Farmer Education
Enables Precision Farming of Dairy Operations

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1. ABSTRACT

Precision dairy farming is the application of information technologies to dairy cattle farm management and allows to increase both the performances and the profit of the farm production processes pursuing objectives of low-input, high-efficiency and sustainability. Recent studies clearly showed that the critical point of adoption rate of precision farming technology in dairy farms is represented by farmer education level. This paper describes the role of farmer education, and its constraints, on driving the efficacy of precision farming techniques adopted by a certain dairy farm. The paper also describes a possible application to a specific dairy cattle production area in Italy. The proposed conceptual model showed as farmer education enables and stimulates the efficacy of precision farming technologies. The conceptual map consisted of 6 causal-loop named: Precision farming; Reports; Break even; Efficiency target; Farmer background; Education demand. Further developments should include the stock and flow diagram of the reviewed relationships and the model calibration using local information on farmer capabilities.

2. INTRODUCTION

Precision agriculture consists in the application of information technologies to production agriculture. Precision dairy farming, in our specific case, is the application of information technologies to dairy cattle farm management. The adoption of techniques of precision agriculture is conceptualized by a system approach aimed to re-organize the total agriculture system pursuing objectives of low-input, high-efficiency and sustainability (Shibusawa, 1998). Due to the advances in technology and information systems, agricultural industry is now capable of gathering large comprehensive data on production variability in both space and time (Zhang et al., 2012). Emerging technology of precision agriculture allows farmers to adjust for within the variability of each production unit (field, animal, etc.). The aspiration to respond to such variability on a fine-scale tuning has become the goal of precision agriculture (Whelan et al., 1997).

As summarized by the Figure 1, the efficacy of the precision agriculture allows increase both the performances and the profit of the farm production processes. The adoption of precision farming techniques assumes the activation of a reinforcing loop that turns-on with the investment in technology. Technology provides information on the production processes (recorded data, etc), and acts stimulating the planning of strategies to improve the production efficiency. The gain in efficiency, expressed in terms of additional profit, should be partially invested in more technology, enhancing the precision agriculture level of a given operation (Figure 1).

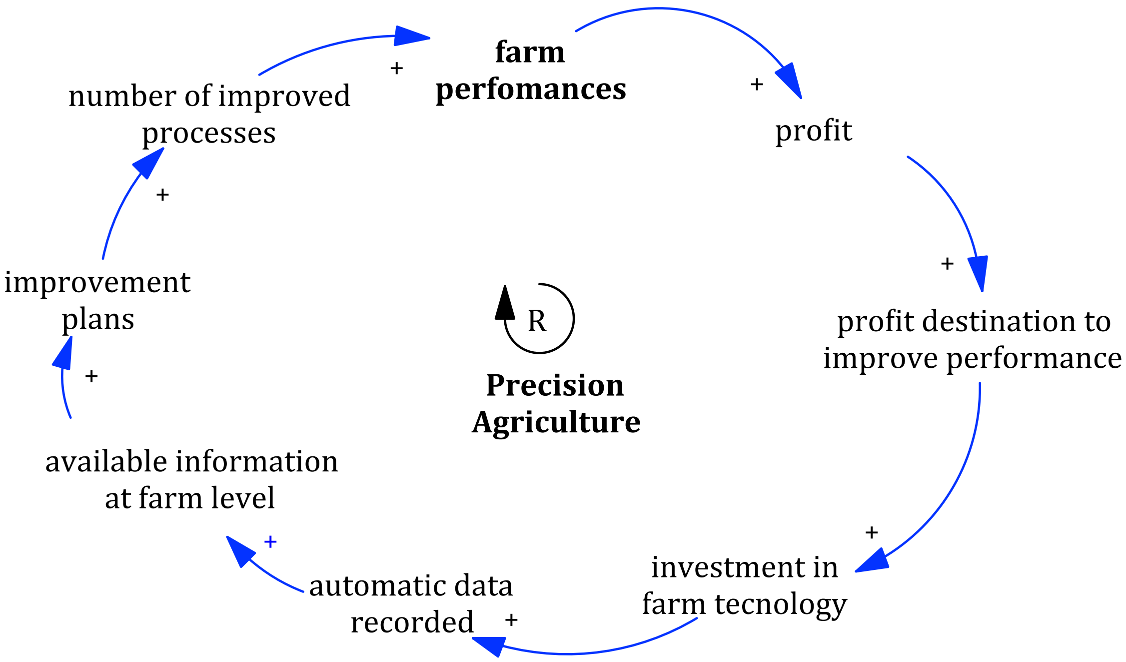

Figure 1. Theoretical role of the adoption of precision farming practices in a generic agricultural farm.

