A normative planning device to link economics with practice: the case of up scaling in dairy farming

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Abstract

Nowadays, the complexity of farming decisions demands for interactive and communicative planning which takes into account the farm specificity. On the one hand, whole-farm planning techniques become necessary, on the other hand, communicative techniques must help to keep it simple in order to treat problem-driven questions appropriately. This paper describes first-stage results of a process of combining whole-farm planning with communicative techniques in a decision support system for dairy farmers. Scale enlargement, a possible often idealized solution after EU milk quota abolishment, is used as a case. For dairy farmers, helped by their advisers, who want to expand their farm as a reaction to this change, the straightforward question is "what is the optimal scale for a specific farm?". The answer to this question is not generic, but proved very farm-specific. The whole-farm approach consists of mathematical programming to capture essential decision influencing factors such as farm and farmer's characteristics. In this paper we describe an action research between advisers and scientists, which has led to the incorporation of mathematical programming in a DSS that is currently used for advising farmers with growth aspirations. Although farmers and advisers are not familiar with this technique, first results show that it works. Some success factors defined are the fact that every party involved in this research is convinced of the usefulness of implementing mathematical programming in a DSS. It was also clearly stated that advisers were the end user of this tool so a wider range of farmers could be reached. By modelling themselves, the advisers learned a lot about mathematical programming. This ensured that the modelers thought about what was entered into the model and problems were quickly solved. In conclusion the way the results are presented to the farmers is crucial for a successful implementation. However some challenges are still in search of an answer.

1. Introduction

It can no longer be denied that the dairy sector is transforming. Milk production is stimulated by the increasing demand for milk products worldwide. Nevertheless, volatile milk and feed prices, changing policies, the competition for land and the growing societal concerns about the impact on the environment put the sector under pressure. This complex decision environment demands for interactive and communicative planning which takes into account the farm specificity. This need becomes highly apparent in cases where a sudden and more general change in the decision environment entails a generic solution perception which ignores the farm specificity. However farms can differ for example in size, labour availability, technical performances etc., moreover farmers themselves have different expectations and management capacities. This diversity requires a farm-specific approach when making decisions.

In a reaction to the changing environment in dairy farming, up scaling is seen by many farmers and advisers as the most obvious strategy to follow. Also social psychological factors can make farmers dream of a larger scale. Nevertheless, it is not straightforward to determine the optimal economic scale, as this optimum is very much farm-specific and scale enlargement can be considered as a whole-farm problem. Moreover, the scale enlargement dreams of the farmer often do not correspond with the reality of optimizing the use of farm-specific assets, resources and growth potential. After analyzing accounts, advisers are mostly able to confront the farmer's dream with reality. The complexity of the scale enlargement problem, however, precludes advisers to determine a farm-specific optimal economic scale. Consequently, it becomes difficult for the farmer to make a decision.

The use of operational research (OR) methods in a decision support system (DSS) can help to solve this problem. Mathematical programming (MP), for example, is an OR method that can be used to determine the farm-specific optimal scale. Unfortunately, while OR methods are often used for research purposes, they are hardly ever used for decision support in practice. Moreover DSS themselves are rarely implemented in practice (McCown, 2002; Walker, 2002). In literature, various factors are reported that lead to implementation problems: often the tools are not communicative, irrelevant for the users (Voinov and Bousquet, 2010; Walker, 2002), too complex to understand or use (Le Gal et al., 2010; Vayssières et al., 2011; Walker, 2002), not flexible (Walker, 2002), not regularly updated, etc. Some solutions, like participatory modelling are suggested by the same authors but they have not been validated in practice so far.

This paper aims at identifying success factors from a process of collaborative work on building an OR tool for practical and communicative farm planning. We describe the process of incorporating MP in a communicative DSS which is currently used in practice for advising dairy farms on their optimal economic scale. This process is still ongoing as the tool is currently being refined. In this paper, we describe preliminary results.

The elaboration of the paper is as follows. First, we focus on the process as it emerged. This description provides the "data" for our analysis. In a following section we describe the success factors of this process. We distinguish between success factors concerning the use of mathematical programming, factors concerning the collaboration between advisers and scientists and factors concerning the use of the DSS by the adviser in his communication with the farmer. In the final section some conclusions are drawn.

