NEW INNOVATION APPROACHES IN PRECISION FARMING – THE EXAMPLE OF THE BASE FERTILIZATION PROCESS

S. Klingner, J. Friedrich, and M. Becker

Department of Business Information Systems
University of Leipzig
Leipzig, Germany

M. Schneider

Agri Con GmbH
Precision Farming Company
Ostrau, Germany

ABSTRACT

Recent years have shown tremendous precision farming innovations. However, these innovations are currently limited to new equipment (hardware) and software. What is missing is the link between these two innovation dimensions, especially in service driven approaches: process management. In this paper, we present a holistic approach for supporting efficient and effective precision farming processes. It is based on an improved soil sampling device and an appropriate tool called IPS. The approach is evaluated based on the use case base fertilization.

Keywords: Precision Farming services, information management, service engineering, Base Fertilization, Soil Sampling

INTRODUCTION

As in other economical domains, customers of Precision Farming (PF) companies demand highly individualized services and detailed results (Manzini, Vezzoli and Clark 2001, Piller and Kumar 2006). To satisfy these demands, collaborations between various companies (service consortiums) are increasingly required. In doing so, every company can provide its effective approaches in a productive way (Meca and Timmer 2007, Min, et al. 2005).

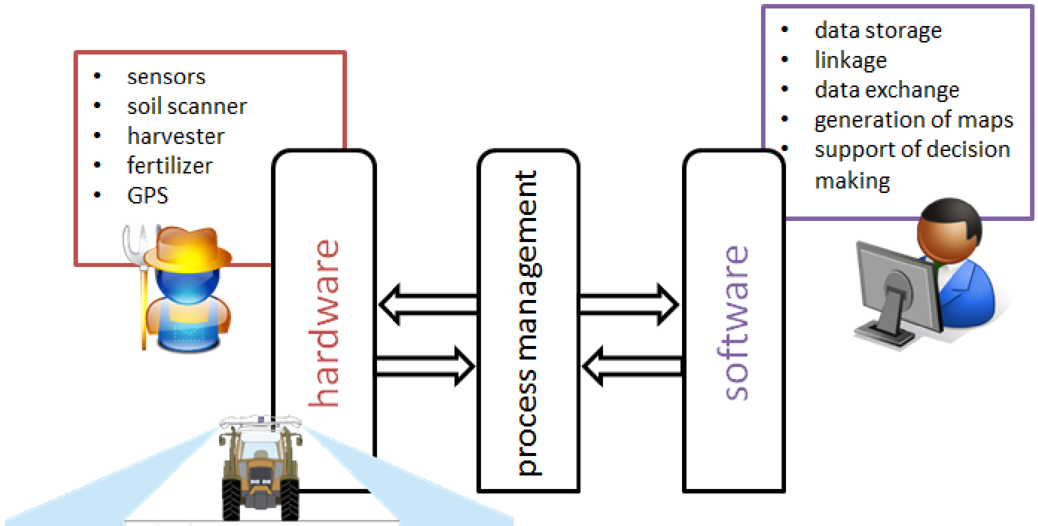

Figure 1. Precision Farming Innovation Dimensions

For efficient service provision technological innovation has to be complemented with elaborated strategies for application of these technologies. Likewise, the scalability of service approaches represents a challenge, while business models should provide the flexibility to limit risks due to seasonality or weather. Thus, innovation in precision farming has to be raised to the next level.

Innovation dimensions in PF can be divided into the three dimensions *hardware*, *software* and *processes*. Using hardware like sensors, it is possible to gather large volumes of data that can be monitored, interpreted and post processed by software. In addition, the process dimension is relevant for providing efficient services by linking the other dimensions (see Figure 1). We argue that past research mainly focused on advancements of the first two dimensions, whereas process aspects were not sufficiently considered. Therefore, the solution presented in this paper follows a threefold approach, including all three dimensions. To illustrate the holistic approach in a practical context, the base fertilization process is used as an example.

The solution consists of a newly developed, innovative soil sampling device as exemplary hardware, web-based software for visualizing, calculating and managing the corresponding results in terms of nutrient distribution maps as well as application maps and a process structure to link hard- and software as efficiently as possible.

The paper is structured as follows. After giving a brief overview on services in the domain of PF, dimensions for innovation in PF are described in the paper. By means of a use-case, the previously introduced innovation dimensions are exemplary presented and described in detail. This allows for a practical presentation of the theoretical findings.