Both economic and environmental targets of production efficiency are pursued by precision farming (Brown et al., 2012). The ecological footprint approach, used to determine the environmental cost of anthropogenic activities (Kitzes et al., 2008), highlights the role of the precision agriculture in lowering the environmental cost of food production. It is based on the statement that an increase in production efficiency, based on the minimization of the input used to obtain a given product, could help to save natural resources.

A system dynamics model was developed by Fisher et al., (2000) to describe the potential adoption rate of precision farming in agribusiness management. Fisher et al., (2000) used a diffusion model, inspired to the studies of Homer (1987), to demonstrate the utility of sophisticated management tools in aiding decision making of agribusiness managers. In particular, they used the SD approach to forecast the farmer adoption and the resulting diffusion of yield monitor and mapping technologies. Considering all stakeholders of agriculture production, the authors included the initial capability in economics, agriculture and performance among the exogenous factor whereas the learning variable was defined as “formed in a somewhat more complex fashion being affected by technology capabilities”. The final model of Fisher et al., (2000) accounted for attitudes towards new technology adoption considering different ranges of age of adopters.

In a recent survey on dairy farmers opinions, Bewley and Russel (2010), suggested that many factors could limit the adoption rate of precision farming technologies (Table 1).

Table 1. Factors influencing slow adoption rates of Precision Dairy Farming technologies (adapted from Bewley and Russel, 2010).

Factor	**Farms, N**	**Frequency, %**	**Related with farmer education***
Not familiar with technologies that are available	101	55	YES
Undesirable cost to benefit ratio	77	42	NOT
Too much information provided without knowing what to do with it	66	36	YES
Not enough time to spend on technology	56	31	YES/NOT
Lack of perceived economic value	55	30	YES
Too difficult or complex to use	53	29	YES
Poor technical support/training	52	28	YES
Better alternatives/easier to accomplish manually	43	23	YES/NOT
Failure in fitting with farmer patterns of work	40	22	YES/NOT
Fear of technology/computer illiteracy	39	21	YES
Not reliable or flexible enough	33	18	YES/NOT
Not useful/does not address a real need	27	15	YES/NOT
Immature technology/waiting for improvements	18	10	YES/NOT
Lack of standardization	17	9	NOT
Poor integration with other farm systems/software	12	7	NOT
Compatibility issues	12	7	NOT

* our consideration on original items.

From our point of view, data reported by Bewley and Russel (2010) clearly showed that the critical point of adoption rate of precision farming technology in dairy farms is represented by farmer education, often related with the most common opinions of the farmers reported in Table 1. For that reason this paper aims to focus on the role of farmer education and its constraints on precision dairy farming. The paper describes the causal loops involved in the success of precision farming adoption and a possible application of the model to a specific dairy cattle production area in Italy.

3. THE SYSTEM DYNAMIC HYPOTESYS OF PRECISION FARMING

3.1. Adoption of precision farming techniques in dairy cattle farms

Precision dairy farming is based on different disciplines including informatics, biostatistics, ethology, economics, animal breeding, animal husbandry, animal nutrition and process engineering (Bewley and Schutz, 2008). The main reason to approach with precision dairy farming is to focus the performances of the individual cows within the farm instead to focus the average goals reached by the farm or the cattle groups. Technology is used in this contest to measure animal and environment parameters and to record and/or elaborate the gathered information in order to get feedbacks from the production process and support the decision making process.

The main objectives of precision dairy farming are: 1) to avoid herd losses and in particular to avoid the animal medical treatments by reducing the detection time of diseases; 2) to maximize the individual cow production and its efficiency by improving cow management. In these terms precision dairy farming should stimulate increases of economic benefits both for cost reduction and additional yield; furthermore it improves environmental benefits due to the reduction of input used in the farm operations per unit of product.

In this contest we developed a conceptual model of forces driving the efficacy of precision farming techniques adopted by a certain dairy farm. The causal map of the conceptual model is described by the causal loops reported in Figure 2 and named as following:

- Precision farming (R1): consist of a reinforcing loop based on the concepts underlined in Figure 1. It is divided in two loops (R1a and R1b) to account for the two main advantages generated by the adoption of precision farming technologies (i.e. reduction of herd losses and additional milk production, respectively). The loops show that the adopted technology allows to: increase the number of information available at cow level, improve the farming practices, obtain profits that can be in turn invested in more technology, further improve the farm efficiency.
- Reports (R2): the reinforcing loop acts within the loops R1a and R1b explaining how they work. In fact, R2 tracks the information flow coming from farm technological equipment; gathered information from farm equipment are commonly summarized in automatic reports which must be read from the farmer in order to focus inefficient areas and practices.
- Break even (B3): the balancing loop describes the effect of the cost of the adopted technology on the profitability of the investment.
- Efficiency target (B4): the balancing loop describes the improvement of the efficiency allowed by the reduction of herd losses. It assumes a minimum target of losses and a gap between present and target values of herd losses; the expected reference mode of the herd losses is a goal seeking behavior.

