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Smart Transformation of Community-Based Approaches in Japan

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ABSTRACT

Digital farming is the latest stage of modern agriculture, which let us lead to the question "who makes decision on farm management with full of data?" Exploration for answering to the question needs at least two storyboards of thinking in a systems approach: a new stage of farm work mechanization and a new phase of farm work decision in physical and cyber spaces. Typical topics introduced here were: four phases of decision in precision agriculture, community-based approaches, digital farming scheme and target, cyber-physical farming model, and policy linkage, which are usually involved in the movement of agricultural transformation. These topics will help readers to explore the future farming schemes in countries.

Keywords: precision management, community-based, cyber-physical, mechanization

INTRODUCTION

In 2020 the COVID-19 pandemic has changed the whole lifestyle and social system in the world and still the pandemic disaster is currently affecting a lot of people. Smart transformation has been driven by changes in digital communication networks, which was attacked by the pandemic with systems down. There have been trials conducted to re-construct the new institutional and digital networks under such constraints.

Population decreasing society has come in Japan with lots of new complex issues, such as shrinks of local community and industry. Community-based approaches were useful to combat against such complex or trade-off issues in the fields of not only agriculture but also local society (Shibusawa 2015). Systems are changing in the sectors of not only industry but also administration during the last five years (Shibusawa, 2016b). Smart society 5.0 was a phrase of target in the 5th 5-year basic program for science and technology innovation in Japan (CSTI 2016), which covered agricultural sectors: a smart food chain system and a smart agricultural production system. This implies that the agricultural issues became critical in the government policy of Japan, such as losing expert skills and knowledge, less new-coming young farmers, frequent damages by natural disasters, and market pressures. Furthermore, there still have been conventional constraints, such as people who are still convinced that traditional practices and social ways of decision making, can lead leaders to change through smart transformation.

On the other hand, Japanese industry and economy has experienced long-term depression effects and a new break-through event has been expected. The agriculture has got a lot of interest as people are exploring new frontiers in industry innovation, and that is why advanced technologies were expected to be applied into agricultural sectors. The STI program has promoted the innovation in agriculture and related business fields. People called the new projects by phrases like "smart agriculture" and "smart food chain". Goals of the projects tended to be shown by different terminology, such as "cost-effective and market-in farm management", "restoring/rehabilitation from disasters", "agro-medical foods for health and life", "water conservation agriculture", and "STI has oriented SDGs practices".

The ICT strategy of agriculture was also issued by the government to enhance the interoperability and portability of data/information (SHIT 2014), which has encouraged the inter-ministry projects and activities as well as the collaboration between different sectors of industry. An idea of agro-medical foods was also re-organized in 2016 to expand the fields of precision agriculture (Shibusawa 2016a).

