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Agriculture in Japan
New developments in Smart Agriculture

1 Executive summary

The agricultural sector in Japan is facing acute labour shortages, which are anticipated to get worse in the coming years. Furthermore, the age group involved in farming is prevalently over 65 years old – with 60% of farmers older than 65 – and farmers are having troubles to find successors for their farms. In addition, the demand for Japanese agricultural products abroad is steadily rising, and Japan is starting to struggle to meet it and supply its own domestic market.

The Japanese Central Government, academia and the private sector are facing these challenges head on and have invested in technology to resolve these problems. In particular, the government has taken initiatives – so-called Strategic Innovation Promotion Programs (SIP) – to foster innovation with applied, cross-disciplinary funding policies. It has also invested into infrastructure that will enable new technologies. Academia and the private industry have recognised that state-of-the-art technologies like AI, IoT, ICT and self-driving robots can be used to solve practical problems in agriculture and have invested in it. This has opened a new promising market that was predicted to grow rapidly in the next five to six years. The Japanese Smart Agriculture market is expected to be valued at approximately ¥33 billion by 2023.

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2 Situation and Challenges

Japan's economy is facing a serious demographic challenge with a decreasing and rapidly aging population. In a report recently published by the National Institute of Population and Social Security Research, Japan's population is predicted to fall 6.3% by 2030 and 16.3% by 2045 compared to 2015 – Tokyo being the only exception to this trend (1). The labour force will not only decrease because of the shrinking population but also because the population, on average, is rapidly getting older. These two effects will reduce the working-age group (15-64) by 37.7% on average by 2045. However, rural communities and smaller prefectures are likely to be more affected, with Akita prefecture, located at the northern tip of Japan's main island, projected to see a 65.1% drop in its labour force by 2045 (1). This general trend is already heavily affecting the agriculture sector today.

The population engaged in farm work – roughly 2 million people in 2015 – represents only 1.65% of the Japanese population (2) (3). According to the 2015 census by the Ministry of Agriculture, Forestry and Fisheries, less than 10% of the labour force mainly engaged in farm work is below the age of 45. Alarmingly, more than 60% of farmers is above the age of 65 (2) (see Figure 1), compared to 26.6% in the whole population (1). This lack of young workers is not expected to disappear in the foreseeable future, as the agricultural sector has been steadily losing in popularity these past few decades.

The decreasing population threatens the agricultural sector on a fundamental level as it inherently entails a shrinking domestic market for agricultural products. Some financial analysts see ranking up exports as a solution, given that the demand for Japanese products is increasing abroad – 2017 saw a 7.6% increase to ¥807.6 billion (4).

These two concurrent trends – decreasing work force and increasing demand – show that to remain competitive on the market, Japan's agriculture, which momentarily does not rely on immigration for

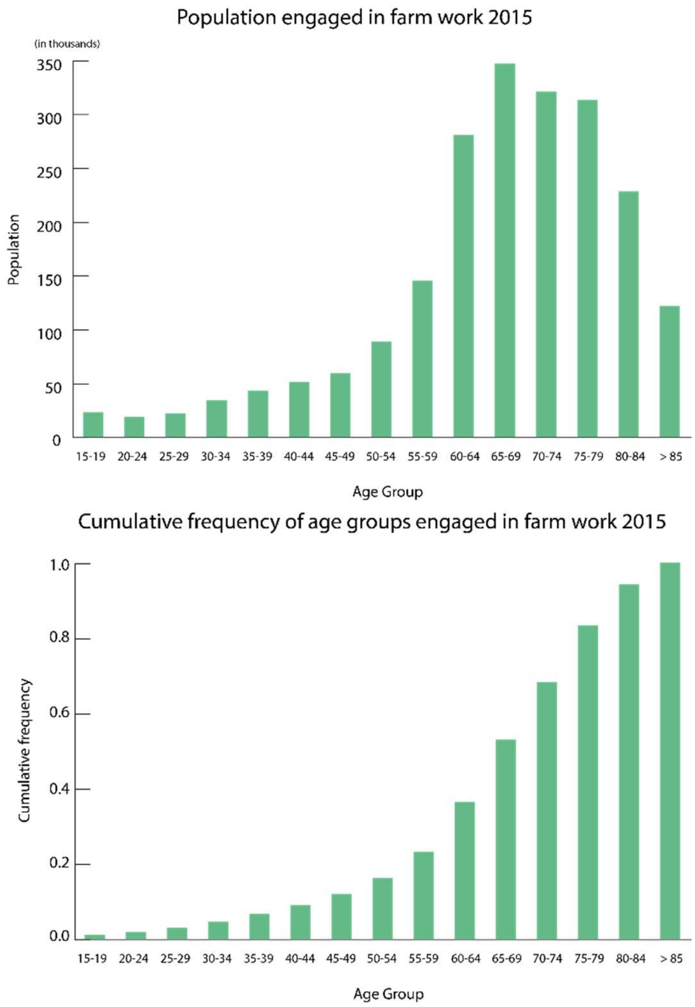
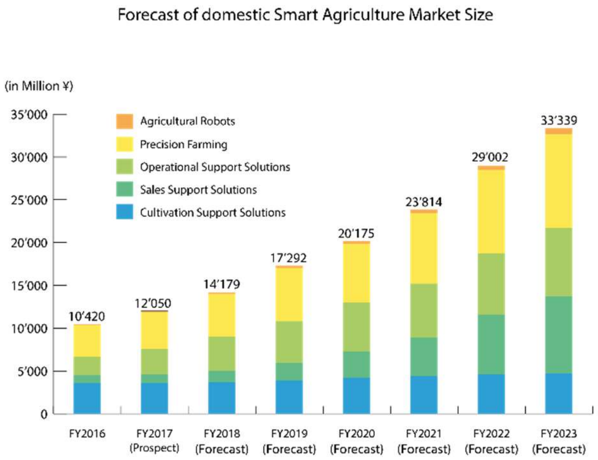