- <u>Farmer background (B5)</u>: the balancing loop represents the bottleneck of the system. In fact, the assumption of success for the adopted precision farming technology only works if the farmer has enough background to read automatic elaborated reports, to understand it, and to get the right skills to apply adequate changes to farm production processes.
- <u>Education demand (R6)</u>: the reinforcing loop is activated by the loop B5. In fact, the faster the farmer increase his competence, the faster he performs good report analysis and the faster he perceives the potential improvement allowed by adoption of precision farming; it, in turn, stimulates an higher level of farmer education, to take even more advantages from adopted (or adoptable) technology.

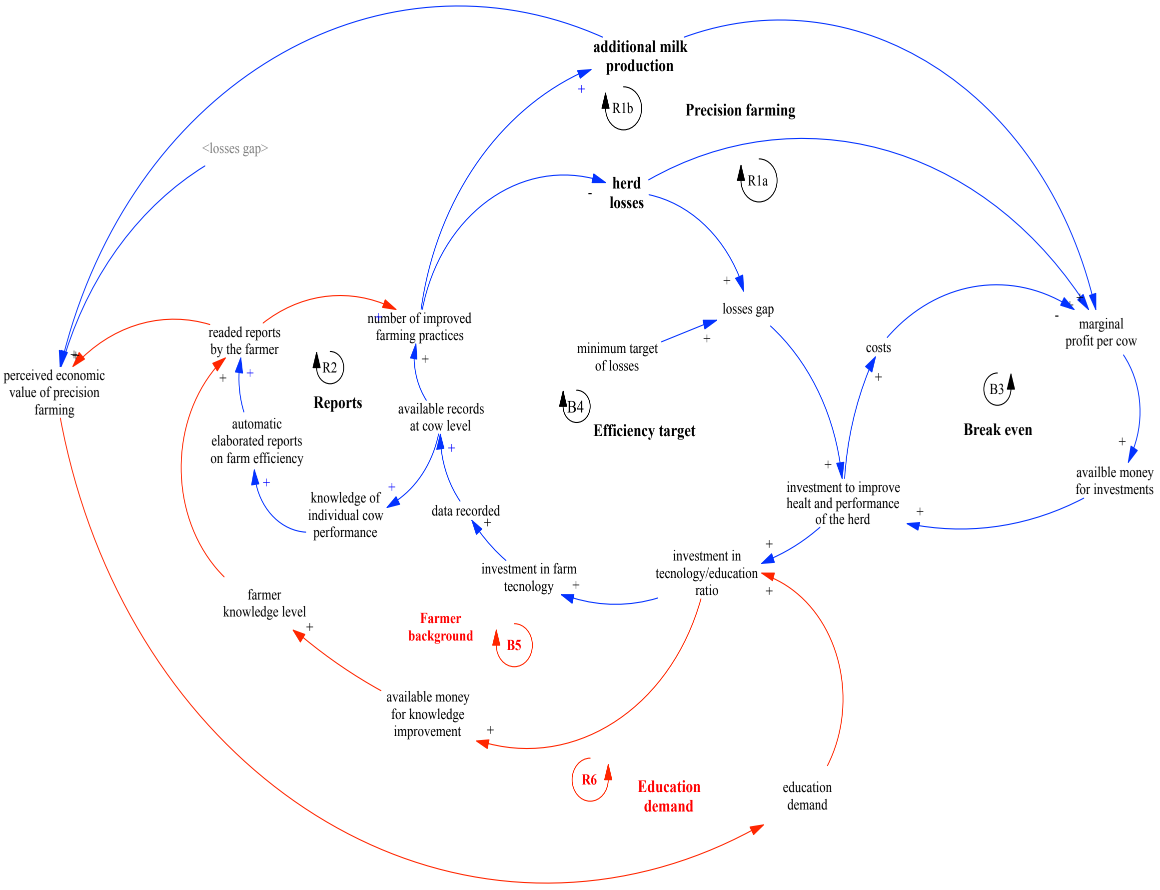

Figure 2. Causal loop diagram indicating the role of farmer educations plans to strength the efficacy of precision farming technology adopted by dairy cattle farmers.

