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Environmental evaluation of three alternative futures for organic dairy in Denmark

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Abstract. Objective of this study was to explore sustainability of scenarios for organic dairy farming based on visions and goals of the future, by parameterization at farm level. The scenarios were in agreement with the scope of principles for organic farming; health, ecology, fairness and care. Scenarios were designed using stakeholder and expert opinions and then translate them through choice of relevant production parameters to a farm unit design. This resulted in three vision-based scenarios, one animal welfare (ANW), one environmental (ENV) and one using all possible new technologies to enhance productivity and efficiency (business as usual, BAU). The amount of milk produced per ha was, 9500, 7215 and 5188 kg ECM respectively for BAU, ANW and ENV. Stocking density was 1.41, 1.38, and 0.88 Livestock Units respectively for BAU, ANW and ENV, parallel to large differences in required import of feed. The different organic farms of the future are to be evaluated on the environmental impacts, green house gas (GHG) emissions, nitrogen surplus and energy use, economy, and social acceptance.

Key words: organic dairy farms, scenario analysis, environment, animal welfare

INTRODUCTION

In 2006, organic dairy farming accounted for 37% of the organic market turnover (365 mil €) in Denmark. Its development has been decisive for the organic farming structure (Mogensen, 2004). The current marked share for organic products in Denmark is close to 7% and increasing (Lund-Jensen, 2008). The last seven years of organic dairy farming development in Denmark can be characterized by a "mainstream strategy". This mainstream strategy is characterized by introduction of new technology, scaling-up, specialization, and increasing production level (Fig 1).

One problem with the mainstream strategy in organic dairy is that consumers and society sometimes have difficulties identifying differences between conventional and organic production (Oudshoorn et al., 2008). This especially is the case for organic dairy farming, as fertilizers and pesticides are not used as intensively in conventional dairy farming as in conventional horticulture or arable farming. Animal welfare organizations, consumers and research are questioning conditions in organic farming management practices in Denmark.

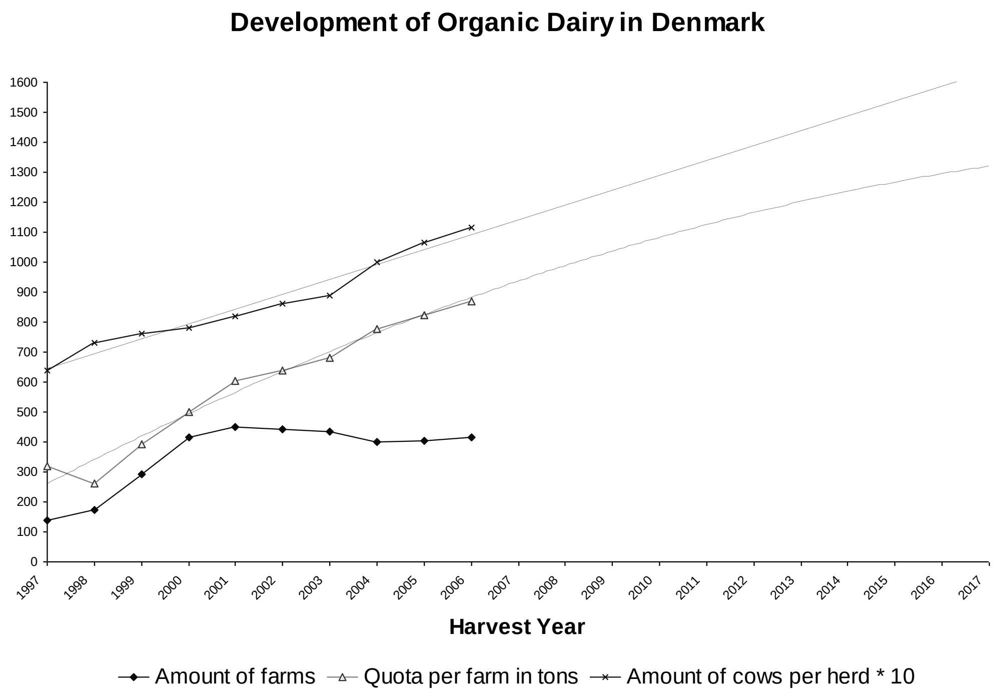

Fig. 1. Development of dairy sector in Denmark (IFRE, 2008).

Objections brought forward are: lack of grazing (Kramer, 2006), weaning of calves after two days (Wagenaar and Langhout, 2006), lack of free space in barns (stress), disappointing taste of products (Claudi-Magnussen, 2001), and energy requirement for mechanical weed control (Dalgaard et al., 2002).

Another problem with mainstream organic dairy in Denmark is inherent to the speed of technology development and confrontation with moral and ethical acceptability (Markussen, 2003). Implementation of technology and measures for scaling-up can have large impact on many aspects at the same time, for example production efficiency and intensity (yield per ha or animal unit) or self-sufficiency of feed production, animal welfare and societal issues like landscape or product quality (Mogensen et al., 2004; Haas et al., 2006; Bos et al., 2007).

