Design of big data acquisition for professional grower based on smart agricultural machinery systems

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Abstract

The last 20 years have seen an increase in agricultural technology and information systems intended to improve yields, reduce costs, and environmental sustainability production. However, these technologies haven’t delivered to practical farmer yet. This research looks at the challenges of creating step changes for precision agriculture, how to make big data which obtains from agriculture machinery for young farmer. This presentation focused on the importance of big data solution for inheriting farm management. Smart rice transplanter, smart 2nd fertilizer applicator and yield monitoring combine harvester (i.e. smart agricultural machinery systems (SAMS)) have been employed in order to monitor spatial temporal variability of topsoil depth, soil fertility and crop status for variable rate fertilizer application. As a result of field experiment indicated that 7,000,000 dataset of soil information, 65,000 dataset of crop status and 10,000,000 dataset of yield dataset were observed from the SAMAS. Variable fertilization design based on the experience of professional farmers also result in 20% fertilizer cut than conventional way and 30% harvest efficiency was improved. We concluded that the determination of variable setting values in field management with big data, the algorithm can be reflected the judgment of professional farmers. We should not apply only from the scientific aspect.

Introduction

Agriculture is presented with a significant potential to enhance system management capability based on rapid data collection and analysis as technology advances and increased regional digital connectivity are achieved. As agriculture robots and sensors crop up on farms and farm data grow in quantity and scope, farming processes will become increasingly data driven and data-enabled. Rapid developments in the Internet of Things (IoT) and cloud computing are propelling the phenomenon of what is called Smart Farming (Sundmaeker et al., 2016). In crop-production agriculture, Big Data comes mostly from sensors on site, yield monitors, remote sensing by unmanned aerial systems or satellites, and interpolated weather information. In addition, tapping into Big Data’s potential will require open data, standards, interoperability, and discoverability to converge, and that is currently far from the case. Precision agriculture tools, when coupled with innovative data-mining procedures and predictive models based on artificial intelligence, will be able to deliver personalized recommendations at an appropriate spatial scale, so that agricultural productivity and environmental performance can be truly improved. Big Data will cause major changes in scope and organization of smart farming. Business analytics at a scale and speed that was never seen before will be a real game changer, continuously reinventing new business models. Big Data will also cause major shifts in power relationships between the different players in the Big Data farming stakeholder network. For example, Toyota Co. Ltd. announced that IT tool developed in 2014, for meaning to organize data gathered from independent field laborers into a central database so that work on scattered, independent rice farms might be better managed. The tool generates and distributes daily coordinated work plans to multiple laborers at different rice fields over a large area. As laborers report their progress via smartphone or tablet to a central database, administrators can manage the overall cultivation.

On the other hand, we must consider who is information stakeholder and who is key person that take risk for variable rate management. The current development stage does not reveal yet towards which main scenario smart farming will be developed (Wolfert et al., 2016). Furthermore, agriculture is chaos, and running a highly successful agricultural enterprise requires an understanding of the system's complexities. Agricultural practitioners themselves have been shown to generally agree that farming is increasingly complex, especially as new technology/management options arise (Bennett et al., 2013). Modeling adaptation depends on the skills, experience and knowledge of each producer. The modelled adaptations presented to the farmers provided a good basis for a highly context-specific discussion on the viability of different adaptations. Modelling approach, for example pests and diseases, increasing energy and fertilizer costs, market and financial constraints, as well as environmental considerations (Kalaugher et al., 2017). Published algorithms have been sensor-specific and incorporate a variety of site-specific information depending on the sensor system being used. The reliance on these complex algorithms has resulted in slow commercial adoption rates despite well-documented success in both small- and large-scale research and demonstration studies (Phillips, 2015).

Considering the above report, our research team aimed to focus on establishing smart agriculture as producer's know-how as information infrastructure. Japan is well known to patchwork field and the size of one field is relatively 0.3ha as shown in Fig. 1. Ministry of Agriculture, Forestry and Fisheries pushes forward movement to integrate a farm of 0.3ha with a 1ha scale to realize effective work. Therefore, growers accumulated soil and cultivation information after years of their experience naturally. However, their average age is already over 68 years old already (Ministry of Agriculture, 2015).

