Using Food and Agriculture Cloud to Improve Value of Food Chain

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The agriculture and food industries (agriculture, fishery, related manufacturing and distribution industries and restaurants) of Japan are integrated through the food chain and form a large market worth 99.2 trillion yen in terms of domestic production. In demonstration experiments where agricultural production is assisted by means of information and communications technology (ICT) systems, which Fujitsu has been conducting since 2008, it has been found that agriculture has a close relation to its related industries, and when assisting agriculture it is necessary to consider the impact on the entire food chain. Of the challenges relevant to the entire food chain including agriculture, this paper discusses the stable supply of agricultural produce, stability of agricultural management, and improvement of food chain efficiency. It goes on to present ways of solving these challenges with cloud computing. The possibility that agricultural producers and stakeholders in the food chain will benefit from this food and agriculture cloud, which is intended to make contributions to all agriculture and food industries, is also described.

1. Introduction

Food, indispensable to human life, is supplied to consumers by agriculture and food industries consisting of the agriculture and fishery, related manufacturing and distribution industries, and restaurants. The way this supply operates is called the food chain and ISO 22000 (an international standard for food safety management systems) defines it as "a sequence of stages and operations involved in the production, processing, distribution, storage and handling of all food and food ingredients from the primary production to final consumption." Domestic production in the agriculture and food industries that support the food chain is worth 99.2 trillion yen, accounting for about 10% of the domestic production of Japan's entire economic activities of 1001.3 trillion yen, and occupying an important position in terms of the nation's economy.[1)]

Since 2008, Fujitsu has been conducting a development and demonstration experiment on an information and communications technology (ICT) system (farming management system)[2)] that assists agricultural producers engaged in agriculture as a business. The results seemed to strongly indicate that ICT would be of help to agriculture by enhancing communication with various agricultural producers (such as managers, employees and part-timers). We also felt, through hands-on farming training, a strong sense of the need to take customers and their customers into consideration. For example, when agricultural producers provide high-quality produce, one benefit is that the entire food chain including processors, retailers and consumers can obtain high-quality products. Accordingly, it can be assumed that ICT assistance for agricultural producers concerns the entire food chain. From a demonstration experiment with more than one agricultural producer, Fujitsu has acquired knowledge regarding various challenges relevant

to the entire food chain including agricultural producers. Based on actual experience, using ICT has been found to have good potential to help overcome challenges in relation to the following three points in particular.

- Stable supply of agricultural produce
- Stabilization of agricultural management
- Improvement of food chain efficiency

This paper discusses the current situation and challenges in relation to the above three points, the possibility that using ICT will have a positive effect on the entire food chain, and Fujitsu's approach to overcoming the challenges. Through this approach, Fujitsu intends to realize a food and agriculture cloud that helps to both industrialize agriculture and construct the optimum food chain.

2. Stable supply of agricultural produce

For food-related industries to operate in a stable way, the stable supply of produce from agricultural producers is essential. Unlike the manufacturing industry, however, agricultural production, which has to deal with nature, may find it hard to continue stably supplying produce in a way that satisfies four conditions (four constants)[3]:

- Constant time: supplying produce at a given date and time
- Constant quantity: supplying given quantities of produce
- Constant quality: supplying a steady quality of produce (in terms of size, safety, etc.)
- Constant price: supplying produce at constant prices

This section presents the current situation and challenges facing the food chain in relation to the stable supply of agricultural produce, and describes Fujitsu's approach to applying ICT in agricultural production.

2.1 Factors hindering stable supply

Through the demonstration experiment with agricultural producers, we have realized anew that there are three factors that tend to prevent agricultural producers from stably supplying produce.

2.1.1 Natural phenomena including weather conditions and disease and insect damage

Natural phenomena may cause a delayed harvest due to factors such as poor growth, bad harvests, or poor quality and this may bring about the following situations.