Figure 1 Population Engaged in Farm Work by Age Group (Mainly Engaged in Farming Operated by Household) and Cumulative Frequency of age groups engaged in Farm Work. Data from the Ministry of Agriculture, Forestry and Fisheries (2)

workforce, has to be less dependent on manual labour and rely on technology to solve its structural difficulties.

In this broader context, Smart Agriculture, a market totalling ¥10'420 million (95 million USD) in fiscal year (FY) 2016, is projected to see a 300% expansion until FY2023 to an estimated ¥33'339 million (305 million USD) (see Figure 2) (5). Smart Agriculture is a relatively young market, relying on upcoming technologies, mainly information and communication technology – including big data and IoT – and robotics to increase agricultural production, reduce costs, facilitate sales and provide a safer work environment for labourers. It comprises the cultivation support sector, which, amongst others, produces solutions for cloud farming and compound environmental control, helping farmers to regulate the artificial climate of greenhouses. Sales support solutions connect producers with buyers through ICT. Operational support solutions reduce the workload for administrative tasks and help to predict harvest yield and time by relying on past data and weather forecasts. Precision farming exploits state-of-the-art technologies to develop unmanned farm machines and autopilot to reduce the time required for highly repetitive and automatable processes. Finally, agricultural robots are being developed for everything from assistive exo-skeletons to harvesting robots.

While cultivation support solutions is one of the biggest market shares in FY2016 with ¥3'472 million, it is expected that sales and operational support solutions will increase after FY 2017 (5). Additionally, precision farming will also increase in value starting FY2018, as unmanned vehicles and equipment will be more widespread – in parts because of the modern QZSS GNSS (see below).



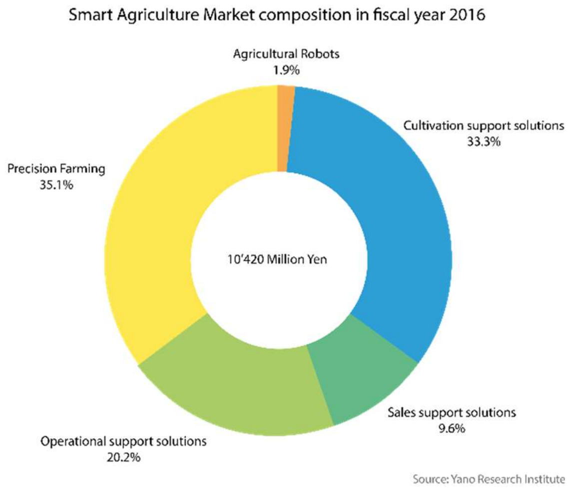


Figure 2 Transition and Forecast of Domestic Smart Agriculture Market Size (left) and Composition Ratio of FY2016 Domestic Smart Agriculture Market by Solution (right). Source: Yano Research Institute Ltd (5)

3 Solutions: Policies and Technology

To face the structural problems facing the agricultural sector, Japan is in dire need for new technologies that increase automation and mechanisation of labour-intensive tasks and boost labour efficiency. These solutions are spearheaded by the private sector, academia and the Japanese Central Government.