2. Process description

2.1. *Initiating the collaboration*

The process was initiated by a discussion about the use of OR techniques in practice between an economic researcher and an adviser specialized in dairy farming. They both lead a team of researchers and advisers, respectively. They have a basic education in agricultural economics and farm planning, the adviser has a rich experience in various aspects of dairy farm accounting, the scientist has a specialized OR education and farm management research experience. The conversation started about current challenges in dairying, but their discussion soon turned into a common concern: "Why is an existing rich toolbox of OR not used in complex farm planning situations?" The scientist stated that MP tools are a formalization of economic decision problems and thus have the potential to assist in making decisions in practice. The adviser confirmed that several questions in practice involve optimization problems, but he indicated that advisers need support to understand and use mathematical programming in practice. They agreed to work together on the practical question which was proposed by the adviser: "What is the optimal

economic scale for a dairy farm?" This research question was based on concerns of farmers with investment plans: 'can we expand our farm?' 'How much can we expand?'.
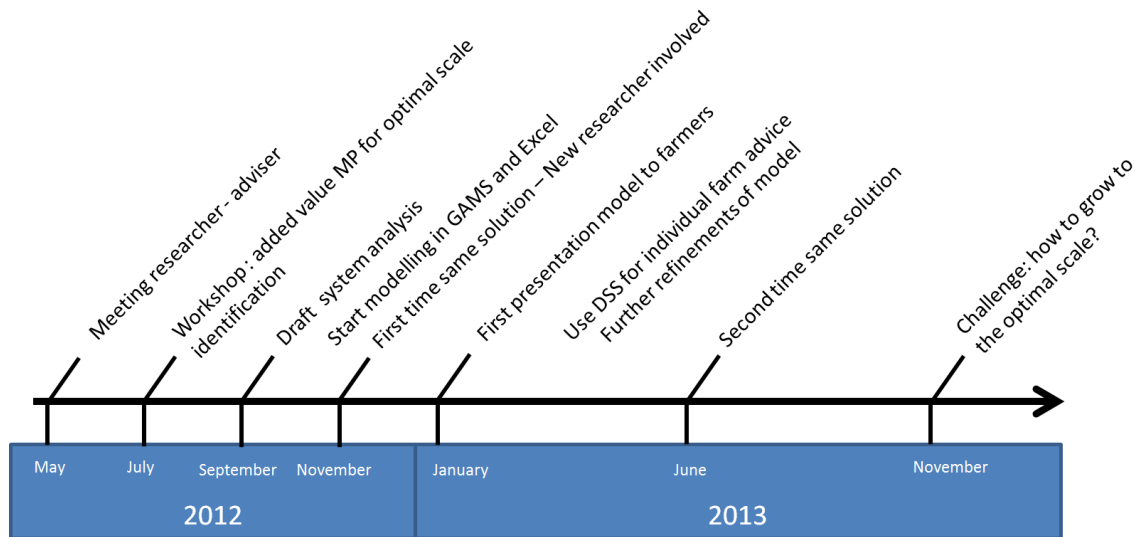

Figure 1. Timeline with different milestones

A first workshop was organized by the researchers and advisers in which four advisers and six researchers took part. The aim was to reach a consensus on the use of MP to address the problem of scale enlargement and look if further collaboration was possible. With different examples the researchers made the advisers aware of the potential added value of MP. The advisers presented some work they had already done about optimization of feed rations on dairy farms using mathematical programming. It became clear that it is not easy to construct a communicative DSS based on MP, since this is a complex technique with a specific terminology. Moreover to answer the research question mentioned before whole-farm modelling would be necessary. This is difficult for a system like dairy farming where not every input and output is precisely known. During this workshop, a first discussion on which factors are important for determining the optimal farm scale took place. It was agreed that in a next step further system analysis would be performed jointly by the advisers and researchers. Finally it was decided that both an adviser and a scientist would model themselves. Moreover, the choice was made to model with two different software types. The advisers would use Excel, a software which they are confident with. The scientists would use the General Algebraic Modeling System (GAMS), a more sophisticated software for MP. The goal in this co-developing process was that both models pursue the same solution and verify this solution. Periodically meetings would take place to compare both models. In the further process after this workshop two advisers and two researchers work further on this project. One researcher and one adviser collaborate actively and will construct the models. The other researchers and the adviser have a more supportive role.