1) Agricultural producers lose the best timing at which to sell their produce because of a delayed harvest, and are compelled to sell at low prices. A bad harvest of produce of adequate quality causes sales to fall short of estimates. In either case, there is a need to procure and deliver replacement produce if sales fall, and thus procurement costs are incurred.
2) Delayed or insufficient supply from agricultural producers causes processors and retailers to lose the best timing at which to sell their goods, resulting in lost profits. If goods are hastily procured to make up for the shortage, the costs, including distribution costs, are relatively high.
3) Consumers may be obliged to buy at prices that have soared due to the insufficient supply.

2.1.2 Disparity in supply and demand

In common case examples, a good harvest nationwide increases supply but consumption does not increase at the same rate and supply exceeds demand, which causes prices to fall, and leads to the following situations.

1) Costs of agricultural production, shipping and distribution are greater than the selling prices and agricultural producers are unable to sell, which forces them to discard their produce on the fields and causes deficits equivalent to the production and disposal

costs.

2) Retailers can enjoy lower procurement costs but the selling prices fall as well, and they end up with lower profits.

2.1.3 Difficulty of timely operations

The same crop may show different states of growth due to different growing conditions and operations to be conducted at a given time (timely operations) may also differ. For this reason, farmers must have an understanding of day-to-day states of growth and environmental information, including soil and weather information, so that they can make appropriate judgments for timely operations. However, human error may often cause the following situations, which hinder timely operations.

1) Insufficient gathering of information on the states of growth, such as disease and insect damage, leads to wrong judgments on operations.
2) Inadequate communication of instructions from responsible persons to workers leads to erroneous operations.

An inability to conduct timely operations may bring about a reduced harvest due to a delayed harvest or poor quality because of inadequate pest control, resulting in the same situations as those caused by natural phenomena such as weather conditions and disease and insect damage, and this may affect the entire food chain.

2.2 Fujitsu's approach

On the basis of the current situation regarding the stable supply of agricultural produce, this subsection describes the assistance measures deduced by focusing on the difficulty of timely operations mentioned above, identifying challenges in relation to reducing human errors, and conducting a demonstration experiment that makes use of ICT.

1) Causes and challenges

For producers who have many pieces of farmland located over wide areas, farmland management is more complex and difficult and this may result in them not visiting the farm areas enough and in an incomplete sharing of information gained from these rounds. For this reason, it may not be possible to conduct adequate operations in a timely manner, and this is a factor that reduces production volume. One agricultural producer who cooperated in the demonstration experiment has more than 200 pieces of farmland with the most distant ones 6 km apart from each other (where the average distance in Japan is 3.7 km based on a survey by the Ministry of Agriculture, Forestry and Fisheries [MAFF]).[4] We also found it inefficient for farmers, during hands-on farming training for outdoor-grown vegetables, to have to travel between pieces of farmland many times and spend 5 to 10 minutes driving each time. The large number of pieces of farmland that need to be visited for rounds in one day made it totally impossible for the farmers to determine the detailed conditions at individual pieces of farmland. Under such circumstances, the burden of farm round management on people in charge of rounds is heavy, and this makes it difficult for them to gain an understanding of the conditions. In addition, information shared by members of the organization tends to be inconsistent because of the large amount of information. For this reason, farmers tended to forget to conduct operations decided based on the results of the rounds. This in turn caused a delay in timely implementation of harvesting and weeding operations, resulting in a reduced harvest, or a delayed harvest or a poor quality one, or both.

2) Assistance measures

To mitigate this heavy burden of farm rounds, we thought that if all members of the organization could share information about which farms to visit for rounds at a given time and operations to be conducted were identified based on the state of rounds, then this might help to reduce human errors. We developed a

function that makes use of mobile phones to embody this idea and implemented it in the farming management system. This function automatically consolidates into the system information about the pieces of farmland already visited for rounds gained from GPS information of mobile phones carried by the people in charge of farm rounds. Indicating the pieces of farmland to visit based on the consolidated information has ensured that farmers do not forget the pieces of farmland to be visited. In addition, we made the information about the actions decided based on the state of rounds and their progress available for sharing in the system to prevent omitted operations (**Figure 1**).

