cows, which brings the risk of disease introduction, "High-Tech" achieves a higher score on the Animal health index in comparison to "Aver-Heino". In both situations the minimum score for ANNA is not achieved.

In general the resulting performance on CSFI, animal health index, and ANNA as a result of improving societal sustainability is equal for the conventional ("High-Tech^{+}") and the organic dairy farm ("Aver Heino^{+}"). Only on TGI-35L does "Aver Heino^{+}" achieve a higher score in comparison with "High-Tech^{+}". This higher score is the result of the introduction of a deep-litter barn.

5. Discussion and conclusions

In this paper, we successfully included worker physical health and societal sustainability indicators in a dairy farm LP-model. The model offers the opportunity to analyse differences between and within dairy farming systems with respect to the level of economic and social sustainability. The selected indicators are the most suitable indicators for measuring physical health and societal sustainability at present. Improved and new indicators that comply with selection criteria can easily be included in the farm model in future.

Two experimental farms, a conventional dairy farm and an organic dairy farm, with an optimal level of farm management were used as examples to demonstrate the farm model. Differences in PLI score are relatively small in the conventional and organic systems. Differences in working hours per week between/of High-Tech$^{(+)}$ and Aver Heino$^{(+)}$ are explained mainly by the lower intensity (i.e. larger area), manual pest control, and deep-litter barn. These differences between conventional and organic systems regarding work load are consistent with a study of the sustainability of organic Dutch dairy farms (Spruijt-Verkerke et al., 2004). The PLI however is not very sensitive, as it was designed for different agricultural sectors. Still, the PLI gives additional information about the work load and the corresponding physical load for back disorders and for neck, shoulder and upper-extremity disorders. The limits of exposure to the risk variables will be reconsidered in a new version of PLI, which probably will increase its sensitivity. When available, this new version of the PLI will be included in the farm model.

The differences in the societal sustainability of dairy farming systems are considerable. We conclude therefore that the societal sustainability performance of conventional as well as organic dairy farming systems can be improved by applying additional management measures. In this study only small differences exist in the food safety, animal-health and landscape-quality performances of the conventional and organic systems in the basis situation (“High-Tech” and “Aver Heino”, respecively), as well as in the situation of improved societal sustainability (“High-Tech^{+}” and “Aver Heino^{+}”, respectively).

With regard to microbiological *food safety*, no evidence on commercial farms supports the assertion that organic products are safer than conventional products (Kouba, 2003). In the area of chemical food safety, organic products might be safer than conventional products, as no pesticides and fewer veterinary drugs are used (Kouba, 2003). In this study we assumed an optimal level of management, which minimised the risk of residues in conventional animal products. As a consequence, the similar level of food safety of conventional and organic systems in our results is consistent with that mentioned in the literature.

In *animal health*, commercial organic and conventional dairy farms can show a differing prevalence of specific production diseases (e.g. mastitis, parasite-related diseases and metabolic disorders; Hardeng and Edge, 2001). Several studies (Hovi et al., 2003; Lund and Algers, 2003; Sundrum, 2001) have concluded however that, with respect to *overall* animal health, and production diseases in particular, no differences exist between the two farming systems. This implies that the similar performance of the conventional and organic dairy farms in our model is consistent with the literature.

The score on *animal welfare* is higher for “Aver Heino^{+}” in comparison with “High-Tech^{+}”, as dairy cows and young stock are housed in deep-litter barns. Deep-litter barns, however, are not commonly applied (18%) on organic dairy farms (De Jong and Van Zoest, 2001). The obligation of grazing for organic dairy farms guarantees, nonetheless, a minimum level of animal welfare. So far, 90% of all Dutch dairy farms apply grazing (De Bont and Van Everdingen, 2004).

For what concerns *landscape quality*, the empirical research of Hendriks and Stobbelaar (2003) find that organic dairy farms on average achieve a better score. Apparently organic dairy farming systems and organic dairy farmers are more amenable to management measures to improve landscape quality. Variation in the landscape quality of both conventional and organic farms appears to be considerable, however. This indicates that conventional dairy farms can achieve scores similar to those of organic dairy farms, as shown in our study.

These observations endorse our conclusion that the level of societal sustainability is determined mainly by the management measures applied, and that this level is hardly related to the particular farming system. This means that a better performance in societal sustainability is mainly dependent on cost-effectiveness of the management measures that help improve it, and on the attitude of the dairy farmer. For dairy farmers, as well as for society, it is relevant to know which management measures are beneficial for both economic and societal sustainability.