From the juridical point of view, the collaboration started with the construction of a gentleman's agreement, clearly expressing the mutual interests of both partners. The individual interests became guaranteed through choices such as the software (Excel as a precursor for practical tailor-made planning devices, GAMS for flexible scientific enlargements of the model) and research outlets (popular magazine articles allowing the adviser to valorize new insights, scientific papers allowing the researchers to share insights on topic and process with the scientific community). In a later stage, this gentleman's agreement was consolidated in a contract.

2.2 *Building the model*

During a second meeting, the researchers and advisors analyzed the production system of a typical dairy farm in Flanders. The economic choice problem was converted in a mathematical form. For this form an objective function and corresponding restrictions were defined. Furthermore the modelers decided which information would be used as input for the model. Each production factor (land, capital, labor) of the dairy farm and the links between these factors were discussed. It was decided which technical, financial and economic relations on the dairy farm were important to answer the research question. In addition the modelers determined if the tool could be developed generic, with different farm types as examples for the farmers, or if it had to be farm-specific, so the model could be used to simulate every farm. The second options was chosen because the variety of farms/farmers requires a farm-specific approach in the decision making process. At the end of this meeting an initial system analysis of the dairy farm was drafted and the modeling effort could start.

During different meetings and by mail an intensive information exchange was established between the modelers concerning MP and the system analysis. Based on exchanged knowledge, preliminary models for dairy farms were constructed and presented to each other. Using two software types allowed for verification of the models by searching for the same solution with the same data input. During the building process, some difficulties occurred. The researcher, who developed the model, was not familiar with dairy farming, making it difficult to understand some aspects of the management operations on dairy farms. A new researcher became involved in the modelling process with a technical background in dairy farming. This accelerated the tool development. The other researcher became more a supervisor during the modelling process. After some refinements of the models and adding some additional constraints, both models reached again the same solution.

2.3 *Presentation and use of the model*

The advisers first presented the model to dairy farmers during a management workshop. By then, the modelers already realized that farmers had not to be confronted with the complexity of MP. The advisers showed the input parameters that were used in the model, the different aspects of the farm calculated in the tool and the investment options. The farmers had to be able to interpret the results. Therefore a sensitivity analysis was performed to show how the optimal solution changed when inputs were changed. This was graphically presented: the advisers showed optimal number of cows under varying parameters like milk price, milk production per cow, land availability and price per stable place. It was also indicated which aspects of the farm were limiting the optimal solution.

After this first presentation advisers started to use the model in combination with other advisory tools as a DSS in discussions with individual farmers. The model calculates an optimal growth scenario for a specific farm based on average technical and economic results of this farm from several years. With this result an investment plan is calculated, which uses the same data as the model. This plan is during the discussions compared with other investment plans for this farm. These investment plans include the farmer's goals and anticipations and what the adviser thinks is good for this farm. Because the tool is connected to the investment plan calculator, adjustments can be made to the input parameters during the discussion, so farmers can see immediately what would change if they for instance improved technological performance. The tool also shows the farmers why a particular solution is chosen: is there for example a shortage of land or capital? It is possible that the tool indicates that there is no optimal growth scenario. Using

sensitivity analysis the tool can then show which technical and financial parameters have to be improved before a growth step can be made. This happens graphically.

During these discussions with farmers some new challenges emerged based on the remarks of farmers. The advisers indicated that the DSS should be able to take into account not only economic interests of the users, but also other factors of the farmers decision environment. For example, farmers have to be able to choose which management options they want to use on their farm. Do they want to work with hired labor? Do they want to outsource the rearing of their calves? This is handled by introducing additional restrictions into the model. Originally a time factor has not yet been taken into account in the model. So a new research question about the dynamics appears: "How to grow in time to the optimal scale?".

3. Critical success factors

During the process, as described in the previous section, many decisions were made, some of them supported by literature, some by experience, others by deduction, and, in the worst case, by intuition. In this section we describe the success factors of the collaboration. We distinguish between aspects concerning the use of MP, those concerning the collaboration between advisers and researchers and those concerning the use of the DSS by the adviser in his communication with the farmer.