3.1 Government policies and infrastructure

In an effort to support and foster innovation in the agricultural sector, the Japanese Central Government has made policy changes to facilitate research and product development by private corporations and researchers (e.g. policies concerning drones; see below). Additionally, it has foreseen the need for key enabling technologies and infrastructure – such as the new QZSS Global Navigation Satellite System (GNSS) – that it has funded and developed.

3.1.1 Cross-ministerial Strategic Innovation Promotion Programs (SIP)

Society 5.0 is the framework for future technological development put in place by the Japanese government. It recognises the potential that Big Data, Deep learning, AI, IoT and ICT have for every sector of the economy, including agriculture, and everyday life. Therefore, these technologies were identified as strategical for economic development. In this context, the Cabinet Office realised that new developments would occur through interaction of traditionally distinct disciplines. Eleven SIPs were developed to target key economic and social issues. With a specifically allocated ¥50 billion (450 million USD) budget, they promote research and innovation in these fields from basic research, to product development and commercialisation in coordination with the private sector (6).

The Technologies for Creating Next-Generation Agriculture, Forestry and Fisheries SIP aims to develop technologies such as smart farms, increase the attractiveness of agriculture by increasing farmer’s revenue, and improve quality of life. Under the management of the National Agriculture and Food Research Organisation (NARO), it supports the development of new technologies and products for specific applications. Projects include crop growth information collection systems (e.g. with drones), water reservoir management systems, and unmanned agricultural robot systems. These systems accrue a significant amount of data, which can be explored by software (i.e. AI, deep learning) to produce an optimal farming plan, control environmental conditions in greenhouses, make a sales plan or facilitate new research. The projects funded by the SIP include both data acquisition systems as well as data analysis.

3.1.2 Quasi-Zenith Satellite System (QZSS)

Because of the steep and densely populated terrain of Japan, reception of the US-owned Global Positioning System (GPS) is not good enough for elaborate applications (7), which need sub-meter or even centimetre-level precision, as is the case for drone positioning or autonomous vehicles. The Japanese government recognised this problem in the early 2000s and decided, in collaboration with the Japan Aerospace Exploration Agency (JAXA) and industry stakeholders, to build a satellite-based augmentation system for the GPS in the Asia-Oceania region.

The Quasi-Zenith Satellite System sends out the same signal as GPS, making it available for existing receivers, but adds so-called sub-metre level augmentation service (SLAS) (8) and centimetre level augmentation service (CLAS) (9). These two systems are novel in the sense that they require less ground infrastructure to existing solutions to reach centimetre level accuracy, such as RTK (real time kinematics). This opens a big region of Eastern Asia, Oceania and Australia for this new service, which requires less expensive ground infrastructure (10). The first satellite (MICHIBIKI-1) was launched on September 11th 2010 joined by three others in 2017 (MICHIBIKI- 2, 3, 4). QZSS service was originally planned to start in April 2018 but has been postponed to November 1st 2018 (11). Three additional satellites are planned to be launched after 2018.

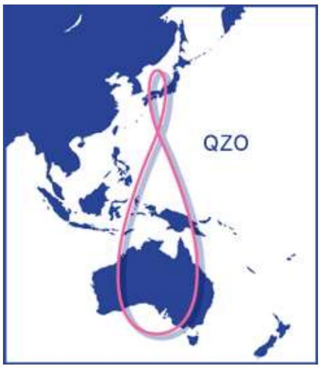


Figure 3 Main area where QZSS is available.
Source: Quasi-Zenith Satellite System (7)

This new system opens new technology development in Japan, because it enables applications that were not possible before. Amongst others, this new service makes driverless farm machinery and autonomous drone applications possible, although only in limited areas for safety reasons (9).

3.2 Smart Agriculture

3.2.1 Internet of Things (IoT) in Agriculture

As in other fields, IoT is seen as a useful tool to closely monitor and adapt environmental conditions for optimal growth conditions in open fields or in greenhouses. One example, produced by SoftBank-owned PS Solutions (12), in collaboration with CKD Corporation and Ericsson Japan, is e-kakashi™ (13). It is a platform where sensors, measuring such factors as temperature, humidity, soil water content, CO_2-levels, and solar radiation, are connected to a cloud-based AI that can then control actuators. They can turn on/off sprinklers, liquid-fertilizer pumps, heat pumps, and CO_2 generators or open/close windows in horticultural facilities, thus providing good growth conditions to improve the yield and quality of crops. While this is only one example, many big tech companies also entered this field and now provide practical solutions combining AI and IoT to reduce farmer's workload by taking care of easily automatable processes. Although they rely on the same technology the scale of the facilities they are used in vary massively. Fujitsu's Akisai cloud-based AI can be used in small facilities but also in big lettuce factories, which can produce thousands of lettuce heads per day. These systems can not only be used to effectively increase yields but they can also predict the harvesting period, which is necessary for production planning, management and sales.