Both agricultural practice and institutional decision makers who care for environment and social consequences are asking for scenarios which can show alternative futures, from the continuous main stream development. This could be used for channeling funding and political strategies on research towards a continuing growth of the organic sector (Anonymous, 2008). Scenario studies can identify contingencies, uncertainties, trends and opportunities (Miller & Waller, 2003) and are a qualitative method. In order to evaluate different future alternatives, system assessments can be made. This "top-down" development strategy has been used in many years, especially in companies (Schnaars, 1987). Contrary to modeling or extrapolation methods to predict the future, scenario analysis is based on an intuitive, narrative description of alternative futures (Börjeson et al., 2006; Meyer, 2007). It is necessary beforehand to describe the goals of the scenario design and to restrict the amount of alternatives, in order to focus on the desired information. Designing scenarios and defining them provides scope to subject them to scientific evaluation of consequences. This introduces multidisciplinarity, and can elucidate both the primary sector as well as the political decision makers. Using known mechanisms of development, and focusing on selected parameters, can further explain drivers and constraints that might be influenced if this is desired. The approach of Sonesson et al., (2003) was designed to incline sustainable development at farm scale and used in this study. Evaluation of these future farm alternatives can be done on the level of mitigation options of greenhouse gas (GHG) emissions, mineral surplus, and related entities like energy consumption (Olesen et al., 2006; Weiske et al., 2006; Bos et al., 2007; Halberg 2008; Küstermann et al., 2008; Thomassen et al., 2008).

The objective of this study, therefore, was to explore scenarios for organic dairy farming based on visions and goals of a sustainable future, in order to make evaluation on environmental impacts possible. The scenarios should be in agreement with the scope of principles for organic farming; health, ecology, fairness and care (Anonymous, 2007) and standards in Denmark (Anonymous, 2007[b]).

METHOD

At the Royal Academy of Sciences in Sweden, a group of scientists (Sonesson at al., 2003) have developed a framework to develop and build scenarios for sustainable agricultural production. This framework defines and builds goal-vision based scenarios at farm level focusing on all sustainability aspects; i.e., economic, environmental and societal aspects. Each goal-vision scenario is a plausible future outcome of organic dairy production that is optimized for one or a few aspect(s) of sustainability.

This framework consisted of the following steps:

1. The production system was defined taking into account regulations for organic dairy production in Denmark.
2. Goal-vision based scenarios were defined, focusing on sustainability issues presently valued high such as economic viability, environmental impact and animal welfare (Oudshoorn et al., 2009). The process was participatory, using stakeholder discussions on the subject.
3. Production parameters, essential for achieving goals and visions, were identified.
4. For each scenario, the specific farm design was quantified by specifying actual values for different production parameters involved. This parameterization of production parameters was based on extrapolation of historical data and expert knowledge.

Definition of organic dairy production system. Organic dairy production should comply with organic EU council regulations (EF, 2007), as well as the national standards (Announcement, 2008). The national standards describe grazing practice with a minimum of six grazing hours during daytime between 15 April and 1 November. It is prohibited to fixate animals, and young stock should be housed in groups and have access to grassland after three months. The organic dairy association (including dairy industry) in Denmark agreed on an application limit of 140 kg N out of animal manure per ha, even though EU regulations allow 170 kg N/ha. The N load out of manure is calculated as sum of N in manure excreted by the herd, as we assumed no import or export of manure in all scenarios. In addition, homegrown roughage was considered a pre-emptive, as transport of large amounts of silage over large distance is not realistic in the Danish situation

Choice and design of scenarios. Three scenarios were defined in this study and their choice and design were based on 1) a workshop with stakeholders; 2) active participation of the first author in construction of a report on future development of organic farming in Denmark; and 3) expert knowledge .

Below, each scenario is described in more detail.

1. The first scenario implies continuation of the present marked-driven development, where economic efficiency and production intensity are the main drivers, and is referred to as business as usual (BAU). The BAU scenario was used as baseline reference as it is supposed to be the most likely future development. We further assumed that labor costs keep on increasing and automation development continues.
2. In the animal welfare scenario (ANW), economic efficiency is subordinate to animal welfare, including animal health aspects like freedom of choice to lay down or come outside.
3. The environmental scenario (ENV) focuses on mitigation of greenhouse gas (GHG) emission, saving of fossil recourses, decreasing emission of N and nature aspects like biodiversity and a varied landscape.

Business as usual (BAU), is defined as the scenario that will develop if market values, animal ethics and wealth remain as present. This scenario is driven by economic incentives, both from farmers and retail. In order to maximize milk yield from the available area, all heifers are sold to an organic heifer hotel after three months of feeding with fresh milk (i.e. legal minimum for feeding with fresh milk). A heifer hotel is a farm that specialized in raising and nursing of young stock. Heifers necessary to replace culled milking cows, are repurchased some weeks before calving. All bull calves are sold straight after birth for non-organic fattening production. New technology like AMS, management soft-ware programs and online sensors are assumed to be implemented, ensuring a very high milk yield per cow. The free-range slatted floor system in partly open barns is expected to prolong. Minimum standards on grazing are respected.

Animal welfare (ANW) scenario, is defined as fulfillment of the five 'freedoms' as proposed by the Farm Animal Welfare Council in 1979. These freedoms imply the animal is 1) free from hunger and thirst; 2) free from discomfort; 3) free from pain, injury and disease; 4) free from fear and distress, and 5) free to express normal behavior. In accordance with these five freedoms, animal health is an integral part of animal welfare. In the ANW scenario, economic efficiency is subordinate to animal welfare, and measurements to improve animal welfare or its public awareness are incorporated. Hence, annual milk yield per cow is lower than in BAU. A lower milk yield per cow has been advocated to be less stressing for cows and to increase cow health, and, as a result, the average longevity of the herd (Ruis and Pinxterhuis, 2007; Hamilton et al., 2002). It is expected that future consumers of organic dairy products will demand extended weaning periods. Both heifer and bull calves, therefore, are allowed to suckle for three months (Wagenaar and Langhout, 2006). Hereafter, only necessary heifer calves are kept for replacement of the herd and all other calves are sold. The type of animal housing and the amount of grazing hours influence animal welfare (Ruis and Pinxterhuis, 2007). In this scenario, cows are housed in free range stalls with an extended floor area, deep pit contrary solid concrete floors, a high roof and, therefore, natural ventilation. This choice affects costs of building and acquisition of straw material. In addition, adequate grazing area adjacent to the barn is assumed with free excess in the summer period from 15 April to 1 November.