SERVICE ENGINEERING IN PRECISION FARMING

Similar to manufacturing and software engineering, service engineering is an approach focusing the efficient and effective development and management of services (Fähnrich and Meiren 2007). Service engineering provides methods and tools covering the complete service lifecycle, starting from the conception and realization of new services to the optimization of existing services. Therefore, the identification of relevant internal and external factors influencing the service provision is fundamental.

In PF, the increased complexity leads to a higher demand for services. Where highly specialized methods and tools for analysis and processing are developed, the necessity for external expertise and *co-operation* of various stakeholders reveals. Farmers are rarely able to afford expensive technology or do not have the knowledge or skills to perform the required activities on their own (Reichardt and Jürgens 2009). Therefore, many tasks in PF are conducted collaboratively in specialized service consortiums leading to a growing complexity of value chains. Accordingly, processes need to be managed comprehensively to allow for efficient and productive service provision, transparent for all participated stakeholders.

Next to the above mentioned aspect of *co-operation* there are other factors that influence the service planning and provision in agricultural processes in general (Klingner 2013). These factors are *weather dependency*, *seasonality* and *dispersion*.

Due to the fact that almost every farming process requires for certain *weather* conditions (haying requires dry weather; for soil sampling, an appropriate soil moisture content is needed etc.), service providing companies need to develop flexible service processes, to allow for an efficient short-term scheduling of personnel and equipment.

Also *seasonal* variability has great impact on the productivity and efficiency of service provision in PF. In the agricultural domain, the growing and harvesting cycles define the timeframe of the processes. Furthermore, the challenge of efficient capacity utilization emerges. This challenge is characterized by the trade-off between overconsumption and underconsumption of resources. For example, trained employees need to be held available throughout the whole year even in times when certain services cannot be provided. Therefore again, services need to be able to meet the farming domains' need for flexibility.

Furthermore, service providing companies have to deal with the high level of *dispersion* in agricultural structures. While some regions are dominated by a few agricultural holdings with large farm-size, especially farmers with small- and medium-sized farms are potential customers for service providing companies. Since they cannot effort the cost for comprehensive PF methods on their own, purchasing services is a reasonable alternative to benefit from the advantages of these extensive methods. In order to meet their customers' requirements without losing their productivity, service consortiums in turn need to develop strategies to handle the regional dispersion.

Based on these challenges, it is feasible to assume that productivity improvements cannot be achieved by software and hardware innovations solely. To tap the full potential of new hardware and software innovations, likewise services in PF need to be focused. Therefore, the following chapter introduces a holistic approach, covering hardware, software and service as the three dimensions of innovation.

INNOVATION IN PRECISION FARMING

Nowadays, innovations in Precision Farming are mostly bound to further developments and new solution approaches on the technical level. However, for efficient provision of services the management of processes is essential as well. The following chapters give an overview of the various dimensions of innovation in Precision Farming.

For a precise management of cultivation processes, conventional farming *hardware* has been modified and equipped with satellite-technology and various sensors (Lu, et al. 1997, Reyns, et al. 2002). Furthermore, new agricultural machinery like soil scanner or aerial drones are launched onto the market to optimize the cultivation process (Raush, et al. 2013, Wal, et al. 2013). Therefore, farmers can choose from a wide range of PF hardware. However, training is necessary to fully utilize the new equipment. In addition, small- and medium-sized farm owners are often not able to purchase expensive equipment (Reichardt and Jürgens 2009).

For performance measurement purposes, the activities conducted on the field are usually logged nowadays. Since raw data has no value for its own it needs to be stored, processed and analyzed for extracting knowledge. These activities are supported by *software*. It is also possible to utilize additional information like meteorological data or historical yield data for a comprehensive interpretation of the data set. Thus, the decision making process can be supported adequately.

As mentioned above, the two dimensions hardware and software need to be linked appropriately to ensure an efficient cooperation between all stakeholders. Thus, it is also necessary to implement *process management* additionally.

To achieve innovation on the dimension of processes, existing service processes have to be recorded, modelled, analyzed and optimized. This way, inefficiencies like media disruption or even data loss through transfer of data between various systems can be specifically identified and avoided (Bendell 2005). Simultaneously, interfaces that are necessarily required for an appropriate co-operation of various stakeholders become obvious and can be defined precisely. By providing these interfaces, an appropriate data management with failure free and efficient data transport and data processing can be ensured.