At the beginning of the development, there were problems such as inadequate farmland judgment logic. But, with the cooperation of Fujitsu Laboratories, improvements have been made including reworking of the judgment logic. As a result, the system's ability to reliably record the actual results and the convenience it offers when scheduled arrangements changed due to rainy weather have received favorable comments. One example of the system's effect is the way it helps improve harvests by preventing farmers from forgetting to go on rounds and helps them implement appropriate operations in a timely manner.

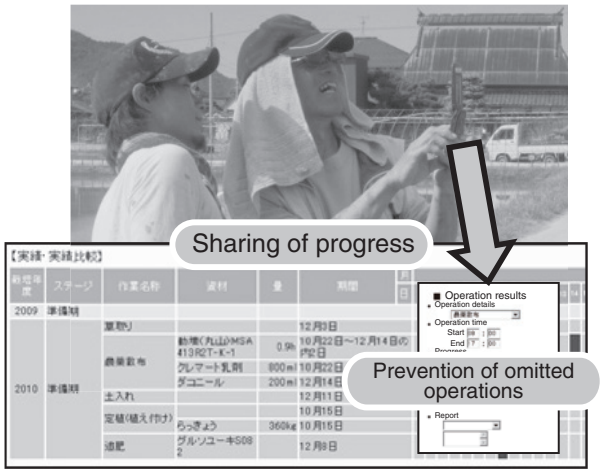

Figure 1
Sharing and management of work progress.

3. Stabilization of agricultural management

Stabilization of agricultural management helps agricultural producers to remain in business and helps them stably provide produce to the food chain. Based on interviews with agricultural producers, it was found that the following two points are important for stabilizing agricultural management, as with other industries.

- Ensuring stable revenues: continuously making certain profits
- Developing human resources: developing successors for continued management

Focusing on the points above in relation to the stabilization of agricultural management, this section presents the current situation and the challenges, and describes Fujitsu's approach to helping agricultural producers by making use of ICT.

3.1 Current situation of agricultural management

3.1.1 Ensuring stable revenues

Through the demonstration experiment with agricultural producers, we have renewed our awareness of three factors that tend to prevent agricultural producers from ensuring stable revenues.

1) Of the retail selling prices of produce, agricultural producers generally only receive half [5] and profit margins are essentially small. One reason for this is that agricultural producers are unable to set selling prices at an appropriate level to make good profits and often end up selling at a loss. Possible causes of this situation include agricultural producers' insufficient understanding of production costs, including labor costs, and unoptimized production plans.
2) Meteorological disasters such as bad

weather and disease and insect damage lead to problems including a decreased yield of produce. Measures must be taken to mitigate these risks and minimize damage.

3) Changing market conditions cause fluctuations in the prices of agricultural produce and stable profits are not ensured. To make stable profits, it is effective to carry out contract production in which the four constants (constant time, constant quantity, constant quality and constant price) mentioned at the beginning of the previous section are established before the start of production. This allows agricultural producers, retailers and consumers to sell and buy at constant prices even if the market prices change. An important factor in achieving this is how agricultural producers can achieve the four constants.

3.1.2 Developing human resources

Agricultural producers are aging and 60% are aged 65 or older.[6] Private farmers often do not have anyone to whom they can pass on the know-how accumulated by elderly experts. In farming organizations consisting of many people, management and production know-how tend to be concentrated in a small number of experts. In many cases, know-how is unformalized implicit knowledge and difficult to hand down, which is a cause for concern with regards to long-term and stable continuation of management into the future.

3.2 Case examples of Fujitsu's approach

This subsection describes Fujitsu's approach to making use of ICT to overcome the two challenges in relation to agricultural management mentioned in the previous subsection.