Environmental scenario (ENV) is defined as a scenario that will anticipate the increasing demand for environmental consideration. It focuses on mitigation of climate change, saving of fossil energy use (Bos et al., 2007) and decreasing of N losses to air, water and soil (Erichsen et al., 2008). The scenario is modeled to be self-sufficient regarding nutrients and fodder, i.e. all roughages and concentrates are home grown. This choice is made because a high self-sufficiency is found to be associated with as a low nutrient surplus, and therefore, a low potential for leaching of nutrients. Furthermore, a high N surplus is found to be associated with reduced biodiversity (Haas et al., 2006). Even so, relatively high milk yields are obtainable (Mogensen, 2004). A balanced rotation altering clover grass with cereals and whole crop silage makes this possible. However, without purchased concentrates, fewer dairy cows can be fed from the total amount of farm land available.

The future housing of the animals is assumed to become more focused on mitigation of volatilization, comprising regular scraping of floors and use of straw as bedding material to reduce ammonia emissions (Gilhespy et al., 2008). In this scenario, therefore, additional straw has to be purchased.

Identifying production parameters. Key production parameters are those parameters that define the organic dairy system and create the scenarios. Conflicting areas between the goals and visions of the three scenarios were described and discussed among stakeholders, in order to clarify choices that had to be made as part of the production design at farm level.

Many parameters are strongly interrelated, therefore general principle differences between the scenarios are described in Table 1.

Parameterization of production parameters. Parameterization of key parameters was based on extrapolation of historical data and iterative discussions with experts.
Farm size was decided to be 200 ha, as being a plausible size for 2020, taking in account the expectation of enhanced growth (Fig 2).

Table 1. Schematic overview of production parameter principles for three scenarios for organic dairy farming in Denmark.

Production Parameters	I – Mainstream	II – Animal Welfare	III – Environmental Care
Diet	50-60% roughage (minimum required by law), >7 kg concentrate/cow grass silage/maize	>70% roughage. ≈ 5 kg concentrate/cow grass silage/ hay/ WCS	>75% roughage < 5 kg concentrate/cow Grass silage/ WCS /
Grazing area	0.15 ha/cow	>0.35 ha/cow Day and night grazing	0.3 ha /cow Time limited grazing
Labor	Minimized	No limit, no minimum	No limit, no minimum
Herd technology	Automatic milking/ fully integrated ICT 2.5 milking per day	Conventional milking	Conventional milking
Housing of the animals	Permanent, slurry based	Deep pit stall	Special low-emission barn
Storage of manure	Slurry tank	Manure heap	Slurry tank
Herd management/ calving strategy	Focused on high yield Culling rate 40% Weaning after suckling 3 days Bull calves sold for slaughter after birth Heifer hotel	Focused on animal welfare Culling rate 25% Weaning after 3 months (♀+♂) Bull calves sold when 3 months Surplus heifers sold when 3 months	Subordinate Culling rate 30% Weaning after 3 days Bull calves sold for slaughter Surplus heifers after birth
Field rotation	Close by and distant rotation, maximum 2 years of ley	Grazing has high priority	Production of concentrates
Field technology	Mainstream, all work done by contractors, high level of technology	Mainstream, all work done by contractors	Energy saving, soil preservation
Intensity	High input	Moderate	Low input

AMS; automatic milking systems CMS; conventional milking systems

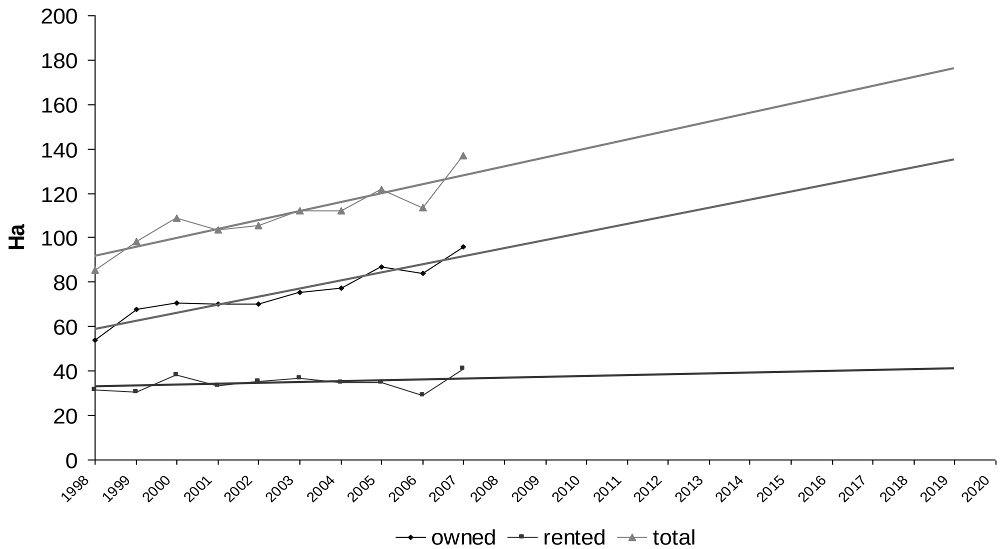

Fig. 2. Development of acreage of full time organic dairy farms in Denmark from 1998 to 2007 and prospect (data from IFRE, 2008).