Thus, a detailed management of all process steps supports a fluent workflow. To support optimized processing, software like information system (IS) which is adjusted to the certain specific needs of these processes can be used.

THE USE CASE OF BASE FERTILIZATION

To illustrate the findings presented in the previous chapters, the exemplarily use case of base fertilization is introduced. Basically the use case consists of three steps. First, the soil samples have to be taken on the fields which must be supported by specialized hardware solutions. Second, the soil samples have to be analyzed in laboratories. The results as well as the derived fertilization recommendations have to be presented to the customer. Third, the required resources – hardware, software and human resources – for providing the base fertilization service need to be integrated efficiently. Therefore, the corresponding processes have to be defined and adequately supported. In the following paragraphs, the three steps are presented in more detail.

Soil sampler "on-the-go"

With the soil sampler "on-the-go", a totally new soil sampling concept was developed to accelerate the soil sampling process in the field as well as assuring a high soil sampling quality. Soil sampling has been a time-consuming manual process, where every single soil sample had to be taken by hand. This means, that the sampler had to stop his car, manually trigger the soil sampler, collect every singly soil sample from the sampling machine and number it in accordance to the protocol sheet.

For the new soil sampling "on-the-go", the unit is mounted to the back of an off-road car and is powered from the car's on-board electronics only. Without stopping the car, the soil cores are taken in the soil sampling zone. The soil sampling depth can be adjusted between 0-10 and 0-30cm. The soil sampling velocity on the field is between 10-13km/h. Thus, a soil sample on a 3-ha-grid cell, consisting of 20 cores, can be taken in 3 minutes.

Agri Port

The web-based software Agri Port was developed to provide a cloud based precision farming data management tool where the user can start immediately with the agronomic analyses of his information. Furthermore, Agri Port is used to turn the site-specific information into agronomic management recommendations. The farmer is able to reconstruct the whole process of nutrient mapping. Agri Port illustrates all the sampled fields with corresponding time designation, analysis data are available with a single click on the requested sample (actual as well as former analysis data) and cultivation recommendations are given. With a few clicks, the farmer can download the application file in the right data format required for controlling the site-specific application of e.g. base fertilizers.

With the web-based approach, also the crop consultant can have access to the data and provide consultation. The monitoring of all service steps makes the entire process highly transparent for the customer and the provider.

Information-production-system (IPS)

IPS is a collection of defined business processes and corresponding tools which support the service provision. The software consists of two modules. While the module *IPSmobil* supports the work on the field by automated data acquisition and protocol generation (before, the manual completion of the protocol sheet, where GPS-data of the taken soil samples, soil classification and additional farm data has to be noted, was a time-consuming process), the module *IPShq* supports the interaction between all service partners providing standardized data formats. This allows for an efficient, media-disruption-free communication. Therefore,