3.2.1 Ensuring stable revenues

1) Causes and challenges

In agriculture, the suitability of planting plans (which crops to grow where and when) made before production has an influence on production and a decisive impact on profits. For stable revenues, gaining an understanding of sales and costs and making planting plans that maximize revenues are important. However, planting plans become more complicated and more difficult to make as the scale of farming gets larger. Examples of elements to consider include the availability (planting conditions) of land, sunshine, soil information, conditions of repeated cultivation, use of agricultural chemicals, labor costs per piece of farmland and operating rate of agricultural machinery. This complexity hampers appropriate planting and may lead to reduced profits. In addition, agriculture involves many natural risks such as the weather but taking measures for all kinds of risks is difficult for reasons including high costs.

2) Assistance measures

We thought it would be good to consolidate information necessary for planting plans into the farming management system by offering it in a format that allows managers to easily make decisions. This would help managers to promptly and accurately make decisions and formulate optimum planting plans.

Accordingly, a demonstration experiment of a planting simulation function started to offer information in a format that was easy for people to understand. The information was offered after preprocessing elements that can be decided automatically (judgment on planting suitability of soil or on repeated cultivation, for example). This function is intended to help managers create the optimum planting plans in a short time. In addition, a demonstration experiment on a resource simulation function that allows prompt planning of an appropriate allocation of workers and agricultural machines started as well.

Taking advantage of these simulation functions by building a track record year by year is believed to allow planting plans to be improved each year (**Figure 2**).

Name of field Area of field		Planted crop Cropping type	State of growth Cultivation plan	Plan Result	Start End		Harvest	October Beginning / Middle / End	Noven Beginning / Mid
2001	1 あやちゃん下 14.0a	キャベツ春まき 春まき栽培	終了	更新 追加		予 実	5,600kg 10,072kg		
2001	2 あやちゃん下 14.0a	新黒田五寸 夏まき栽培	栽培中	更新 追加	終了	予 実	5,600kg		
2002	1 開田 左 8.0a	石川 早生栽培(マルチ)	栽培中	更新 追加	終了	予 実	800kg		
2002	1 開田 左 7.0a	紅薩摩 普通	終了			予 実	1,050kg		
2004	1 病院前 12.0a	赤目 晩生栽培(露地)	栽培中	更新 追加	終了	予 実	1,200kg		
2021	1 開田9a 9.0a	キャベツ春まき 春まき栽培	終了	更新 追加		予 実	3,600kg 2,465kg		
2021	2 開田9a 9.0a	黄金芋 普通栽培	栽培中	更新 追加	終了	予 実	1,350		

Figure 2
Planting plan.

3.2.2 Developing human resources

1) Causes and challenges

Very few organizational farming groups have many seasoned experts and inexperienced young workers (without inherited know-how) alone engage in field operations. For this reason, wrong decisions or responses may be made when problems occur in field operations, possibly causing delayed or erroneous operations. These cases must be assumed when building an environment in which young workers share management and production know-how.

2) Assistance measures

We had the following idea: using the farming management system to make information about the site whenever a problem occurs available for sharing between young workers and experts, and enabling experts off-site to make decisions and giving instructions based on the on-site information, and thus allowing know-how to be passed on. We also thought that going further and sharing the results of the experts' decisions and instructions across the organization would make it possible for the instructions given once by experts to be shared by all young workers.

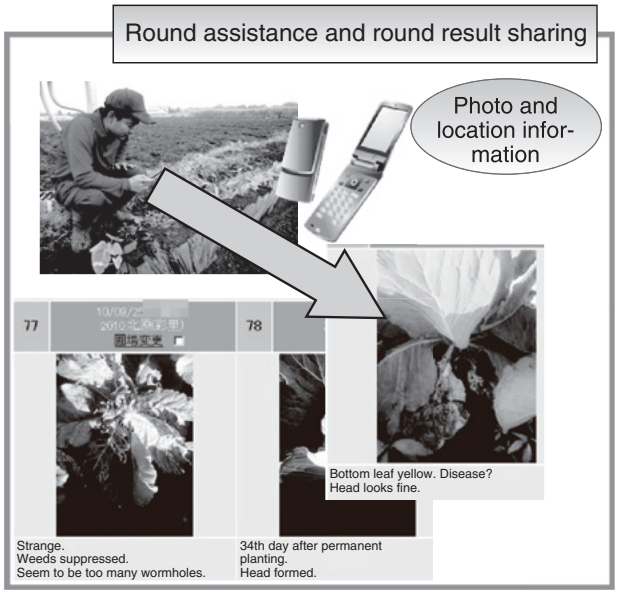

Figure 3
Function to assist walk-around inspections.

