# DECISION SUPPORT FOR MIXED ECOLOGICAL FARMING SYSTEMS BASED ON PHYSICAL PRODUCT FLOWS

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## Introduction

This paper is part of a project that deals with a model approach in order to support the development of sustainable farming systems (see Wolfert *et al*., 1997). Sustainability can be split up into three dimensions: *economic*: farmers must have reasonable incomes, *ecological*: the quality of natural resources must be maintained and *social*: the farming system must be socially accepted. Sustainability is a goal; 'mixed' and 'ecological' are technological ways to reach it. Mixed is defined as the integration of arable and animal production in one managed unit. Ecological is a synonym for organic. However, sustainability must be reached by interaction of the farmer with his farming system on one hand and with the ecological, economic and social environment on the other. This interaction is reflected in decision making in which self-reflection plays an essential role (Röling, 1994).

The desired model must generate and structure data to support decision making of a mixed ecological farmer in order to reach and maintain a sustainable farming system. Because of the self-reflection aspect, the model also has to function as a learning environment. Operational and tactical decisions have to be taken into account. Strategic decisions refer to changes in the kind of production system and are therefore outside the scope of the current model. This paper focuses in particular on modelling of the physical production process in terms of product flows.

## Material and Methods

The Ir. A.P. Minderhoudhoeve – an experimental farm in the Dutch Flevo polder – isused as a case study for the model. It is a mixed ecological farm of 90 hectares, integrating arable, field vegetable, roughage and milk production. More information about this farm can be found in Lantinga & Van Laar (1997) and Lantinga & Oomen (1998)

Figure 1 outlines the system layout from a decision-making point of view. The process informatics is the core part of the model, where the actual decisions are made. At the bottom, the physical production process is defined in terms of primary processes that transform materials, life phenomena and energy into products and services. The physical flow model represents these processes in terms of of data on input, output and processes. It contains data that are relevant for decision making. Thus it acts like a data filter for the process informatics.

The physical production process is a dynamic process that forces the farmer to make decisions at certain moments. Filtered data from the process form the starting point. These are combined with external information (e.g. weather conditions, market prices) and business information. The business information system provides basic data like farm size, human resources but also business goals. These goals are farm-specific and have to be made explicit and quantified. The business information system is not yet worked out and will not be described in this paper.

In addition, the farmer will also use mental references, based on experience and tacit knowledge. This is often a very important factor in successful decision-making, but cannot be modelled. However, by saving decisions and their corresponding data in a 'historical database', an attempt is made to support the mentioned process of self-reflection. In this way the model doesn't only support actual decisions, but also supports the development of effective decision behaviour.
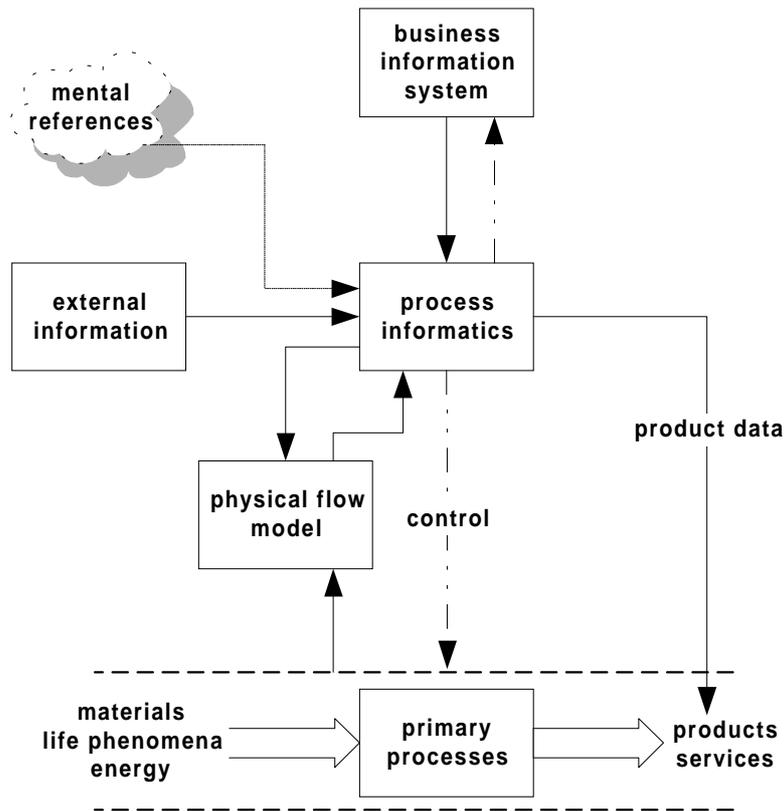
**Figure 1.** System layout. Except for the thick wide arrows at the bottom - those are *material* flows, all other arrows represent *data* flows. Further explanation in the text.