Given a N availability in the system, for each crop a possible yield was determined based on actual data of yields related to nitrogen application rates and their expected future development. In combination with knowledge on robust rotations and necessary feeding entities for milk production (Mogensen, 2004), this resulted in a preliminary quantification of amount of ha for each crop in different scenarios. Subsequently, crop yield and crop area were used to calculate the amount of feed available for the herd. Furthermore, given the annual milk yield per cow and the assumed culling rate in each scenario, herd size could be calculated within the boundaries of grazing requirements. Herd size and annual milk yield per cow were then used to calculate exact feed requirements and correspondingly, crop rotation was adjusted and concentrate requirement was estimated. This was done to validate if the dairy cow diet consisted of satisfactory amounts of energy, protein, starch and structure. In an iterative process the nitrogen balance for the fields and fertilizer effects were used to adjust the crop yields, and thereafter checking the feed supply.

Crop yield. Average yields for wheat and barley have slightly decreased the last decade (Fig. 3). It seems there is a need for extra effort to improve crop yield and stability in organic cereal production. However, we assumed a minor increase in crop yield in all scenarios as there currently is transition to from low yielding grains to high yielding cereals like triticale and oats.

Yield potentials for roughage crops grass, maize, and whole crop silage as well as the cereals used for concentrate, are derived from long term organic rotation research, as presented in Mogensen et al. (2007). The yield potentials for the future were estimated according to expected technological innovations and nitrogen availability within the system. The yield levels are estimated by using the last five years of actually registered yields on organic dairy farms in Denmark (Mogensen et al., 2007).

To compute the dry matter (DM) yield of a crop for a given amount of N application, the following marginal N effects were used. Adding one kg of N fertilizer results in an additional DM yield of 7 kg for grass-clover, of 11 kg for cereals and of 15 kg for whole crop silage. No reference study on marginal effects of N fertilizer application on organic maize was found. However, maize yields tend to drop when not fertilized on a high level, due to slow spring growth in cold soils. To guarantee sufficient concentrates in the ENV scenario, all animal manure was used to fertilize cereals and maize.

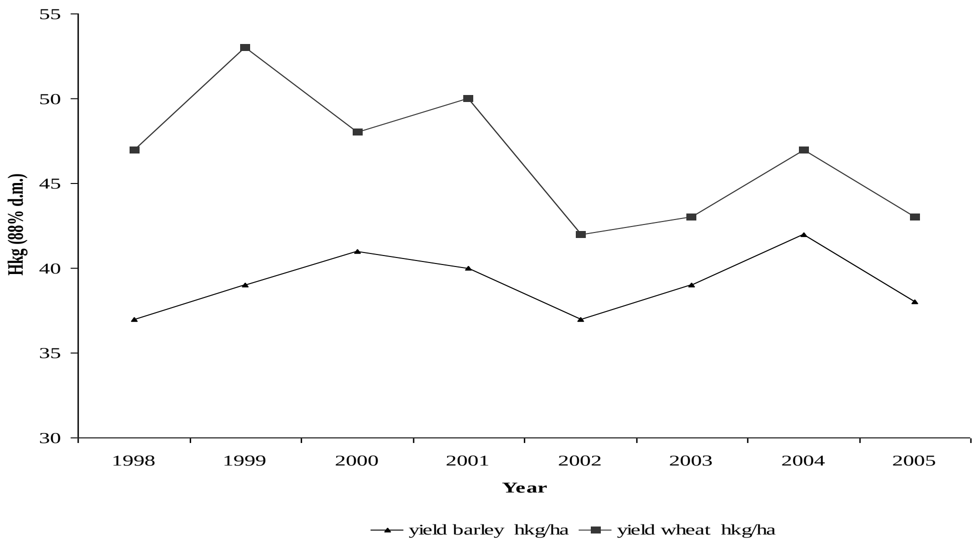

Fig 3. Average yields in hKg ha^{-1} for organic dairy farms from 1998-2005 (IFRI, 2005).

Herd size and milk yield. In order to calculate the number of milk producing units (MPU) in each scenario, N excretion is related to the diet and the milk yield of a cow. The following formula was used to compute the N-excretion per milk producing unit (MPU) (Poulsen et al., 2001).

N excretion per MPU = (SFU per MPU × g crude protein per SFU / 6250)- (kg milk per MPU × % protein in milk / 638) - 1.7

where Scandinavian feed unit (SFU) is a standard feed unit that corresponds to the energy of one kg barley which equals 7850 kJ.

The maximum N application out of animal manure is 140 kg per ha and this was the limiting factor for BAU. Annual milk yield was estimated 9500 kg ECM (extrapolation to 2020, from yield average of the last 10 years predicts higher, but feeding premises prevent this, Fig. 4), this indicates a maximum of 1 milking cow per ha, excluding young stock.