To achieve this, we made a system in which information about problems faced by young workers in the field could be shared in the forms of photographs and comments and accumulated as data including know-how (**Figure 3**). Specifically, photographs were taken with mobile phones and comments were input so that real-time reporting on the situation

could be done even from remote places. To minimize the burden on workers on site, a mobile application that is simple to use was created so that farmland and planting information would be automatically recorded. A function was also developed to help the users review the difference between the plans and actual results in terms of overall planting as well as day-to-day operations based on operations, harvest data and image information.

The participants made positive use of these functions, and so they proved useful in encouraging communication including active information sharing between young workers and led to a spirited atmosphere in the workplace, which has strongly suggested that the system works well.

4. Improvement of food chain efficiency

The present food chain adequately plays the role of distributing the necessary goods. Based on interviews at farming sites, we believe that sharing information in relation to production and demand could help further improve efficiency in the food chain.

This section focuses on the points of information sharing concerning the improvement of food chain efficiency by presenting the current situation and challenges and assumed solutions by means of ICT.

4.1 Current situation and challenges

Through the demonstration experiment with agricultural producers, we have rediscovered three factors leading to reduced efficiency in the food chain:

1) Insufficient information on consumption trends

Due to insufficient information about consumer trends, the produce grown may not sell, and this sometimes forces agricultural producers to discard their produce or sell it at lower prices, and the expected revenues may not be obtained.

2) Insufficient production information

Retailers may not put the unsold agricultural produce for fresh sale to appropriate secondary use because of insufficient production information, and this sometimes causes sales to fall short of the estimates.

3) Insufficient distribution information

Insufficient distribution information may prevent agricultural producers from arranging trucks for shipping the produce in a timely manner and the produce loses freshness.

4.2 Assumed solutions

The problem of insufficient information described above is a result of certain business owners being unable to share their information with other business owners who need it. It is thought that sharing the necessary information between individual business owners would solve the problem as shown below.

1) Sharing of consumption trends

Sharing with agricultural producers the information owned by retailers about quantities of sale, time of sale, selling prices, consumer responses at point-of-sale and changes in demand allows the amount of loss from disposal to be reduced.

2) Sharing of production information

Sharing with retailers the information owned by agricultural producers such as planting plans, growth information, estimated harvests, production history information and harvest date and time allows the leftover produce to be effectively used for other applications including processing rather than discarding it. Furthermore, retailers can prepare and offer information about the areas of production to consumers and feed the sales information back to agricultural producers.

3) Sharing of distribution information

Sharing with agricultural producers the information owned by distributors including availability of trucks and time required for travelling allows a harvesting schedule to be

made in such a way that produce remains as fresh as possible. In addition, a shipping schedule that minimizes the waiting time can be made as well.

By taking these points into consideration, information sharing is believed to have a considerably positive effect. Business owners including agricultural producers are able to not only reduce waste by avoiding disposal of produce but also improve the freshness of produce and add to it production and processing information in a better way than they do at present. We think that sharing information on the food chain with business owners other than agricultural producers, retailers or distributors (such as recyclers) will make it easier to create further value (**Figure 4**). In the future, linking with information owned by business owners outside the food chain, such as weather forecast information, has the potential to bring about a further improvement in food chain efficiency.

5. Conclusion

Of the challenges relevant to the entire food chain including agriculture, this paper has focused on three challenges where use of ICT is expected to have a beneficial effect (stable supply of agricultural produce, stabilization of agricultural management and improvement of food chain efficiency) and presented the current situation and Fujitsu's approach to overcoming the challenges.