3.1 *Success factors concerning the use of mathematical programming*
We consider the use of MP as a first success factor. From the beginning of the modeling effort, advisors and researchers were convinced that MP is the best solution to answer the considered research question. MP makes it possible that besides the optimal solution, additional information is available for the adviser and farmer to support the decision making. On the one hand the sensitivity analysis allows to identify the limits within which an investment choice stays economically optimal (Figure 2). On the other hand, shadow price analysis reveals the limitations of the farm to optimize the scale. These benefits were also cited by Berentsen and Giesen (1995). Other advantages they identified, which are also applicable here, are the possibility to easily incorporate new activities, improve existing techniques by changing coefficients or easily alter prices of production factors in the model.

A second success factor is the whole-farm approach. We follow this approach since every decision made about optimal scale will affect the different aspects of the business, whether it is about economic, financial or technical aspects of the farm. However, we can easily create a model that is too complex, which makes the model less user-friendly and obsolete for practical use. We try to prevent this by introducing only those relationships which are important for the management and taking into account the information which is available on the farm. We focus mainly on the technical, economic and financial relationships on the farm, less on biophysical relationships. The main goal of this model is not calculating an exact economic number. It has to give additional information to the farmer and adviser to support the decision making about optimal scale (Berentsen and Giesen, 1995).

We choose to optimize an economic indicator, but we cannot assume that farmers make decisions solely based on an economic point of view. Often other conflicting interests are also taken into account in the decision making (Le Gal et al., 2010). We deal with this in the tool by introducing restrictions that take these conflicting interests into account. This is a third success factor.

Another success factor of this DSS is that the MP model is not used as a standalone tool, but employed in combination with existing management tools. This enhances the successful implementation. The farmer does not see the complex model but has the possibility to use the results optimally in his decision making. What the optimal scale means for his/her own farm is translated into investment plans. This is for the farmer a familiar tool with recognizable financial, economic and technical indicators. The results of the sensitivity analysis and the shadow price analysis are presented graphically to the dairy farmer. The use of recognizable indicators to present results of OR methods for practical farm advice was previously applied by Van Meensel et al. (2012).

We consider the fact that the model is farm-specific as final success factor within this section. The input used in the model is based on the technical, economic and financial results of the last five years for the farm. Moreover specific wishes of the farmer are included in the model. This results in a farm/farmer specific solution, which makes it for the farmer more interesting to simulate with a DSS (Carberry et al., 2002).

3.2 *Success factors concerning the collaboration between advisers and researchers*
The fact that we have chosen to work together with advisers is seen as a success factor. They can act as a bridge between farmers and scientists. Both consultants and scientists benefit from the collaboration. Scientists can reach more farmers with their research and advisers have the ability to support farmers with scientific tools (Carberry et al., 2002).

A major success factor of this collaboration is that consultants and scientists rapidly agreed on the objective of the DSS. Voinov and Bousquet (2010) cited this as a critical step of the participation process. This is drawn up into a contract which brought clarity in the objectives of both parties. This leads to a sense of responsibility on both sides to invest enough time in the development process.

The research question "What is the optimal economic scale for a dairy farm?" currently concerns farmers and was proposed by the advisers as research question. For advisers it is interesting to provide them with a scientifically based answer and for the scientists this is relevant research. This bottom up approach increases the willingness to participate in a research (Voinov and Bousquet, 2010).

This willingness is even more increased by the interest of the advisers in the research method used. Due to the nature of the question the advisers are convinced of the usefulness of MP. Additionally, advisers already used the method for feed ration optimization. But some support is needed for them to extract the maximum information from the output of MP.

Another success factor is that already during the first workshop an agreement was obtained on a work plan with a number of concrete steps. First a system analysis would be performed, which helped the modelers to avoid modelling useless restrictions / create inappropriate models. Afterwards the advisers and scientists each would start with the modelling in different software programs and pursue the same model output. Because both the researcher and the adviser are developing a model, they both better understand how MP works, what the advantages and disadvantages are and which relationships of the dairy farm are considered in determining the optimal solution.