3.2.1 Precision farming and autonomous, self-driving agricultural robots

In Japan, Smart Agricultural Machinery Systems (SMAS) are still mainly under development and have not yet been widely commercialised. There are two aspects to these developments: the first being autonomous self-driving machinery and the second the integration of GNSS receivers and sensors into farm machinery to monitor field and crop conditions.

While agricultural robots only represented less than 2% of the smart agriculture market in FY2016 and is not expected to become much larger (see above), autonomous driving is one of the key technologies needed to sustain large-scale agricultural operations to supply the domestic food market in a country suffering from acute labour shortages. Kubota is one the leading companies in this regard and unveiled its first self-driving rice transplanter in 2016, followed in January 2017 by a self-driving tractor (14). The QZSS will certainly help to go in this direction with precise, around-the-clock, geolocalisation. However, for this technology to be widely introduced, it will require a government policy change, as current regulations do not accommodate it. In a similar fashion to self-driving cars, it is expected to be introduced in several steps, starting with supervised self-driving machinery, where farmers drive a second tractor and can monitor the self-driving machinery, resulting in a boost of up to 30% in work efficiency while tending to fields. The agriculture ministry is anticipated to introduce regulations to allow full automation with remote control in 2020 (15).

Machinery with integrated sensors that can record soil parameters is not readily available yet. One example is Kubota's rice Dynamax Revo Combine Harvester that can tell the "taste" of the harvest (14). However, scientific trials of the available technology are under way. In a 2017 SIP-funded study by a team from Tottori University and the National Agriculture Research Organisation (NARO), tractors and rice-transplanters were fitted with GNSS receivers and sensors that can measure important factors such as soil depth and temperature, amongst several others. All this information could then be made visible on a map and used to apply varying quantities of fertilizer in accordance with the local needs. Hence, it was possible to reduce the quantity of fertilizer required by 20% and harvest time took only 30% of the time usually required (16).

All these self-driving vehicles cost about 2 to 3 million ¥ (20'000 to 30'000 $) more than conventional models. Given the usually small scale of farming operations and the average size of fields in Japan, this additional cost may prevent most farmers from acquiring these new technologies. Indeed, in order to take advantage of this type of equipment, a structural change will have to take place in the Japanese agricultural sector. A move towards farming cooperatives and industrial-scale operations is foreseen to occur. This might happen sooner in the Hokkaido region than in Kantō and Kansai. Specifically, in Hokkaido, the average surface of fields is already quite big and are more appropriate to exploit these new technologies. In contrast, in Kantō and Kansai, fields tend to be smaller which also limits the attractiveness of such farming equipment.

3.2.2 Drones

While technology and legislation for drones – or unmanned aerial vehicles (UAVs) – is still being developed in Japan, as elsewhere around the globe, autonomous drone usage is likely to become popularised in the near future for agricultural applications. Indeed, flight beyond visual line of sight (BVLOS) is less problematic in open fields than in densely populated cities. Additionally, the new QZSS service will make centimetre level accuracy possible for drone positioning around the clock at any location in Japan starting from late 2018.

In Japan, tech companies already offer diverse products combining drones, AI, IoT, Big Data and blockchain. For example, OPTiM, in collaboration with Saga University, developed drones that autonomously fly along a set path through fields and spray insecticide at targeted areas where many insects gather (17). This has many potential advantages for farmers: drones can operate at any hour of the day or night, farm workers can devote their time to other tasks, and less insecticide is used. Drones

can also provide useful information on crops in fields or greenhouses through advanced image analysis (18), and show areas of fields/rice patties that require more fertiliser (19).
The legislation concerning BVLOS flight currently requires a safety assistant to have the UAV in line of sight at any moment. This will change by the end of the year 2018, as the transport and industry ministries recently announced (20). This policy change will open the way for autonomous flight on farms as long as the drones fulfil safety regulations.