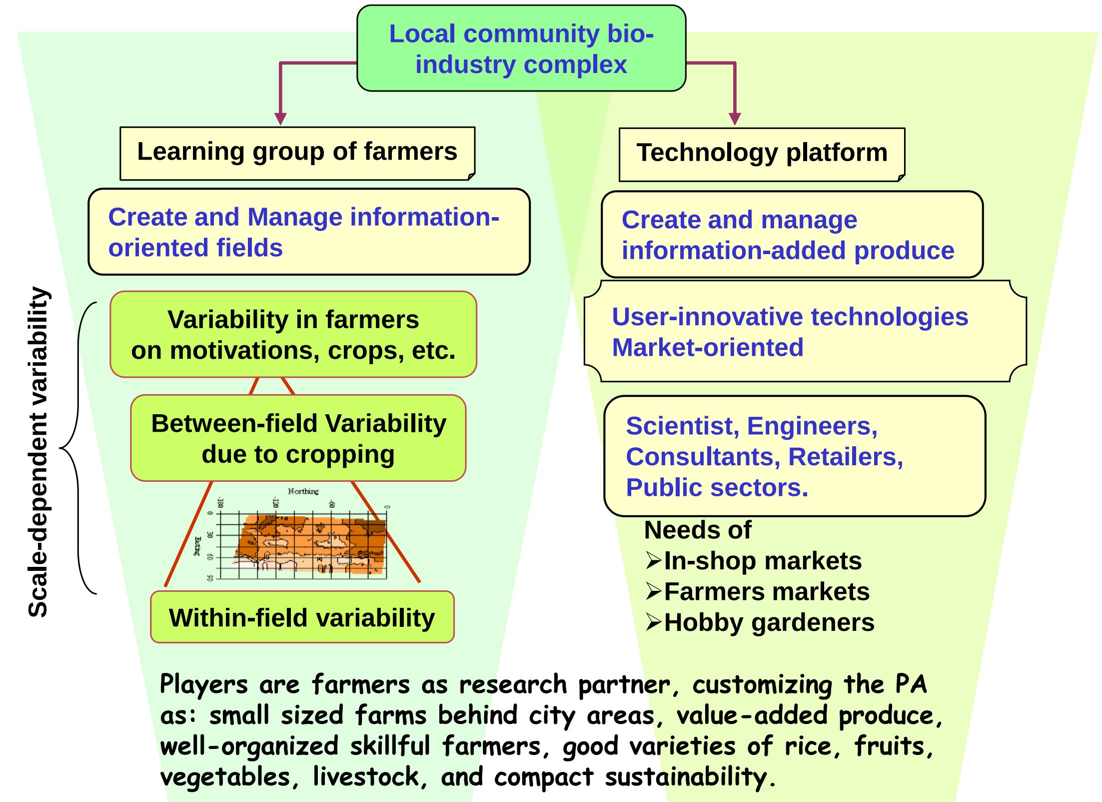

Figure 1. Scheme of Community-based precision agriculture.

The objective of the paper is to discuss the current trends in precision/smart agriculture focusing on farmer-centric on-farm experimentation with technology innovation and policy linkage toward agricultural transformation.

CONCEPT OF COMMUNITY-BASED PRECISION AGRICULTURE

Prior to describing the community-based approach, it would be better to confirm the definition of precision agriculture and smart agriculture as follows.

Precision Agriculture is a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production. (https://www.ispag.org/about/definition, 2020).

Smart agriculture is the use of new advanced technologies within the food system to promote sustainable productivity by allowing farmers and other stakeholders to make more informed, appropriate decisions. Existing and emerging technologies like big data, online meteorological data, digital technologies, and analytics are important components of smart agriculture technologies. (APO Agricultural Transformation Framework, 2019)

A structure of community-based precision agriculture is composed of two organizations, learning group of farmers and technology platform of industry, and five stakeholders to collaborate with, as shown in Fig. 1 (Shibusawa 2007, 2015). The farmers manage scale-dependent variability of within-field, between-field and farmers' motivation. Consideration needs which variability should be managed for increased economic returns with reduced cost and environmental concerns. It is obvious in Japan that between-field variability is a main target of management because of a style of co-shipment from small fields and inevitably standardized co-working is required. In such a situation digital technology helps farmers for well-organized actions.

In the practice of management, there are different stories in action when one looks at the field variability in different scales. 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 farmers' knowledge and skills. When it comes to covering an area of a few tens hectares including lots of small