Figure 1. Practical Japanese Farm Field. Size of fields are relatively 0.3 ha.

In response to the declining of both production and population, we proposed that utilization of Big Data in agriculture based on smart agricultural machinery systems (SAMS) in order to support farm management succession from elder grower to younger generations. The objectives of this study were to: 1) accumulate Big Data by using the SAMS, 2) evaluate in-situ variability of soil and canopy status and develop strategies of variable rate fertilizer application based on Big Data and grower's experience.

Material and methods

Smart agricultural machinery system (SAMS)

Smart agricultural machinery system is a schema of precision paddy agriculture, which is aiming for standardization of smart agriculture as shown in Fig.2. The SAMS consisted of two functions, 1) measurement of field conditions and geo-location obtained during farm operations (i.e, rice transplanting, top dressing, harvesting) 2). On-the-go N fertilizer application system based on farmer's experience. The sensors in these machinery systems enable collection of immense quantities of data without necessity of laboratory analysis. All the parameter listed below intends to be applied for relative field evaluation.

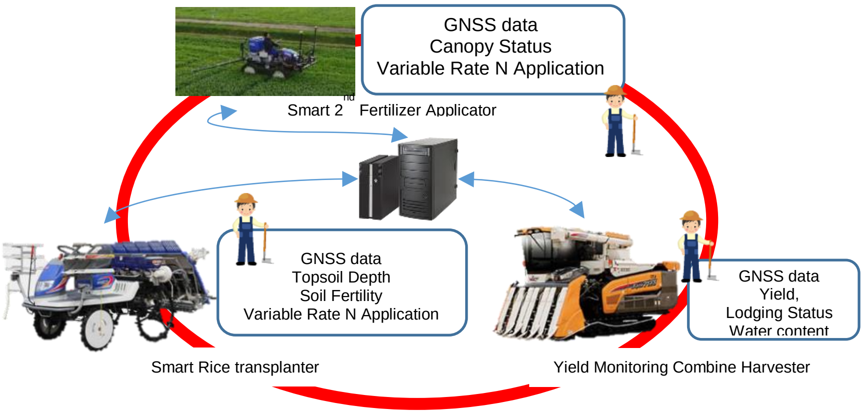

Figure 2. Concept of Smart agriculture machinery system

Smart rice transplanter (SRT)

Smart rice transplanter (NP80DLPEV, ISEKI) consisted of 3 types of on-the-go soil sensor and variable rate fertilizer applicator (VRA), mounted on the machine as shown in Fig. 3. Ultrasonic sensor, electrodes and platinum resistance thermometer were employed for topsoil depth (TD), apparent electrical conductivity (ECa) and soil surface temperature measurement, respectively (Morimoto et. al., 2013). The interval sampling of sensing was 5 Hz, and the volume of VRA could be adjusted every second. The model which set up for VRT was decided by grower themselves by using Android Application (Agri-support, ISEKI). It was consisted of three levels of N fertilizer application rate. The detail of algorithm will describe at the ACPA meeting.

設定する項目をタッチ　減肥設定：減肥あり　田植機接続状態：接続中

default	33.0kg/10a
試し繰出量	4.40kg(計測値)
Specific Gravity	0.82(計算値)
Reduction Rate1	30%
Reduction Rate2	20%
Reduction Rate3	10%

Figure 3. Outline of smart Rice Transplanter and Android application for variable rate fertilizer application

Smart 2nd fertilizer application system (SFAS)