4 Case studies

4.1 OPTiM Corporation

A young entrepreneur, who graduated from Saga University, started the company about 18 years ago. The company still has several research and development collaborations with the university and the prefecture. It has grown to about 200 employees of whom 70% are software engineers.
OPTiM provides two services that are its main sources of revenue. The first is a mobile device security software and mobile device management system targeted to business phones of company employees. Secondly, it sells the license to a remote support software, which is widely used by mobile network operators in Japan, such as NTT and KDDI. In both cases, its customers are mainly based in Japan, East and South-East Asia.
In parallel to these activities, OPTiM is actively developing a platform called “OPTiM Cloud IoT OS” which combines IoT, image and live video recognition software and AI for various applications, including agriculture. The investment in these key technologies has given rise to a number of patents that has propelled the company into the top three companies that create intellectual property in key sectors according to the Japanese government. It is notably the only company in the top five that exclusively produces software and has to compete with tech giants like Panasonic and Sharp (place 1 and 2 respectively).

4.1.1 Development Model: Finding good teachers

One of the strengths of OPTiM is their expertise in image and video analysis using AI and remote support and remote video access. They have found a clever way to transfer their technology from a field of application to the next.
For example, they have a pair of glasses with an integrated camera called “Optimal Second Sight™” that they sell to various companies for teaching and support purposes. In this case, an unskilled worker can get an expert’s support through live video feed on a farm in Indonesia, or an emergency rescuer can get help from an emergency medical doctor while driving to the ER in an ambulance. The development of these technologies was made with leaders in their field and was optimized to fit their specific requirements.
A remarkable achievement is also the highly specified application of their image analysis system to the extremely different fields of agriculture and medicine. In the latter case, OPTiM collaborated with an ophthalmological hospital in Saga Prefecture. Medical doctors there are highly experienced in recognizing patients that may suffer from arteriosclerosis from images of their inner eye. In this way, these doctors “taught” the AI developed by OPTiM how to recognize this ailment. In a similar way, they collaborated with a farmer renowned for the high quality of his tomatoes and “taught” the AI how tomatoes look that are ready to be picked. In both cases, OPTiM can transmit the knowledge of experts in their field to less-skilled or less-experienced customers to increase the quality of their own services or products.
For tomatoes in particular, OPTiM has developed a rover that can take pictures inside greenhouses where tomatoes grow, and, through their Cloud OS, can warn a farmer when and how many tomatoes can be harvested, thus reducing the workload on farmers struggling with labor shortages. It also opens the possibility of even higher degrees of automation in greenhouses. Another bonus is that the quality of the produce increases and it can potentially be sold for higher prices.

4.1.2 Business model

This technology was also applied to farming in fields for pest control. Autonomous drones take images of fields and the AI recognizes the spots that are befallen with insects. Other drones then take up the task to spray pesticides only in these locations. On one hand, this reduces the quantity of pesticides used and thus its cost, but also reduces the substantial amount of work that goes into spraying whole fields.

However, OPTiM has realized that farmers are getting older and are either reticent to use these technologies or would be scared off by its cost. Therefore, the company adapted their business model. They now lend the hardware (drones) and provide the software for free. The latter is rather surprising for a company that makes most money from licensing their proprietary software. Instead, they make money from the increase in quality of the product. Because no or almost no pesticide was used, the harvest can be sold as pesticide-free or organic product, which almost triples its value. OPTiM then takes a cut of the revenues, leaving both the farmer and the company contented.

4.2 Hokkaido University: Vehicle Robotics Laboratory (VeBots)

This laboratory at the Hokkaido University is led by Noboru Noguchi, who is also the director of the SIP for agriculture. VeBots conducts research on autonomous ground, water, and aerial vehicles. Most notably, they have collaborated with a well-known agricultural robot manufacturer to develop autonomous tractors, and combine harvesters that can fulfil the same tasks than traditional farming equipment but without a human driver. Furthermore, they have worked on software to make the tractors as safe as possible. Indeed, the tractors automatically stop as soon as it detects an obstacle, e.g. a human that gets too close from any direction, be it before, to the side or behind the tractor.

Additionally, because one of the challenges that has to be overcome in the farming industry is the problem of soil compaction caused by big farming equipment. To solve this problem, they have developed self-driving tractors that are comparatively small but that can collaborate with each other (see Figure 4 Demonstration of collaborating, self-driving tractors developed by VeBots at Hokkaido University in May 2018). Prime Minister Shinzo Abe presented a demonstration last year at the 14th

Figure 4 Demonstration of collaborating, self-driving tractors developed by VeBots at Hokkaido University in May 2018

Source: Science & Technology Office Tokyo

STS forum in Kyoto.

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