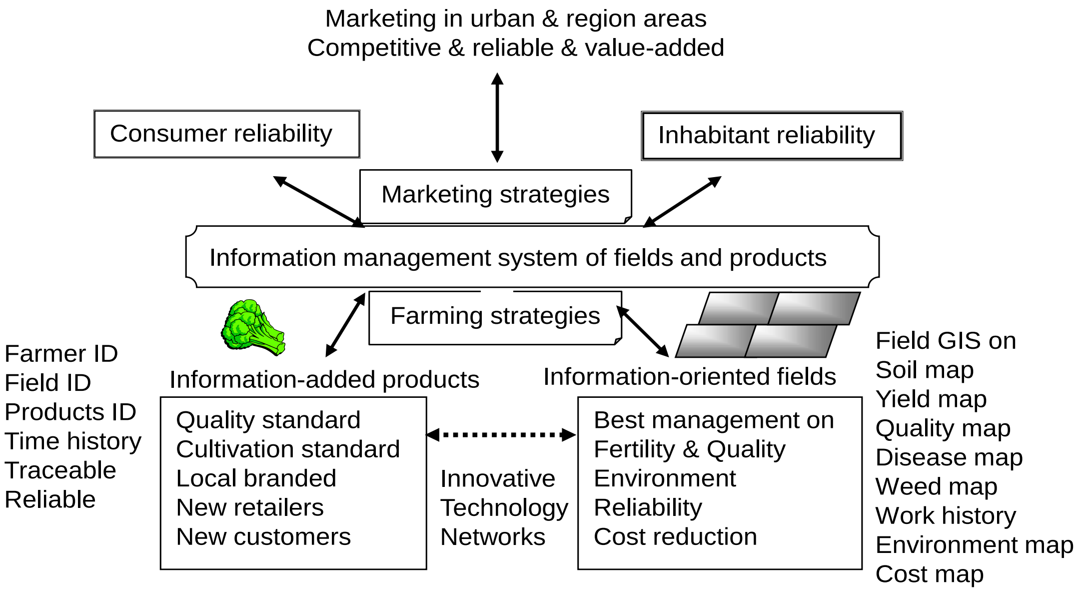

Figure 2. Output potential of community-based precision agriculture.

fields, for example a farm work contractor or a farm company, has to manage the regional variability due to cropping diversity. They also have to coordinate the farmers with different motivations due to different cropping styles. Here we have scale-dependent variability: within field, between field, and between motivations in different scales and different cropping styles.

A combination of the wisdom/experience of the farmers and the technologies of the platform will produce information-oriented fields and information-added products, as shown in Fig. 2, which can reply to the compliance as well as farmer's motivation, such as traceability, productivity, profitability, and environmental concerns. Technology platform was tried in 2001-2011 in Toyohashi, and during the current decade lots of companies have got started to supply variety of technology, which is a part of function of technology platform.

Rural development by introducing precision agriculture is an attractive proposition in Japan because people face serious concerns of depopulation, high aging, downsizing economy and exhausted infrastructure in rural villages and cities. The information-oriented fields produced by precision agriculture practices, are easy to connect with multi-functions of agriculture to manage environmental conservation and designing landscape amenity if it merges with a geographical information system (GIS) covering a whole space of the rural area, aiming at getting reliability of local inhabitants. The information-added products make access to the market with direct communication with consumers.

A learning group of farmers plays important role in the community-based approach (Shibusawa 2015). Activity of Honjo Precision Farming Society (HPFS) showed useful experience as shown in Fig. 3. The first kick was a local context making. City Mayor declared Environmental City Policy in 2001 and some farmers followed, and then organized a learning group. A role of scientists is great important in precision agriculture, helping active learning skills of farmers.

The farmers had workshops to learn its concept and digital technology, and then information-added produce was created for communication, that is, an in-shop experiment. This was not for business but for learning new knowledge with small cost. A membership qualification of the HPFS was to implement environmentally friendly management as “eco-farmers” certified by the local government, creating a homepage of their own, and attending Internet communications, as well as managing the food quality with the highest price in the market. The next action was to organize seminars and workshops on precision agriculture. They invited professionals and scientists to their evening seminars every month in 2003. They then conducted a social experiment on in-shop sales of their information-added products.