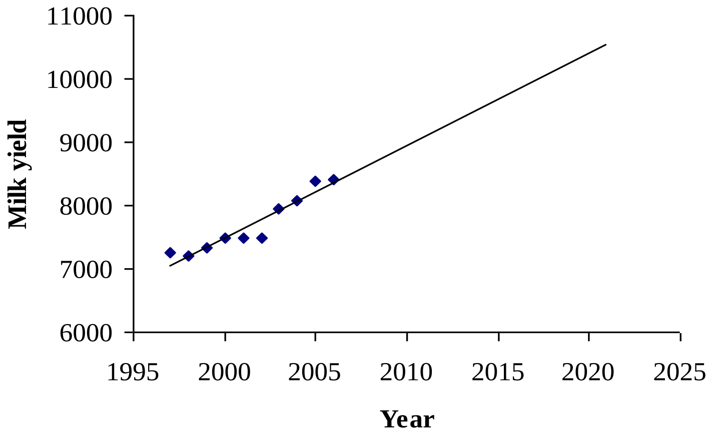

Fig. 4. Registered and predicted milk yield in kg energy-corrected milk (ECM) per cow per year of the Danish Organic Dairy sector as an average of all breeds (DCA.,2008).Energy-corrected milk (ECM) was calculated as defined by Sjaunja et al. (1990).

The herd size of the ENV scenario was dependant on the amount of feed the 200 ha could provide together herd management factors (Table 1). The herd size of the ANW scenario was calculated considering a lower milk yield, together with herd management factors. For all scenarios the following procedure was followed. For organic dairy in Denmark, the average feed conversion rate for a production of 8000 ECM/ year was 0.77 SFU kg ECM^{-1} in Danish Holstein Frisian (Kristensen & Kjærgaard, 2004). To cover maintenance, weight gain and foster growth the cow needs 1090 SFU per year, independent of the milk yield. The feed supply needs for the scenarios were estimated relative to this standard level (Olesen et al., 2005). For all scenarios, best practice for silage quality has been used. After having estimated a feed ration with best practice quality, a more sophisticated calculation of kg ECM, using exact digestion rates for the different feedstuffs and consequences for fat, protein, energy, filling and rumination time level was computed (Strudsholm et al., 1999). In an iterative process the cow's diet was adjusted, to fit the needs at the given level of production. In all organic dairy cow diets, a minimum of 60% of the ration has to be roughage (EU-standard) though only 50% in the first three lactation months. A minimum of 0.15 ha grazing area should be available per MPU (Danish guidelines) in the summer months.

The number of heifer calves on the farm is the result of the period the newborn calves are kept, the death rate, and the culling percentage. In all scenarios, 50% of the cows give birth to heifer calves In the BAU scenario the heifer calves are on the farm 3 months The number of heifer calves is therefore computed as $200 \times 0.5 \times 12/3$. All 1st lactation heifers are bought, so only death rate and culling rate influence the amount of bought animals. Death rate on BAU is assumed to 4% per year which corresponds to high productive herds (Oudshoorn et al., 2009). Bull calves are sold at birth for fattening. Culling rate for the BAU scenario was assumed 40% which is practice for organic dairy farms at present in Denmark (Oudshoorn et al., 2009)

For the ANW scenario, the amount of heifers on the farm depends on the culling rate and death rate. The assumed culling rate is 25% and the death rate 2.7% which corresponds to herds using conventional milking systems with moderate production level (Oudshoorn et al., 2009). The number of heifer calves is therefore computed as (185 × 0.5) + (185 × 0.25) + (185 × 0.027). Bull calves are kept 3 months. The amount of bull calves on the farm is therefore 200 × 0.5 × 12/3.

For the ENV scenario the amount of heifers on the farm depends also on culling rate and death rate. The assumed culling rate is 30% and the death rate 3% (higher than ANW as focus lies on environment). The number of heifer calves is therefore computed as (125 × 0.5) + (125 × 0.3) + (125 × 0.03). Bull calves are sold at birth for fattening. Using ECM production per MPU and figures on amount of young stock on the farm, LSU/ ha could be estimated.

RESULTS

Farm characterization of scenarios. The amount of N from animal manure applied per ha of land is approximately the same for BAU and ANW, i.e. 140 kg/ha and 130 kg/ha respectively, whereas in ENV this was only 86 kg N per ha. Estimated crop yields reflect these differences in available nitrogen in the different scenarios. ENV will prefer using the available N on cereal, thus preventing yield loss. In Denmark, whole crop silage on organic dairy farms usually consist of a large percentage of fodder peas, which due to nitrogen fixation can compensate for the lower nitrogen input (Table 3). Grass-clover yields differ, especially because spring growth is accelerated due to fertilization.

To calculate the amount of available fodder after harvesting of grass, maize and whole crop silage, we assumed that 15% of the gross DM yield is lost during the silage process, whereas 20% is lost during grazing (Olesen, 2005).

Calculation of LSU per ha is based on the CAL, management strategy for young stock and feed supply. It clearly indicates the large difference in intensity for the three scenarios.

The rotations expressed in Table 4 show a significant higher % of grass-clover area in the ANW than in the BAU and ENV scenario. This is due to the high requirements for grazing in the ANW scenario compared to the BAU and ENV scenario. In the ENV scenario a large area is needed for production of cereals to produce feed grains, because no concentrates were imported Alternating cereals (oats, barley, summer triticale) and maize will be sufficient to maintain the grass-clover pastures at least three years.