Smart 2nd fertilizer application system (SFAS) provides the capability to vary the application rate of fertilizer inputs. On-the-go canopy sensor (CropSpec, TOPCON) and variable rate fertilizer distributor (JKB200. Hatsuta) were mounted on a high clearance tractor (JKB23, ISEKI) was shown in Fig. 4. Two Cropspec are mounted on top of the tractor and can read over 3m width of both sides. In addition, CropSpec is an oblique-looking sensor and has own light source, which eliminates the problems associated with ambient light such as cloud cover, low light intensity, shadows. The basic function of form of this sensor is to emit light in the visible and near-infrared spectrum and measure reflected light from the crop. Real-time variable fertilization was performed while traveling according to the control value obtained from the controller. The algorithm of variable rate fertilizer application was set by grower's feeling/experience. First of all, the data (S1) of the CropSpec at the maximum and the minimum of the leaf color was collected with producer. Next, the upper and the lower limit of the fertilizing amount were set based on S1 and grower's feeling as shown in Fig. 5. In this way, the variable rate fertilizer application can be set as an algorithm combining heuristics and sensor values. The SFAS was also equipped with GNSS to enable georeferenced information.

Figure 4. Smart 2nd fertilizer application system with CropSpec. The height of sensor is 3m and the length of fertilizer distributer is 15m

Figure 5. Decision making for 2nd fertilizer application based on grower's experience and CropSpec data (S1)

Results and discussion

Studied area

The studied area is located to the north west of Japan (N: 36.429107, E:136.500854). The location owned by Takemoto Farm Association, consisting of 400 fields with total area of 50 ha. Half of the field (i.e. 200 fields) represent actual field activity and applied as test site (applied VRA), while the rest were use as control (conventional uniform application).

Smart rice transplanter

A number of 314,169 dataset of TD and SFV were obtained by using the smart rice transplanter (SRT) in 2016. These data complemented by 138,092 additional data, collected in 2015. The average of TD in 2015 and 2016 were 212.9 and 215.2 mm respectively. However, the result of SFV in 2016 was shift to higher tendency than that of 2015 ones as shown in Fig. 6. The reason for this is to put manure application after the harvest in 2015, therefore the soil fertility improved very much. As a result, the amount of fertilizer application in 2016 was 14% lower than in 2015 and decreased by 27.2% compared to uniform application.