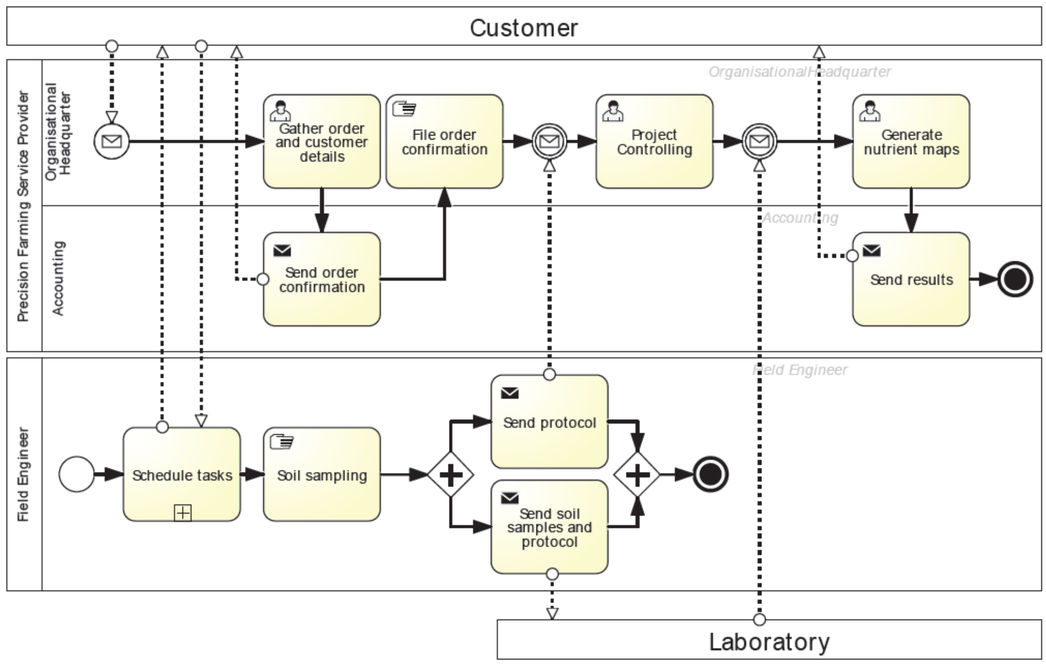

Figure 2. IPShq Process Snippet

adequate interfaces needed to be defined and tools for data processing had to be integrated. This highly standardized service provision leads to an increased productivity and quality.

Figure 2 depicts a snippet from an *IPShq* process. Using these standardized processes, it is possible to identify weak points and problematic process parts. Furthermore, the process advance can be monitored and presented to the customer in real-time. This might also be complemented by an assessment of the remaining processing time.

EVALUATION

To evaluate and quantify the benefits of the introduction of the newly developed systems in praxis, the hardware and software were tested by various technicians. To be able to determine the individual effects of the two systems, the soil sampler and *IPSmobil* were used in different combinations in the field. Afterwards, the log files of three months of soil sampling by ten different technicians were collected. Based on the values extracted of the log files the required amount of time for taking soil samples was calculated. The results are shown in Table 1.

Table 1. Log data for field workers

SoilSampler	IPSmobil	#Technicians	#Samples	Min	Max	Avg
Old	Old	4	2993	291.00s	754.80s	470.65s
Old	New	3	737	287.45s	476.21s	375.71s
New	Old	2	1282	244.50s	249.50s	247.00s
New	New	1	922	200.74s	200.74s	200.74s

The data presented in Table 1 displays the different combinations of systems that were analyzed. It is necessary to note that the results merely show tendencies and cannot be used to derive general predictions. This is caused by the fact that the number of technicians is too low. Furthermore, the analysis period only covers three months and, thus, seasonal effects cannot be captured. This is only possible by analyzing the log data of a complete season.

Regardless of these limitations, the effects showed a clear positive trend for both the soil sampler (hardware) and *IPSmobil* (process supporting software). Due to the different combinations of systems, it was possible to distinguish between effects caused by each system component. The results for every situation are depicted in Table 2. The columns reveal the performance improvements based on different starting points: soil sample old (SSO)/manual protocol (MP), soil sampler new (SSN)/manual protocol and soil sampler old/IPS.

As Table 2 shows, the usage of the new soil sampler decreased the required time by about 47%, regardless of *IPSmobil* was used or not. Similarly, the usage of *IPSmobil* sped up the process by about 19%, also independently of the soil sampler. The overall performance gain when using both new systems was about 57%.

Table 2. Effects of different system components

	SSO/MP	SSN/MP	SSO/IPS
SSO/MP	100	/	/
SSN/MP	+47.25%	100	/
SSO/IPS	+20.17%	/	100
SSN/IPS	+57.35%	+18.73%	+46.57%

Using *IPSmobil* does not only have quantifiable benefits as shown in Table 2. By using the software on the field, the protocols do not need to be written by hand. Instead, they are generated automatically. In doing so, it is feasible to assume that the error rate can be decreased. Furthermore, the standardized processes foster communication with different partners based on the automatically generated protocols.

CONCLUSION[1]

This paper shows that in order to provide PF services effectively and efficiently, innovation has to be done in three dimensions. The three dimensions comprise the development of hardware (e.g. soil sampler “on-the-go”), the development of software (Agri Port) and the definition and optimization of processes and development of tools to link the former two (IPS). We argue that past research mainly focused on advancements of the first two dimensions, whereas process aspects were not sufficiently considered. To illustrate this postulation, the development of a new solution for base fertilization has been described using a case study.

Beyond a more efficient provision of precision farming services, the three modules are the precondition to sell not only the service but also the overall system as a franchise concept. While SME continue consumption of the (optimized) services, large customers are enabled to provide the soil sampling service themselves by acquiring the overall system.

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