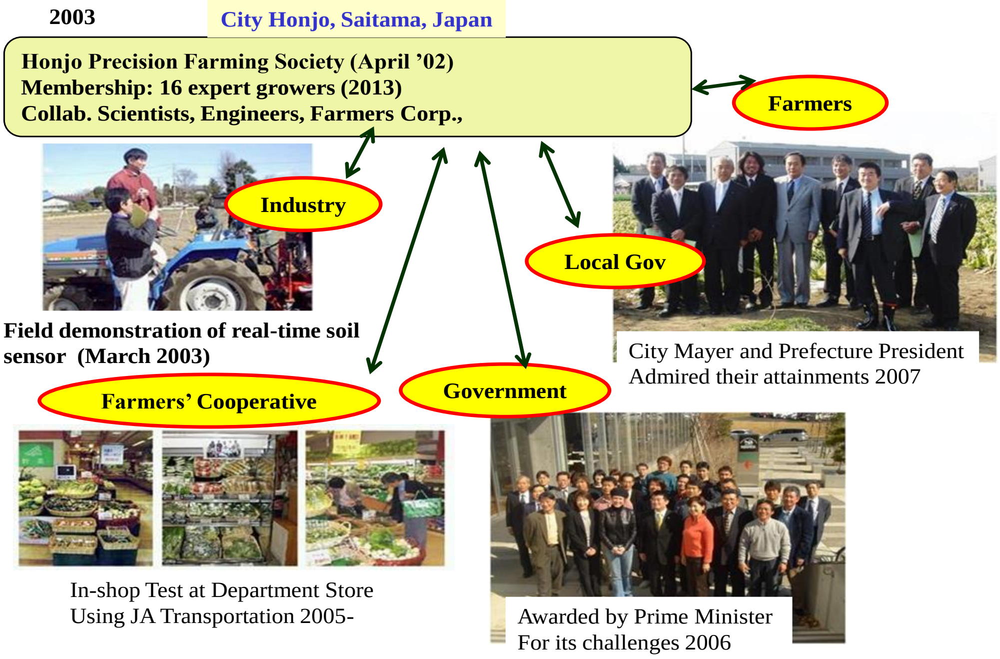

Figure 3. Experience of learning group of farmers HPFS in collaboration with five stakeholders.

In the social experiment, five stakeholders, industry engineers and consultants, farmers' cooperative, local government and city hall, central government, and neighborhood farmers, usually helped the agile group. Co-working scheme was important there.

DIGITAL TECHNOLOGY CHANGES FARM WORK

A brief history of precision agriculture was introduced here. During the current decades, five phases of precision agriculture have been experienced, as shown in Fig. 4 (Shibusawa 2007). The first phase was shaped as site-specific crop management (SSCM), which emerged in early 1990s. Using field maps, dividing a field into small grids and adjusting the inputs to meet the requirements of respective grids, farmers expected to attain both profitability and lower environmental impacts. Commercializing combine-harvesters equipped with a yield monitor and a GPS had enhanced the capability to produce yield maps. This made people recognize that SSCM can be a realistic strategy. This approach is sometimes addressed as a map-based precision agriculture. SSCM strategy promised big farms of decreased inputs and increased outputs by about 20 % compared with traditional practices, but simultaneously the time-consuming works and cost of field mapping were emerged as a bottleneck of its dissemination.

The second phase was sensor-based SSCM associated with variable-rate technology (VRT) as a stage of controlled mechanization of precision agriculture. Variable-rate technology aimed at the adjustment of inputs to meet the requirement on the specific location of the field but sometimes provided excess inputs due to mismatching between conventional agronomical formulae and machine operations, in addition to extra cost of investment. And then the third phase appeared at the definition of precision agriculture as farm management strategy using modern information technology. Since management strategy became the main target, precision agriculture offered to modulate the input-output balance on farm and to expand to medium and small farms.

Figure 4. A brief history of precision agriculture.

The fourth phase was a cost-driven company-based precision agriculture that was accepted on big farms in the US and other countries. This phase was motivated by an increase in profitability through both cost reduction and increased production. The fifth phase was a value-driven community-based precision agriculture proposed in Japan. With the freedom of information technology development, people could choose a strategy with different motivations, such as profitability, environment, quality foods, and regional contribution, followed by producing value-added products and good agricultural practices in organizing small-scale farms.