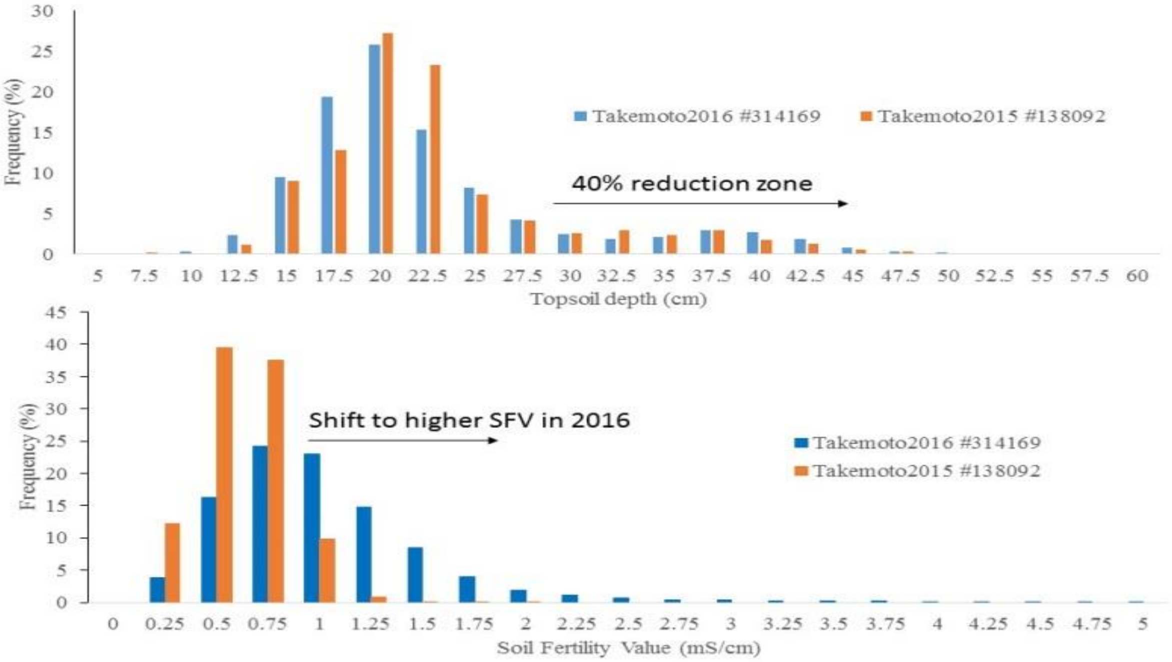

Figure 6. Histogram of TD and SFV in 2016 and 2015

Canopy Data

Since the 2nd fertilization timing is limited, setting of ATARI is very important, in order to incorporate expert know-how into variable fertilization as shown in Fig. 6. As a result, producers designed fertilization application with 3.0 kgN/10a at S1=15 and 1.5 kgN/10a when S1=30. Map of S1 and the results of variable rate fertilization was shown in Fig. 7. From 20 ha of initial study, 67,000 datasets were obtained. It revealed that the S1 map was worth to evaluate in-situ variability of field, especially high S1 was observed among the heading area. The variable application fertilizer system could reduce 2.2kgN/10a and 12% of fertilizer application as compared to uniform application (2.5kgN/10a).

Harvesting time evaluation

The most important parameter in the field assessment is the expansion of the appropriate work area during harvesting season, because the rate of fine-weather in Japan is only 40%, due to Typhoon and monsoon rain. Harvesting under fine day is very important for saving energy for grain drying. In this study, we applied harvesting efficiency for VRA evaluation. The result of time series study indicated that harvesting in conventional practice (non-VRA site) took 3.5 times longer as compared to VRA site. However, this result might be changing due to the weather condition during the growing season. Further investigation is need including the climate database for sophisticate crop evaluation with SAMS database. Further information will describe at the ACPA presentation.

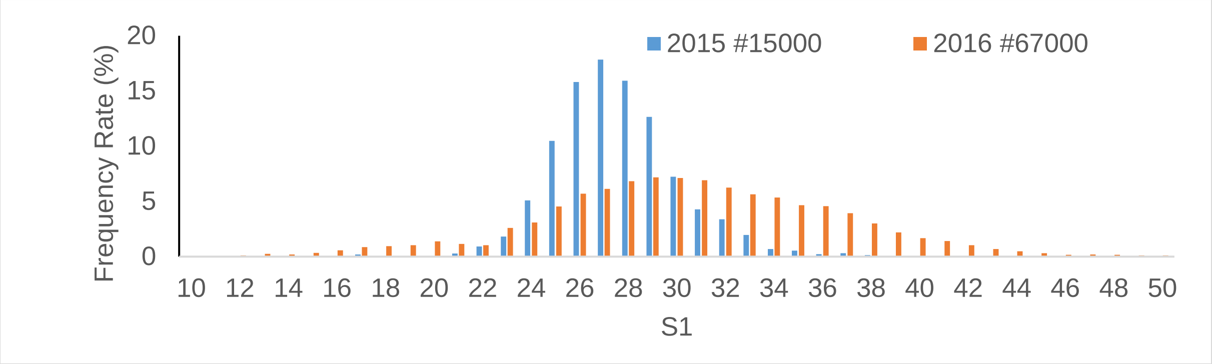

Figure 7. Histogram of S1 in 2015 and 2016. The tendency of S1 of 2016 was getting larger than that of 2015. It is thought that spraying compost increased the growth amount compared with 2015.

Conclusions

This paper conducted the feasibility study of VRA by using SAMS as Japan-Model smart agriculture. Results obtained from 2-years in-situ tests consist of: (1) total 442,261 dataset of topsoil depth and soil fertility value as created by using SRT, (2) total 82,000 dataset of N status was obtained by using SFAS. From this study almost 20% of fertilizer could be reduced during the SAMS adoption. In conclusion, this study suggests that a new paradigm should be created for precision agriculture technology extension. Author proposed that development precision agriculture technology need to consider that visualization of grower's feeling intuitively as well as benefit-driven.

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