A diet of fresh grass-clover, grass-clover silage, whole crop silage, maize silage and barley (rolled or ground) was not sufficient in providing a balanced diet in the BAU scenario. Additional fatty, protein-rich feed ingredients were necessary to fulfil animal requirements and, therefore, rape seed cake was introduced. The non-restrictive import of feed ingredients in the BAU scenario and the relatively small land occupation for grazing, gave the opportunity to grow relatively much maize. This effect is strengthened by the out-sourcing of young stock (heifer hotels).

Table 3. Estimated gross yields in kg dry matter per ha for three scenarios, i.e. BAU: Business As Usual, ANW: ANimal Welfare; and ENV: ENVironmental.

Crops	BAU	ANW	ENV
Grass-clover, silage	6325	6325	5750
Grass-clover grazing	6600	6600	6000
Maize-silage	9200	9200	8050
Whole Crop silage	5750	5750	5750
Cereals (barley, oats, wheat)	4400	4400	4400

Table 4. Production parameters estimated for the three scenarios, i.e. business as usual (BAU), animal welfare (ANW) and environmental scenario (ENV).

Farm Characteristics	dimension	BAU	ANW	ENV
Area in grass-clover	Ha	118	130	115
Area for grazing	Ha	32	70	40
Area for silo maize	Ha	25	10	10
Area whole crop silage	Ha	40	30	25
Area for cereals	Ha	17	30	50
Dairy cows	Nr/farm	200	185	120
Heifer calves	Nr/farm	25	148	96
Bull calves	Nr/farm	0	23	0
Animal density	LSU[1] Ha^{-1}	1.41	1.38	0.88
Milk yield per milking cow	Kg ECM[2]	9500	7800	8300
Milk yield per ha	Kg ECM ha^{-1}	9500	7215	5188
Total milk production	Ton ECM	1900	1443	996
Cow diet (summer and winter)	SFU cow^{-1} day^{-1}	19.8	16.8	17.6
Intensity (summer and winter)	% roughage	63	69	76
Intensity (concentrate)	SFU cow^{-1} day^{-1}	7	5	5
Amount of grazing (summer)	% of diet	22	49	37
Amount of slurry/manure to spread	Ton $year^{-1}$	3062	2724	2546

[1]LSU = Livestock unit is a standardized animal that excretes 100 kg N per year;
[2]ECM = energy-corrected milk.

DISCUSSION

The plausibility and feasibility of the scenarios is a principle part of the definition of scenarios (Berentsen et al., 1996; van der Schilden, 2003; Meyer, 2007). The current situation in Denmark is obviously following the BAU scenario, where average herd size for organic dairy farms has passed 100 milking cows, annual milk yield per cow is increasing rapidly and LSU per ha is close to 1.4 (DCA, 2008). Most dairy herds in Denmark consist of Holstein Frisian, the reason for using this race in all scenarios and making comparison by evaluation possible. However, if animal welfare was prioritized higher, alternative breeds could be introduced. All three scenarios are defined to use up to date technology and information systems. Only BAU is defined to use AMS, as this seemed suitable for the primary goals, high yield and low labor. Animal welfare is certainly a hot topic, but are consumers willing to pay extra? Targeted surveys confirm willingness to pay a premium for better quality, but do not represent the actual buying behavior. The discussion whether or not lower milk yield, more time outside grazing, and deep pit straw housing enhances animal welfare is still pending among experts, but generally accepted by practitioners. Environmental friendly design of the farm unit is built on research studies showing a direct relation between LSU ha^{-1} (Kristensen et al., 2003) and potential leaching from farm N surplus. In addition biodiversity in species decreases with increasing N-surplus per ha (Haas et al., 2006). Numerous minor improvements for environmental care could be introduced, like planting more hedges or small biotopes, shallow and no tillage, but these would be difficult to evaluate, as not many empiric data are available (Hansen et al., 2001). Both animal welfare and positive impact on the environment have been driving forces for consumers to prefer products from organic farming (Hansen et al., 2001) and for farmers (Oudshoorn et al., 2008).

A scenario analysis offers the possibility to integrate a broad selection of sustainability issues, including economy and social aspects. Contrary to most other scenario analysis', the method used to design alternative futures in this research was normative, using goals and visions (Börjeson et al., 2006; Meyer, 2007). This procedure was chosen to secure the social dimension in the analysis. However, opinions can differ on the defined scenarios: are they representative for the perceptions within the Danish organic community, and can they be used in other countries? Not only this can reason other choices for future alternatives, also perceptions on nature (Verhoog et al. 2003) or standards for quality could lead to other choices. In addition, the path to get to the described alternative futures for ENV and ANW was not specified. The end-situation can be used in decision processes with environmental, social or other objectives.

CONCLUSIONS

The objective of this study was to explore scenarios for organic dairy farming based on visions and goals of a sustainable future. The goal of thoroughly documented scenarios on farm scale is to influence the present production environment or development. Simultaneously the outcomes of the negative impacts of present developments towards unwanted future implications can be avoided. By using a participative process with stakeholders and expert knowledge, three scenarios were defined; Business as usual (BAU), animal welfare (ANW) and environmental friendly (ENV). The amount of milk produced per ha was, 9500, 7215 and 5188 kg ECM respectively for BAU, ANW and ENV. All scenarios could be accepted in present regulations and economy, environmental impact and social acceptance should be evaluated for assessment of sustainability.