In addition to data analysis, a farmer – confronted with a range of possible decisions – often would like to carry out what-if-analyses'. This is a second objective of the physical flow model. Therefore the physical production process is modelled in terms of product flows using a multi-input-multi-output (MIMO) approach (Jansen, 1998). This approach splits up the complete production process into several units, where each unit can be uniformly described as a black box with multi-input and multi-output (Figure. 2). At the input side resources and intermediates are distinguished. Resources can be either energy or materials (e.g. nitrogen). Intermediates are products from a preceding process unit. At the output side products, soft by-products and emissions can be distinguished. Products can be either end products leaving the farm or intermediates for a subsequent process unit. Soft by-products are products that are not input for another unit, but quantifiable indicators for 'products' such as animal welfare, aesthetic values, etc. Emissions are all other material flows that are returned to resources, for example N leaching to the N resource. A software tool called Visio[1] is used to visualize all relevant process units and product flows in diagrams using an object-oriented approach. This means that all processes and flows are represented by objects that have their own properties and methods (Booch, 1994). One important advantage is that all data of the Visio diagrams can be stored in a database. This database will be used as a source for program code. In this way consistency between program code and diagrams is assured.

After the farmer has combined all relevant data and done several what-if-analyses, a decision is translated into a control event. Control will effect the actual physical production process and also business information.

Besides supporting management, this approach will also gather much information about the end products, their substance and how they are produced. This links up with the trend of certification in which this is a main prerequisite.
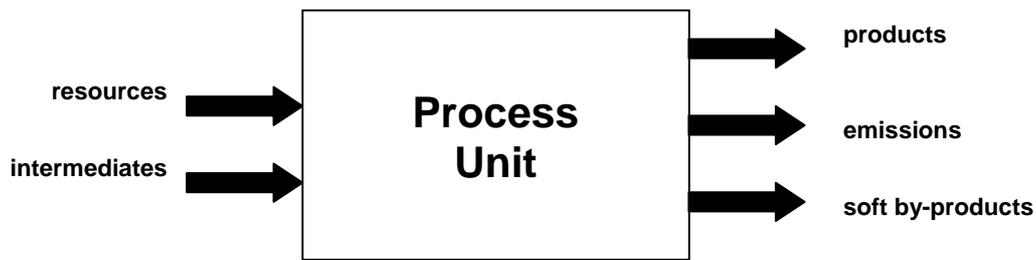
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**Figure 2**. Basic layout of multi-input-multi-output (MIMO) process unit. Further explanation in text

## Results and discussion

The Ir. A.P. Minderhoudhoeve farming system (Lantinga & van Laar, 1997) was divided in several main production lines: milk, potato, bakery wheat, onion, cabbage and several other small vegetable crops. These production lines have been modelled in terms of connected MIMO process units. All process units and flows are drawn in one and the same drawing. However, Visio enables you to distinguish different layers that can be separately visualised. Each production line is assigned to a separate layer. Within a production line the following sub-layers are distinguished: product flows, internal resource flows and emission flows. Figure 3 shows the product flows layer of the milk production line. Division of process units was based on geographical distinguishable units e.g. fields, stores and stables. The principle behind this is that it links up with the farmer's view on his production system in reality.

Internal resources are defined at whole farm level: soil nutrients, air, groundwater and surface water. Each internal resource can be subdivided in subresources. The resource soil nutrients for example can be distinguished in nitrogen/phosphorus/potassium. External resources are assigned to each specific production line. A special external resource is energy. It doesn't make sense to draw energy flows, because all process units use energy. Energy use is, therefore, a fixed attribute of a process unit.

Thus several separate production lines can be distinguished. However, the basic principle of mixed farming is to combine these lines to recycle products as much as possible. Assigning a flow to multiple layers does this. For example, *potato tare* is a primary flow of the potato production line. Potato tare is fed to cows and thus it becomes a flow of the milk production line (see Fig. 3).

One of the next steps is to attach data to flows and process units. What data are defined depends on the specific goals of the farm. For example, one goal may be: no depletion of the nitrogen resource. Therefore all incoming and outgoing flows of this resource must be quantified for nitrogen and the net flow must be zero. However, a main problem is the availability of data because it is often not feasible, technically or economically, to measure continuously and with infinite accuracy. There are three possible solutions to tackle this problem (Jansen, 1998): *(i)* use of norm values, based on earlier experience or estimations, application of norm values obliging the application of spreading to determine the level of accuracy; *(ii)* use of computations, for example for volatile substances by calculating the mass balances of relevant inputs and outputs; *(iii)* use of measurements, for example sampling of silage feed.