In the current decade digital transformation potential has changed the style of farm work and management. Transborder farming (Auernhamrner *et al*., 2000) implies here a system of farm management practices in communicating across the borders of different disciplines or different business sectors, and creating multiple functions and/or values by a single action. For example, a person or machine works on a single job action such as harvesting process with the monitor, which used to produce the amount of crop yield and the yield map through the job. The farm work should be usually done to get high yield under constraints of regulations such as protection of contamination and labour safety. When the innovative technologies, such ICT, internet of things (IoT), artificial intelligence (AI) and robotics (RT), are introduced into the farm practices, a cyber space of the data is also produced at the same time through the practices, which implies a single action plays multiple roles in.

When the data and information are used for throughput management (Goldratt and Cox 1992, Goldratt 1997), the system of farm practices is re-defined as precision agriculture. When the data and information are used for risk management, the system of farm practices is re-defined as good agricultural practices (GAPs). The system of farm practices directly communicates with retailers, and furthermore communicates with consumers by means of products with the information on constraints of food liability, food security, and food quality.

CAPABILITY OF CYBER-PHYSICAL FARMING SYSTEM

An imaginary talk can be done as follows (Shibusawa 2020). If all risks are described, a forward-controlled crop management will be designed. Breeder fixes a crop variety with promised yield and quality under expected conditions or constraints, together with digital data chart, that is, a seed variety with growth data predictive. When a grower gets the seeds or seedlings, what one can do is to monitor the cultivation conditions or constraints and work practices timely or not. The risk is a gap of physical states to the promised states in a spatio-temporal coordinate system. When the risks are evaluated at a location and at a time, a loss of yield or quality is predicted at any time. With this information the plan of crop management could be changed or revised toward a better result at any time. With the experience during the current decades farmers should have respond respectively to different types of risks and its transfer such as economic fluctuations, natural disasters, and farm work management.

Extending the risk-oriented crop management model let us to have a cyber-physical farming system CPFS as shown in Fig. 5. The CPFS is composed of a physical farm, a cyber farm, and its interface system. The physical farm is a real existing farm with management by real people such as farm managers and decision makers who collects the data and information on crops, fields, technology, regional constraints, and farmers' motivations. Putting all data of the physical farm into a cyber space can construct a prototype of cyber farm, which is enriched with the accumulation of data and information. When some simulation of physical farm events is conducted, the cyber farm develops onto the next stage. The interface system is a system of data collection, transfer, and processing work, with data format standards and application programing interface (API).

Human factors are very important but missing parts in the CPFS. Decision making process of farm management is much more complicated. It depends on players such as land owner, farmer contracted, and farm manger contracted, and on short term or long term implication, and also uncontrollable factors influenced. In the physical farm the decision-making process of a person is not described perfectly yet and a data sharing system of interoperability and portability just begins now. In the cyber farm reconstructing the real world is not developed yet and in particular the artificial brain and life to make decision is not tried. Communication of decision-making person on organic brains and silicon brains could be coming in the next 50 years.