The choice of modelling software was taken during the meetings and is considered as another success factor. The adviser started working with Excel. This is an accessible program, which

many people are familiar with and is easy to use in practice (Voinov and Bousquet, 2010). It is often a standard program on the computer, so no investment is needed. The researcher however chose GAMS to model the program. This is software developed specifically for optimization models with powerful solvers available. Moreover the researcher were already familiar with GAMS.

The modelling effort with two different modelers in two different programs was seen as a first validation step during the development process, since there was a common goal to achieve the same solution.

Bringing people together with different specializations was important in this research: advisers with a technical background in dairy farming, researchers with knowledge about operational research methods and economic knowledge. The adviser who developed the model had much interest in MP and the researcher, who did the most modelling had some background in dairy farming. The other researchers and the adviser involved had a more guiding role in the process: they followed the process and gave information when it was necessary. This made it possible that a lot of problems could be solved by mail and only a monthly meeting was necessary.

3.3 *Success factors concerning the communication between farmer and adviser*
For using the tool with farmers, communication to the farmers is indeed crucial. Consultants have a great deal of technical knowledge to support farmers in taking their decisions (Hadley et al., 2002). They establish a trust relationship with the dairy farmer and have a good farm-specific knowledge (Le Gal et al., 2011). After all, farmer and adviser decide together which inputs of the farm and wishes of the farmer are introduced into the model. If the input does not match the management capacities of the farmer, the solution of the tool is useless for supporting the farmer.

Another success factor identified is the fact that the tool has a supportive goal. The DSS does not try to make the decision for the farmer. The farmer himself makes the final decision.

In presenting the solutions to the farmers, the DSS uses familiar financial, economic and technical indicators and graphics (Figure 2). For farmers these are easy to understand representations of the solution, which makes this DSS more accessible to them.
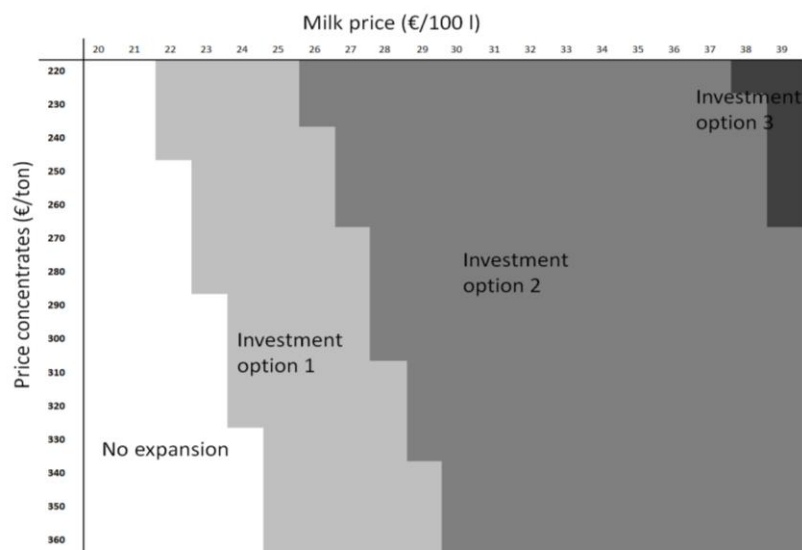

Figure 2. Example of presenting the sensitivity analysis to farmers

4. Conclusion

This research resulted in the construction of a DSS with a high potential to be successfully implemented in practice. Especially the fact that all the parties involved in this participatory action research were convinced of the usefulness of inserting mathematical programming in a DSS led to this success. It was also clearly stated that advisers were the end user of this tool so a wider range of farmers could be reached. By modelling themselves the advisors learned a lot about mathematical programming. This ensured that the modelers thought about what was entered into the model and problems were quickly solved. In conclusion the way the results are presented to the farmers is crucial for a successful implementation. However some challenges are still in search of an answer: Is this approach for instance generalizable/applicable to other farming areas? The advisers and farmers included in this research are highly specialized in dairy farming and looking to use scientific research in practice. We need to look now how to involve other advisers and farmers in this research. In the next stage of this research we will look how the model is used in practice by advisers and farmers.

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