*An illustration of a decision*
In figure 3 we see many inputs for the milk production process unit. At certain moments the farmer has to decide how to feed the cows on the basis of an economic main goal of a certain production. Besides, he will have other goals on e.g. the quality of the manure produced, cow welfare and ammonia emission. From experience and other references he knows in terms of protein, energy and feed structure the approximate input for the cows. First, information must be collected on the amount and quality of available feeds. On the basis of this information he carries out some 'what-if-analyses' and is confronted with the possible consequences regarding his goals. Then he will make a certain decision that is optimal in his opinion. (So, the model is only supporting and doesn't dictate the optimal decision. This leaves room for specific styles of farming.) The decision will influence the production process: stocks decrease, processes are put into motion and indirectly this will influence the physical flow model.
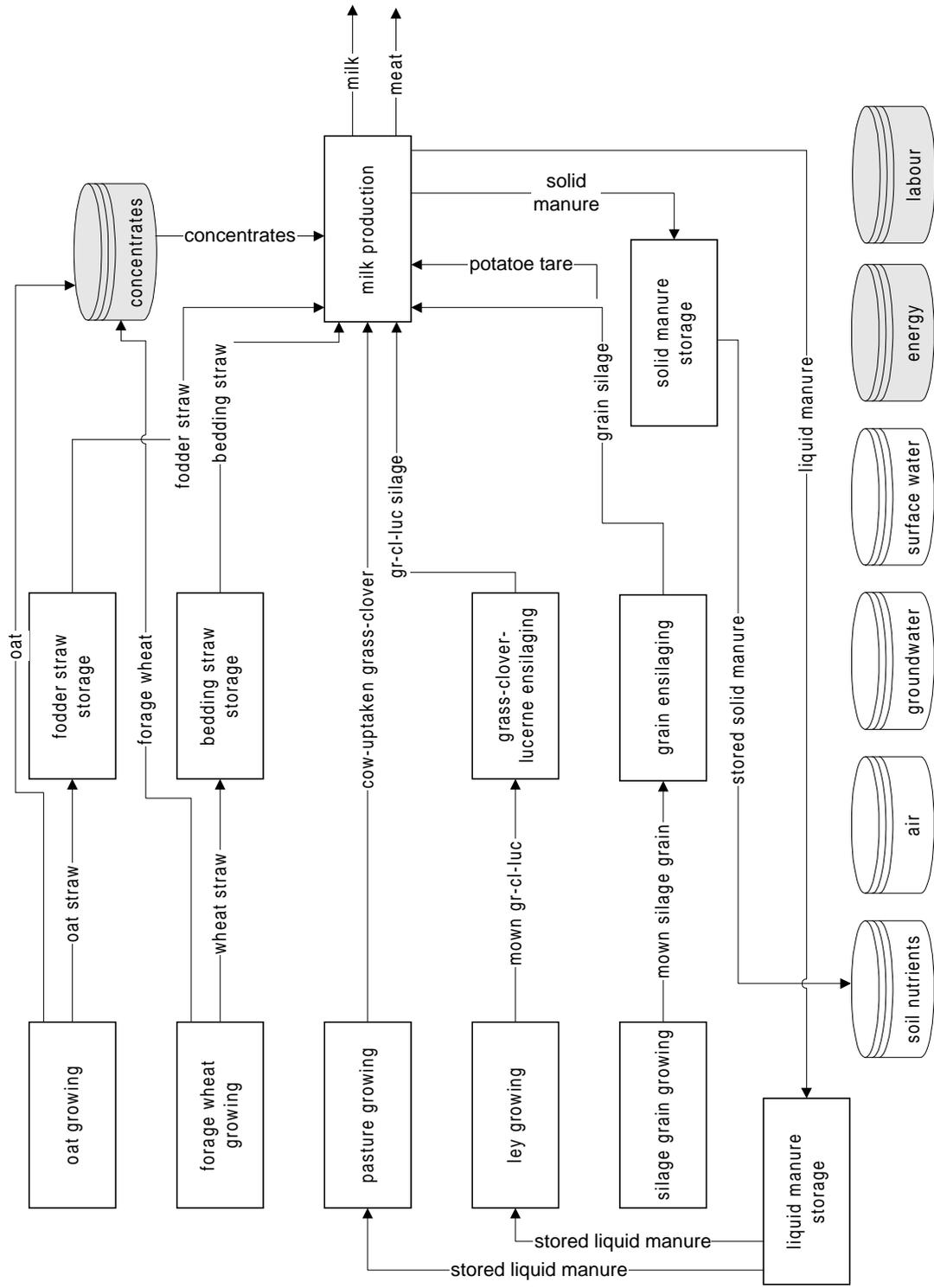
**Figure 3.** An example of a production line (milk production) modelled in terms of product flows. Rectangles represent process units. Drums represent internal (transparent) and external (grey) resources. Only main product flows are shown.

Furthermore the model must be dynamic. First, data must be updated at certain moments and secondly it must be possible to carry out 'what-if-analyses'. The latter function requires definition of transformation functions on input-output relations. These have to be kept as simple as possible. 'What-if-analyses' don't have to provide exact forecasting, but must indicate directions. In addition, soft by-products for each process unit have to be defined quantitatively.

This approach called 'enterprise resource planning' originates from process industry. Looking at one production line, there is convergence of inputs with regard to the main products, but divergence with regard to wastes, emissions and by-products. In highly specialised industry, which is comparable to intensive agriculture like factory farming, this convergence results in high amounts of – often undesired – output. In a mixed farming system, where natural resources are also essential part of the system, this is not the case. In reality these natural resources also exist in specialised farm situations, but then they fall outside the scope of the farm management. We might conclude that this approach results in a more sustainable management of natural resources.

A main difference with industry is that we are not dealing with man-made machines, but ecological systems that have their own autonomous regulation. This makes them less controllable. That doesn't represent a principal difference in model decomposition, but will make its development more heuristic.

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