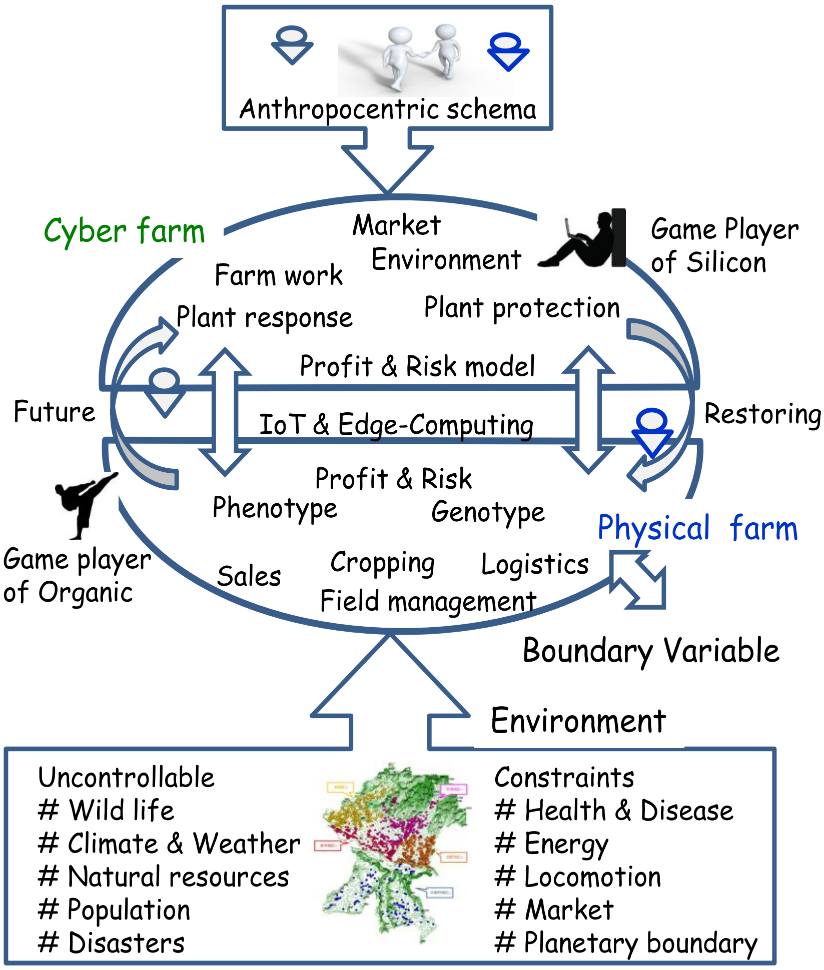

Figure 5. Storyboards of Cyber-Physical Farming System.

PRECISION MANAGEMENT STRATEGY

In the last decades of field experiments working with farmers, four levels of data management strategy were recognized as shown in Fig. 6 (Shibusawa 2018). Level 1 was to simply describe the spatio-temporal variability of the fields, such as soil/elevation mapping, yield/quality mapping, and disease/weeds/growth mapping. The data set of time, location and evidence play the main role. Level 2 was to understand why the variability came out, with help of farmers' knowledge on the work history and the environmental conditions, where analysis and modelling play the main role. Level 3 was to make decisions in order to increase the throughputs under regional constraints. Sometimes changes of the cropping system occurred. Level 4 was the action and evaluation in a holistic view, such as to choose a system of actions under the constraints of labor, machinery, etc.

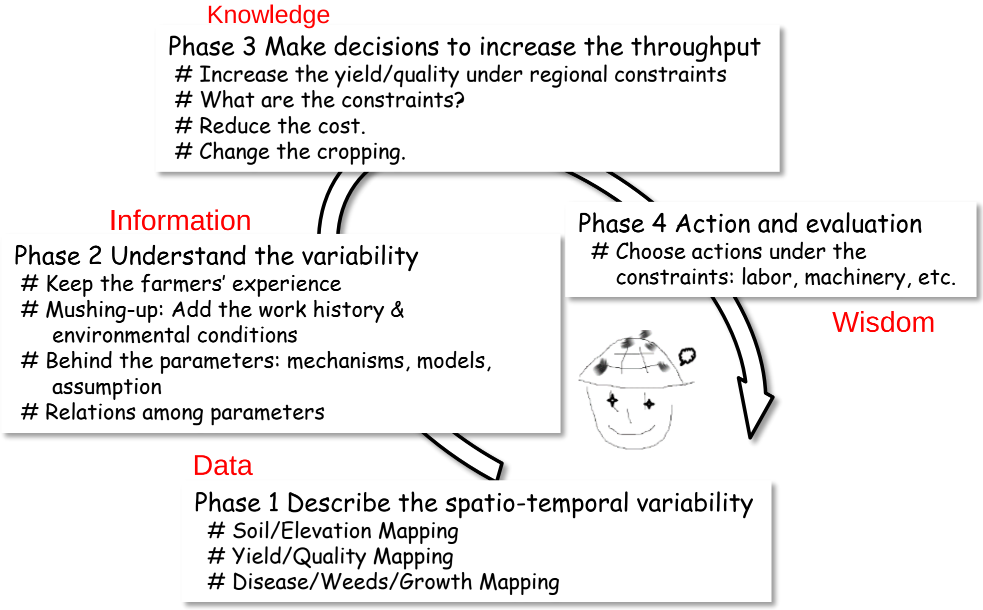

Figure 6. Four phases of precision management practices.

