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A Role of Bio-production Robots in Precision Farming Model of Japan

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Abstract: Community-based precision farming is a new concept of agricultural systems, which leads to organize groups of wise farmers and technology platforms in Japan. The wisdom farmers create a rational farming system to manage hierarchical variability: variability in farmers' community as well as variability of within-field and between-field. The technology platform develops and provides three key-technologies: mapping technology, variable-rate technology, and decision support systems available for rural constraints. Advancement of bio-production robots leads precision farming to the next level, where two technological innovations: how to produce and manage information-oriented fields and information-added products, can be attained.

Keywords: Precision Farming, Innovation, Knowledge Management, Robot

Introduction

Nowadays precision farming has potential to solve intricate issues in agriculture, such as environment versus productivity. It is based on advanced information technology, which includes description and modeling of the soil and plant variability, and integrates the controlled works to meet the site-specific requirements. Precision farming aims at increase in economic returns as well as reduction of energy input and environmental impacts (NRC 1997, SKY-farm 1999).

People tend to consider that precision farming approaches are only available for large scale farms because of their intensive technologies with high cost, and often to estimate that the scale merits can appear on size of the farms with hundreds to thousands of hectares. In Japan, the average farm scale is 1.5 ha and most of the farmers work as a second job. Moreover their ages are over 65 years old in average. We still have a small amount of expert farmers with sophisticated skills and wisdom, producing high quality agro-products and consequently getting income of tens million yen per year. Big concerns of farmers have been how to get confidence from consumers through food supply chains as well as how to increase the efficiency of production and to get/train their successors. Japanese farmers are combating such complex and trade-off problems, which lead to look at the potentials of precision farming of small-scale farms (Shibusawa 1999, 2000, 2001). Bio-production robots have also potential to take precision farming to the next level because of their data-handling ability as well as well-controlled works.

The objective of the work is to introduce concepts of the community-based precision farming model of Japan and to propose a scenario of technology development associated with bio-production robots.

Work Cycle of Precision Farming

High-tech images are engaging in precision farming, which leads us to use information technologies into agricultural practice with the help of systems approach to look at the whole system of farming.

There are three fundamental technologies, as shown in Fig. 1, and the farm works are circularly linked with each other, accumulating the best knowledge and practices (Shibusawa 2000, 2001). Describing the variability in particular within-field variability is the fundamental work. The variability should be understood at least in three aspects: spatial variability, temporal variability and predictive variability over several years. Based on the understandings of the variability, the decision support system provides some feasible solutions for farming practice with respect to trade-off problems such as productivity or profitability and environmental concerns. The decision support system involves data, information and knowledge on crop growth models and market needs. The decision enables the use of variable-rate technology (VRT) for adjusting the agricultural inputs according to site-specific requirements at each location in

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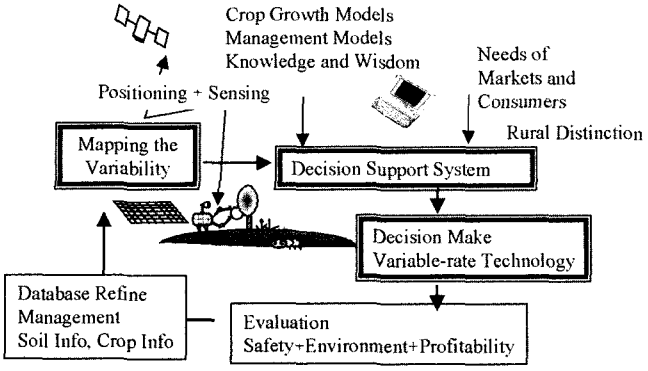

Fig. 1 A developmental cycle of precision farming works.

the field. Consequently the cyclic works enrich the database of farmers in terms of field management, marketing, and cost/risk management. This spiral-developing farm work system is the fundamental feature of precision farming.

Community-Based Precision Farming

Note that precision farming is specialized by variable management, and that the variability requires precision farming approaches. Understanding the variability in-situ is a key point to promote it. In general, there are two types of variability, that is, within-field variability and between-field or regional variability as shown Fig. 2 (Shibusawa 2000, 2003). Within-field variability is embedded in a single field of single plant variety. Between-field variability implies the variability among the fields in which different crops and farm works tend to be managed. When it comes to describe the between-field variability, each field can be treated as a unit of mapping. Consideration needs which variability should be managed for increased economic returns with reduced environmental concerns.