REFERENCES

Announcement, 2008. Based on Law nr. 463, 17th of June 2008.available on www.lr.dk

Anonymous, 2007. The Principles of Organic Agriculture. http://www.ifoam.org/ about_ifoam/principles/index.html.

Anonymous, 2007b . Danish standards for organic growing. In Danish, available on: http://pdir.fvm.dk/Vejledning_om_økologisk_jordbrugsproduktion.aspx?ID=2137

Anonymous, 2008. Development, growth, and integrity in the Danish organic sector. A knowledge synthesis on the opportunities and barriers for a continued development andmarket-based growth in production, processing, and sale of organic products. Available at: http://ecowiki.org/OekologiskUdvikling/HomePage.

Berentsen, P.B.M., Giesen, G.W.J. & Renkema, J.A. 1996. Scenarios of technical and institutional change in Dutch dairy farming. *Neth. J. Agr. Sci.* **44**, 193–208.

Börjeson, L., M. Højer, K. H. Dreborg, T. Ekvall, & G. r. Finnveden. 2006. Scenario types and techniques: Towards a user's guide. *Futures* **38**, 723–739.

Bos, J., de Haan, J. & Sukkel, W., 2007. Energieverbruik, broeikasgasemissies en koolstofopslag: de biologische en gangbare landbouw vergeleken. Rapport nr. 140 Wageningen UR. Available on: www.biokennis.nl (in Dutch).

Claudi-Magnussen, C. 2001. DS-nyt - nummer 2, How does organic pig meat taste? Danish Meat Research Institute. (In Danish). http://www.danishmeat.eu/

Dalgaard, T., Dalgaard, R. & Nielsen, A.H. 2002. Energiforbrug på økologisk og konventionel landbrug. in Danish. Green Knowledge, Ministry for food, agriculture and fishery, arable farming 260.

DCA, 2008. Danish Cattle Association. [Dansk Kvæg]. Kvægbruget i tal. Available onhttp://www.lr.dk/kvaeg/diverse/kvaeg_tal_2008_dk.pdf (in Danish).

Duiker, P.N. & Greig, L.A. 2007. Scenario analysis in environmental impact assessment: Improving explorations of the future. *Environ. Imp. Ass. Rev.***27**, 206–219.

EF, 2007, EU regulation nr. 834/2007 of the 28th of June, which was supplemented withregulation nr. 889 of the 5th of September 2008.

Eriksen, J. Askegaard, M. & Søegaard, K. 2008 Productivity and N-leaching in organic dairy grass-arable crop rotations. Paper presented at EGF 2008, Uppsala, 9–12 June 2008; *Grassl. Sci. Eur.* **13**, 556–558.

Haas, G., Wetterich, F. & Geier, U. 2000. Framework in Agriculture on the Farm Level. LCA Methodology. *Int. J. LCA* **5**,1–4.

Haas, G., Deittert, C. & Köpke, U. 2006. Farm-gate nutrient balance assessment of organic dairy farms at different intensity levels. *Ren. Agric. Food Syst.* **22**(3), 223–232.

Halberg, N. 2008. Energy use and green house gas emission in organic agriculture. International conference organic agriculture and climate change, Enita of Clairmont, France. Available on: http://orgprints.org/

Hamilton, C., Hansson, I., Ekman, T. , Emanuelsson, U. & Forslund, K. 2002. Health of cows, calves and young stock on 26 organic dairy herds in Sweden. *Vet. Rec.* **150**, 503–508.

Hansen, L. Alrøe, H. & Kristensen, E.S. 2001. Approaches to assess the environmental impact of organic farming with particular regard to Denmark. *Agriculture, ecosystems and environment* **83**, 11–26.

IFRE, 2008. Institute of Food and Resource Economics, Copenhagen University. Retrieved from http://www.foi.life.ku.dk/Publikationer/Statistikker/Økologi.aspx

Kramer, C.M. 2006. Afgræsning og automatisk malkning [Grazing and Robotic Milking]. Master Project at Royal Veterinary and Agricultural University, Copenhagen (2006). Available on www.automaticmilking.dk (in Danish).

Kristensen, I.S., Halberg, N., Højlund Nielsen, A., Dalgaard, R. & Hutchings, N. 2003. N turnover on Danish mixed dairy farms. Nutrient management on farm scale: how to attain

European and national policy objectives in regions with intensive dairy farming?". Workshop Quimper, France. Available on http://orgprints.org/

Kristensen, T. & Kjærgaard, A.S. 2004. Malkekøernes foderudnytttelse - Analyser af besætnings data fra studielandbrug. DIAS report. *Husbandry* **58**, 1–9 (in Danish).

Küstermann, B., Kainz, M., Hülsbergen, K.J. 2008. Modeling carbon cycles and estimation of greenhouse gas emissions from organic and conventional farming systems. *Renewable Agriculture and Food Systems* **23**(1), 38–52.

Lund-Jensen, K. 2008 Market development in organic sector in Denmark. (In Danish). In development, growth, and integrity in the Danish organic sector, A knowledge synthesis on the opportunities and barriers for a continued development and market-based growth in production, processing, and sale of organic products, pp 71–84. Available at: http://ecowiki.org/OekologiskUdvikling/HomePage.

Markussen, S.M. 2003 Precision farming – Technology assessment of site-specific input applications in cereals. PhD thesis, Technical University of Denmark (www.dtu.dk).

Meyer, R. 2007. Comparison of scenarios on futures of European food chains. *Trends Food Sci.Technol.* **18**, 540–545.