POLICY LINK

The Council of Science and Technology Innovation (CSTI), Cabinet Office, Japan, had issued the 5th basic program for science and technology on January 19, 2016, and the innovative technologies were targeted as Smart Society 5.0 Service Platform (CSTI 2015). The eleven sub-systems or core programs were organized, including two programs in the agricultural sector, smart food chain system and smart production system. This was the first time for nominating the agricultural sector in the science and technology policy.

The smart food chain system should be worthy of note, and it is composed of four main sub-systems of breeding, growers of production, processing and transportation and consumers. The systems need communication smoothly but there were many obstacles.

To make support for the activity in private sectors, ICT strategy, as shown in Fig. 7, was issued from the government (SHIT 2014). Actually interoperability and portability are required for active users to cost-effectively handle the data and information of the field. The strategy focused on standardization of data and information protocol, commonly available terminology to share the information across the inter-industry and inter-ministry sectors. Intellectual properties are also managed for growers and companies. Consequently, a local industry of agriculture will be changed into a globally active player.

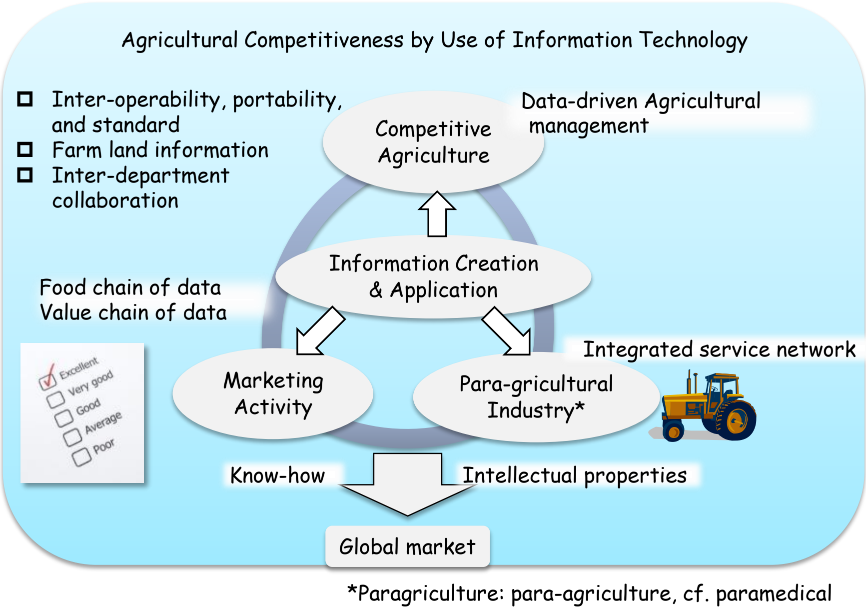

Figure 7. Strategy for creation and application of agricultural information
Source: The Strategic Headquarters for the Advanced Information and Telecommunications Network Society, Cabinet Secretariat, Japan. 2014.6.3.

CONCLUSIONS

Precision agriculture has induced the process innovation of farm management and practices in resonance with different sectors of industry. Community-based approaches with precision management help the next generation for agricultural transformation. An idea of cyber-physical farming system gives a way of thinking how the society accepts the new technology and systems in future.

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AUTHORS' CONTRIBUTIONS

The concept of community-based precision agriculture and its social practice were developed by the author. The author had also contributed in part to the development of the technologies and policies presented in the paper.

DECLARATIONS

The author declares that he has no competing interests in the completion of this paper.