The application of grazing for young stock and dairy cows and herbaceous grassland in the cropping plan was beneficial to “Aver Heino” and “High-Tech” with respect to economic and societal sustainability. Sustainability however also includes an ecological aspect, and the effects of management measures on ecological sustainability should be quantified also. It is recommended therefore to identify more management measures that are beneficial to economic sustainability, physical health, societal and/or ecological sustainability. By using a multiple-criteria decision-making model that includes all relevant sustainability attributes, the effect of management measures on economic, physical health, societal and ecological sustainability can be analysed. In this way trade-offs between all aspects of sustainability can be determined for different management measures. An “overall” sustainability score can be developed by assessing ideal values (utility = 1), anti-ideal values (utility = 0) and weights of all indicators. The “overall” sustainability performance of management measures can be used to support implementation of sustainable management measures. Optimal management strategy however is dependent on indicator weights, which can differ among societal groups. Assessment of indicator weights, and the development of a multiple-criteria decision-making model will be the main topic of the final part of this research project.

Appendix A

See Table A.1

Table A.1
Technical coefficients that are included in the LP-model to calculate the physical health and societal indicators

Measures	Costs (€)	Working conditions (h)	Chemical food safety (points)	Microbiological food safety (points)	Animal welfare (points)	Animal health (points)	Landscape quality (points)
Purchasing non-certified roughage	−1% per kg	–	−7.92	−3.10	–	–	–
Purchasing non-certified concentrates	−1% per kg	–	−18.39	−7.11	–	–	–
Purchasing dairy cows (health status unknown)	€1050 per cow	–	–	−4.47	–	−9	–
Purchasing dairy cows (health status known)	€1250 per cow	–	–	−1.04	–	−3	–
Quarantine for purchased dairy cows	€560 + €43 per cow	1/cow	–	3.29	–	–	–
Purchase of animal manure	Variable	–	–	−4.06	–	−4	–
Prevent contact with neighbouring cows during grazing	€40/ha	2.6/ha	–	3.62	–	4	–
Maintenance of milking machine	€1000	–	7.67	3.88	–	–	–
Veterinary checks	€189.68	1.5		4.10	–	5	–
Participation in monitoring programs (salmonella and para-tbc)	€164.8	4	–	3.95	–	5	–
Develop treatment plan for diseased cattle	€105.83	1	6.30	–	–	–	–
Cubicle housing (dairy cows)	€4100 per cow	Variable	–	2.90	9.5	–	–
Deep litter (dairy cows)	€3750 per cow	Variable	–	2.66	20.5	–	–
Reuse of water	€461.18	–	−7.17	−3.51	–	–	–
Cleaning water trough	–	52	–	2.71	–	–	–
Outdoor drinking of tap water	€1176	–	7.44	3.81	–	4	–
Use of tap water only	€0.48/m^3	–	7.81	3.44	–	–	–
Separate calving place	€560	–	–	4.26	–	6	–
Feeding artificial milk	€50,29	–	–	3.79	–	3	–
Grazing of dairy cows	Variable	Variable	–	–	11–12	–	–
Grazing of young stock	Variable	Variable	–	–	9.5	–	–
Cubicle housing (young stock)	€1650-€1850 per unit of young stock	Variable	–	–	9.5	–	–
Deep litter (young stock)	€1510-€1690 per unit of young stock	Variable	–	–	20.5	–	–
Separate housing of dairy cows and young stock	€100–€200 per unit of young stock	–	–	–	–	13	–
Participation in monitoring program (Bovine Virus Diarrhoea)	€97.85	2	–	–	–	3	–
Cleaning ditch	€260.00	–	–	–	–	–	4
Develop additional slope in ditch	€100.21	1.50	–	–	–	–	3
Develop pool	€50.85	0.33	–	–	–	–	1
Develop marshland	−€584.40	9.2	–	–	–	–	1
Develop herbaceous grassland	−€854.40	9.2	–	–	–	–	2
Protect meadow birds in grassland	−€403.40	9.2	–	–	–	–	1
Fallow land	−€361.00	6.9	–	–	–	–	1
Improve biodiversity of banks and borders	−€3.70	3	–	–	–	–	6
Develop wooded bank and/or thicket	€34.24	8	–	–	–	–	6
Introduce nests for birds, bats and (bumble) bees	€20.80	1	–	–	–	–	4
Develop strategic nature plans	€350.00	8	–	–	–	–	3
General practices	–	–	27.23	33.18	8	24	3

[a] The trade-off coefficient is calculated by dividing the costs by the contribution of the management measure on the score of the specific societal indicator (using the 0–1 relative score).

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