Miller, K.D. & Waller, H.G. 2003. Scenarios, real options and integrated risk management. *LongRange Planning* **36**, 93–107.

Mogensen, L. 2004. Organic milk production based entirely on home grown feed. PhDthesis, Kopenhagen University, faculty for life Sciences.

Mogensen, L., Ingvartsen, K.L., Kristensen, T., Seested, S. & Thamsborg, S.M. 2004. Organic dairy production based on rapeseed, rapeseed cakes or cereals as supplement to silage *ad libitum*. *Acta Agric. Scand., Sect A, Animal Sci*. **54**, 81–93.

Mogensen, L. Kristensen, T. & Danfær, A. 2007. Prototyping of Organic Dairy Production Systems Self- sufficient with feed- Consequences on Productivity, Economy and Nutrient Balance. *Biol. Agr.Hort.* **25**, 13–35

Olesen, J.E., Weiske, A., Asman, W.A.H., Weisbjerg, M.R., Djurhuus, J. & Schelde, K. 2005. FarmGHG, A model for estimating greenhouse gas emissions from livestock. Available on: http://www.agrsci.dk/media/webdav/filer/jpm/plant__1/jeo/farmghg .

Olesen, J.E. 2005. Drivhusgasserne fra jordbruget, reduktionsmuligheder, Report nr. 113, arable cropping Danish Institute of Agricultural Science, Denmark (in Danish).

Olesen, J.E., Weiske, A., Asman, W.A.H., Weisbjerg, M.R., Djurhuus, J. & Schelde, K. 2006. Modeling greenhouse gas emissions from European conventional and organic dairy farms. *Agric., Ecosyst. Environ.* **112**, 207–220.

Oudshoorn, F.W., Renes, R. & de Boer, I.J.M. 2008. Systems in Organic Dairy Production. *J. Ag.r Env. Eth.* **21**, 205–228.

Oudshoorn, F.W., de Boer, I.J.M., van der Zijpp, A.A.K. & Kristensen, T.2009. Quantification of Sustainability Indicators on Organic Dairy Farms using Automatic and Conventional Milking Systems in Denmark. Submitted.

Poulsen, H.D., Børsting, C.F., Rom, H.B. & Sommer, S.G. 2001, Kvælstof, fosfor og kalium ihusdyrgødning - normtal 2000. DIAS report. *Husbandry* **36**, 1–152. Updates for 2007 available on: www.agrsci.dk/ (in Danish).

Ruis, M. & Pinxterhuis, J.B. 2007. "Verantwoorde en communiceerbare argumenten bij Biologische producten; dierwelzijn" in Dutch, [Reliable and communicative arguments for organic products; animal welfare]. Animal Science group, Wageningen University & Research, report nr. 39 Available on www.biokennis.nl (in Dutch).

Schnaars, S.P. 1987. How to develop and use scenarios. *Long Range Planning* **20(**1), 105–114.

Sjaunja, L.O., Baevre, L., Junkkainen, L., Pedersen, J. & Seta¨ la,¨ J. 1990. A Nordic proposal for an energy corrected milk (ECM) formula. In EAAP publication no. 50: performance recording of animals: state of the art, proceedings of the 27th biennial session of the

International Committee for Animal Recording (ICAR), Paris 2–6 July (ed. JAM van Arendonk). Wageningen Academic, The Netherlands.
Sonesson, U., Gunnarsson, S., Nybrant, T., Stern S., Öborn, I. & Berg, C. 2003. Att skapa framtidsbilder. En metod at utforma framtidsscenarier för uthållig livsmeddelsproduktion. In Swedish [Form the future; A method to design future scenarios for sustainable food production] RapportMAT21nr3/2003online
http://www- Mat21.slu.se/publikation/pdf/Metodrapport.pdf (in Swedish).
Strudsholm, F., Aaes, O., Madsen, J., Kristensen, V.F., Amdersen, H,R., Hvelplund, T. & Østergaard, S.1999. "*Danske fodernormer til kvæg"*. Danish feeding. standards for cattle. Report nr. 84. Danish Advisory Service 1–47 (in Danish).
Thomassen, M.A., van Calker, K.J., Smits, M.C.J., Iepema, G.L. & de Boer, I.J.M, 2008. Life cycle assessment of conventional and organic milk production in the Netherlands. *Agricultural Systems* **96**, 95–107.
van der Schilden, M. 2003. Future scenarios of agroentrepreneurship. In: Management and Technology Applications to Empower Agriculture and Agro-Food Systems:XXX CIOSTA–CIGR V Congress Proceedings (Piccarolo, P., ed.), pp 3–14. Universitade gli Studi di Torino, Turin, Italy.
Verhoog, H., Matze, M., van Lammerts Bueren, E. & Baars, T. 2003. "The Role of the Concept of Nature (Naturalness) in Organic Farming." *J. Ag.r Env. Eth.* **16**, 29–49.
Wagenaar, J.P., & Langhout, J. 2006. Suckling calves. In Dutch, Kalveren bij de koe. De natuur werkt. Publicatie Louis Bolk Instituut, nummer LV 60. Internetsite: www.louisbolk.nl/kbdk
Weiske, A., Vabitsch, A., Olesen, J.E. , Schelde, K. , Michel, J., Friedrich, R. & Kaltschmitt, M. 2006. Mitigation of greenhouse gas emissions in European conventional and organic dairy farming. *Agric., Ecosyst. Environ.* **112**, 221–232.