In a single small farm, the farmer can better understand what is going on in each field, which enables to conduct variable-rate application for site-specific requirements with the farmer's knowledge and skills. Overviewing an area of tens hectares including lots of small fields, farmers have to manage the regional variability due to cropping diversity. They also have to coordinate the farmers with different motivations due to different cropping styles, as shown in Fig. 2. Regional precision farming requires how to manage the hierarchical variability: within-field, between-field and between-farmer variability. High-tech approaches like a yield meter with GPS can be available for such a scale of regional precision farming, and moreover measures for environmental concerns should be undertaken in a similar scale of the area.

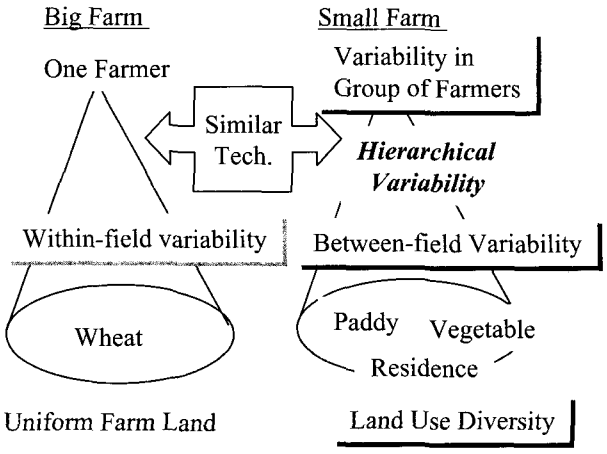

Fig. 2 Hierarchy in variability to be managed on precision farming Japan model.

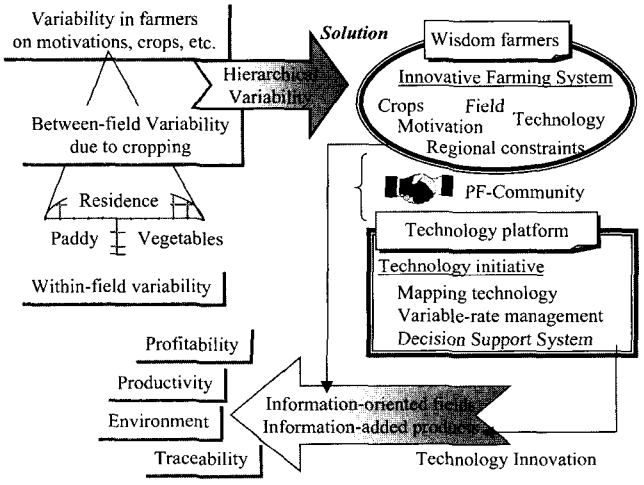

Fig. 3 A Japan model of community-based precision farming.

Managing the hierarchical variability requires two organizations: wisdom farmers and technology platform, as shown in Fig. 3 (Shibusawa 2002). The society of wisdom farmers plays top management of innovation in the regional farming system, such as re-arrangement of five factors of farming system and development of scenarios for introducing the approaches in precision farming. The technology platform develops and provides technologies available for the rural constraints as well as marketing channels for high-quality/ traceable agro-products. A community of the wisdom farmers and the technology platform will produce information-oriented fields and information-added products, which can reply to the consumer confidence as well as farmer' motivation, such as increases in productivity, profitability and traceability, reduction of environmental concerns.

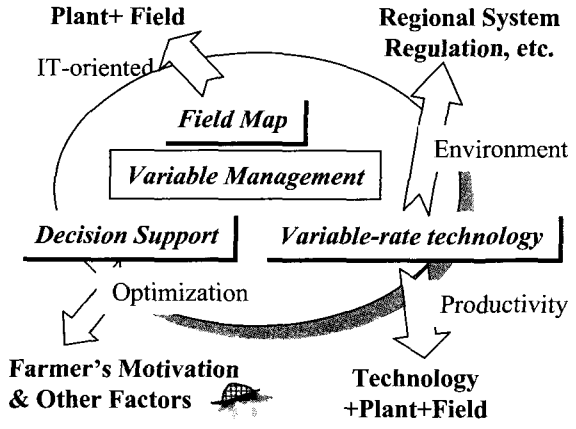

Fig. 4 Precision farming technologies change the whole system of agriculture.