3.2. Hypothesis on the role of farmer education

In our system boundary Farmer Background (B5) represented the bottleneck of the precision farming success whereas the Farmer Education (R6) represented the possibility of escalation for the system success.

As observed by Bewley and Russel (2010) and by Fisher et al., (2000), either the adoption or the utilization of high technology equipment are limited by capability constraints. From this point of view we can suppose three different scenarios evolving from low farmer capability:

a) low adoption rate, if farmers do not invest in technology due to failure in perception of benefits from precision farming;
b) high adoption rate, if marketing policies could be able to sell available technologies even if farmers would not be able to use it; in that case the dairy sector will not reach any benefit from precision farming;
c) high adoption rate, helped by marketing policies including technical support for decision making able to cover the lack of background of farmers; in that case benefit from precision farming could be reached with additional costs.

Considering the options a) and b) we suppose that increase the farmer education could enable the precision farming adoption and its efficacy both at farm and at territorial level.

4. MODEL APPLICATION TO A SPECIFIC PRODUCTION AREA

Target area of model application is the province of Oristano. It is a small area where are located about 200 dairy farms intensively managed; the farms are also associated in a multiple cooperative system for buying inputs and selling products. They operate in a very high homogeneous condition of production in terms of farm size, input availability and economic market. A precision agriculture project has recently been presented to the Sardinia Regional Government by a group of those farmers in collaboration with the local milk plant, the local farmer association, a software house, and various academic partners. The project aimed to increase the efficiency and the sustainability of the production system by adopting high technologies of precision farming to support the herd management (animal feeding, animal reproduction, animal healthy, etc.).

The proposed conceptual model has been developed in order to study the adoption of precision farming practices in the area of Arborea (Province of Oristano – Sardinia - Italy). Further developments of the model must include the model translation in a stock and flow diagram and its subsequent calibration with local information. Existing information must be integrated with new information to be collected in order to study the potential effects of adopting precision farming in the Arborea area (Table 2).

Existing information is mainly based on: present farm performances, farm technology level, potential improvement of animal and farm performances, available precision technologies that could be adopted to reach targets of improvement.

Pursued information mainly regarded the background level of farmers, the capability constraints and the estimation of the effect and costs of education needs and demand in order to enable the precision farming use and efficacy.

Table 2. Examples of information existing and required to study the potential effect of farmer education on the adoption of precision farming technologies in the dairy cattle production area of Arborea (Province of Oristano – Italy).

Available information	**Examples of adopted level of technology, potential improvement and education**	**Score***	**Information available**
Milk yield per cow	Robot; daily records; monthly records; nothing	3 – 2 – 1 - 0	YES
Intake on time unit	Robot; estimated intake; nothing	2- 1- 0	YES
Reproduction data	Activity + Vet. data; activity; Vet. Data.	3 – 2 – 1 - 0	YES
Diseases per cow	Economic expenses; vet. data; nothing	2- 1- 0	YES
Available technology	Equipment and software in the market	From 5 to 0	YES
Potential improvement	Effect of technology on recorded data	From literature**	YES
Potential improvement	Effect of information on available reports	From literature**	YES
Potential improvement	Effect reports on process improvement	From literature**	YES
Potential improvement	Effect of improvement on farm profit	From local data**	YES
Farmer background	Instruction degree	From 4 to 0	YES
Farmer background	Self learning (journals, course, seminars)	From 4 to 0	NO
Farmer background	Understanding of herd efficiency indicators	From 4 to 0	PARTIALLY
Farmer background	Understanding of information technologies	From 4 to 0	NO
Education needs	Cattle nutrition, reproduction, welfare, etc	From 3 to 0	NO
Education needs	Economics, farm management, laws	From 3 to 0	NO
Education needs	Informatics	From 3 to 0	PARTIALLY

*Score attributable to a certain farm in order to quantify its precision farming or background level (higher score higher level). ** to be deducted from available information.

5. CONCLUSIONS

A conceptual model on precision farming has been developed to preliminary analyze the importance of farmer education on the adoption and efficacy of precision agriculture techniques in the dairy cattle production area of Arborea (Oristano Province – Italy). The proposed conceptual model focused the role of farmer education to enable and stimulate the efficacy of precision farming technologies. The present state of the research cover the causal loop map of the studied problem; further developments includes the stock and flow diagram of the reviewed relationships and the model calibration on local information. Local information are partially existing, such as farm performance and data on potential effects of available technologies on system efficiency, whereas others information have to be collected with adequate surveys regarding the farmer’s initial capability and their education demand.

6. AKNOWLEDGMENTS

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