Specifically, demonstration experiments have shown that agriculture-related industries and consumers as well as agriculture itself may well benefit from new services intended for agriculture that help stabilize agricultural management and facilitate the stable supply of agricultural produce. The paper has also suggested the possibility that a greater sharing of information in the food chain will contribute to agriculture-related industries in addition to

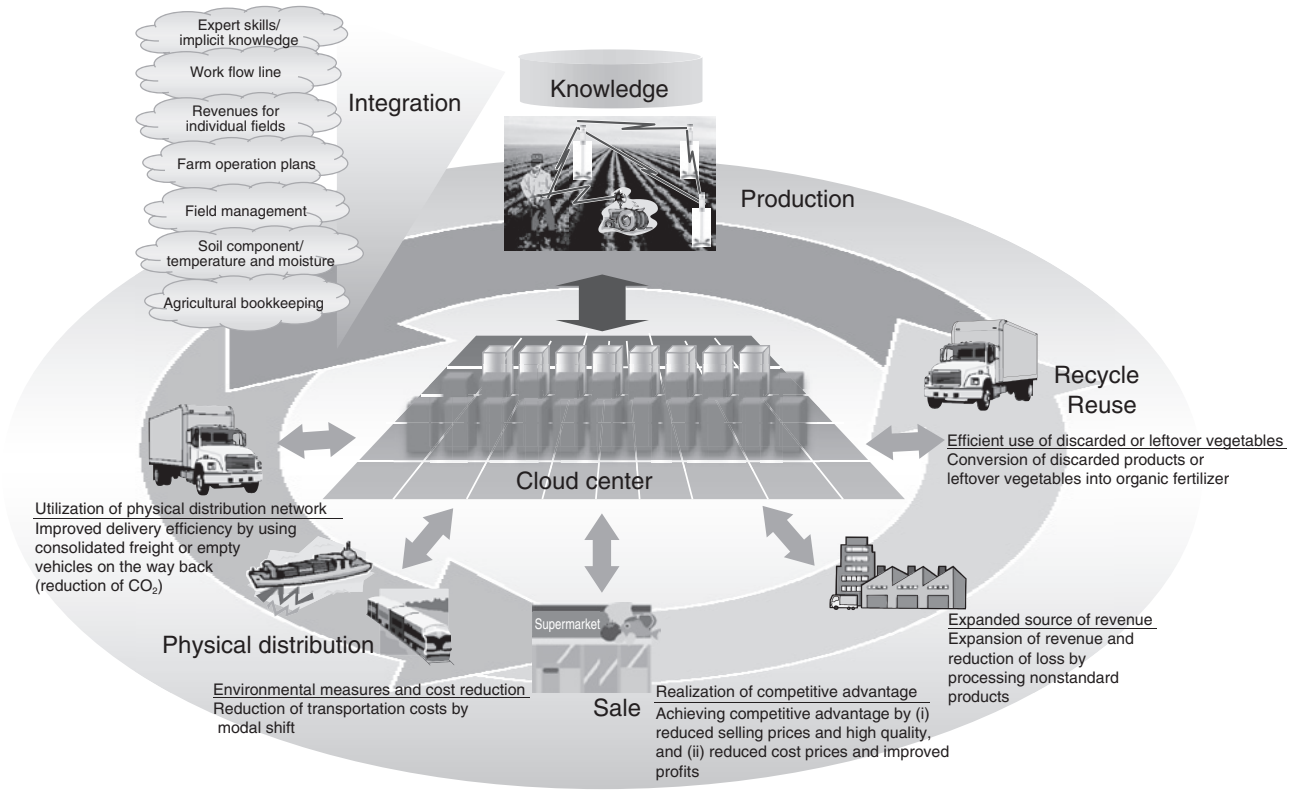

Figure 4
Fujitsu's idea of future food chain.

agriculture itself.

Fujitsu will continue to promote the demonstration and development of services centered on agriculture to further sophisticate the food chain and realize a food and agriculture cloud that makes contributions to all agriculture and food industries.

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