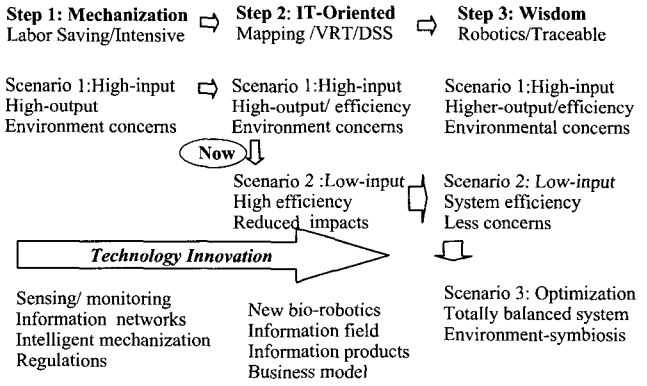

Fig. 5 Development of technology level and farming strategies.

In general, a farming system consists of five factors (Shibusawa 1999, 2000): plant variety, field feature, technology, regional infrastructure, and motivation/intention of farmers. Better integration of the five factors can create a competitive farming system fitted with domestic conditions/ constraints.

Precision farming offers a variable management incorporated with field maps, variable-rate technologies and decision support system. As shown in Fig. 4, generating the field maps makes plant and field factors information-oriented. Variable-rate technology not only increases the efficiency with re-organizing the three factors; technology, plants and fields, but also creates a better solution suitable for the regional infrastructure and/or constraints, such as environmental regulations. The decision support system provides system optimization techniques, which fairly impacts farmers' motivation as well as all factors to be re-organized. Consequently, precision farming brings about an innovation in the whole system of agriculture as it is.

Strategies and Scenarios

There can be three steps in technology development and three strategies for precision farming in Japan, as shown in Fig. 5 (Shibusawa 1999). Step 1 is based on the conventional farming technology with intensive mechanization for labor saving and high quality operations. Step 2 is the stage of developing mapping techniques, VRT machines and DSS in the basis of innovation by information technology. Step 3 is a maturity stage of wisdom-oriented technologies associated with bio-production robots.

Scenario 1 is a strategy of "high-input and high-output" system, Scenario 2 has a strategy for "low-input but constant-output", and Scenario 3 aims at "optimized input-output balance" as the goal of precision farming. Technology innovation gives us freedom of choice in the scenarios.

Nowadays agriculture is dramatically changed from technology step 1 to 2 and scenario 1 to 2. The matured stage of Step 2 is driven by two innovative technologies: field monitoring and agro-products monitoring with robotics, which can produce information-oriented fields and information-added products.

Fig. 6 shows an avenue to encourage precision farming development (Shibusawa 1999). First of all, describe the variability within/without the cultivating fields. Sensors with GPS and monitors for machine application make it easy to measure and describe the variability. Understandings of the variability provide issues to be managed with information-oriented technology and optimization algorithms. A new technology and software can describe the variability in new aspects, which enhances the spiral development of those technologies. Agricultural robots can offer a new phase of

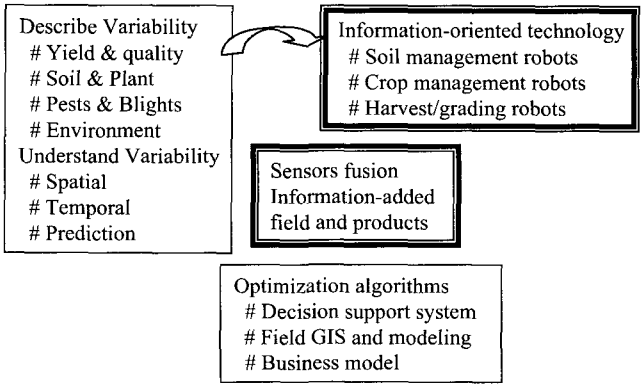

Fig. 6 Spiral development on precision farming technologies.

technology spiral since data/information handling mechanisms have already been installed.

Conclusions

Precision farming Japan model should be community-based with wisdom farmers and technology platform. The wisdom farmers manage the hierarchical variability: variability in farmers' community as well as within-field and between-field variability. The technology platform provides three key-technologies: mapping technology, variable-rate technology and decision support systems available for the rural constraints. Advancement of bio-production robots takes precision farming to the next level because of its potential of data/information handling mechanisms installed, where two key-technologies: how to produce/manage information-oriented fields and information-added products, are sophisticated.

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