A PRECISION MANAGEMENT STRATEGY ON SOIL MAPPING

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Abstract. *With the experience of field mapping practice during the last decade, a simple conclusion of four-level-field-management strategy was summarized. Level 1 was to describe the spatio-temporal variability of the fields, such as soil mapping and yield/quality mapping, and then to recognize the evidence in the field. Level 2 was to understand why the variability came out with help of farmers' experience, such as mushing up of the date, memorizing the work history and the environmental conditions. Level 3 was to make decisions in order to increase the throughputs in long-term implication, looking at increases in the yield/quality under regional constraints and reducing the cost, or change the cropping system. Level 4 was the action and evaluation, such as to choose actions under the constraints of such labors and machinery. Research actions corresponding to the levels are different each other.*

Keywords. *Soil Sensing, Soil Mapping, Knowledge, Precision Management, Farmers' decision.*

Introduction

Blackmore (2002) proposed eight principles in precision agriculture: that (1) precision agriculture is a management process, not a technology; (2) spatial and temporal variability must be measured; (3) the significance of variability in both economic and environmental terms should be assessed; (4) the required outcome for the crop and the farm must be stated; (5) the special requirements of the crop and the country should be considered; (6) ways to manage variability to achieve the stated outcome are to be established; (7) methods to reduce or redistribute the inputs and assess the risk of failure need to be considered; and (8) crops and soil must be treated selectively according to their needs. In 2011, Japanese Society of Agricultural Machinery (JSAM, now JSAMFE) organized a special team and offered the approach for recovering the big disaster of earthquake and Tsunami (Shibusawa 2014): (1) to validate the facts and information on the disasters since there were confusion and complexity, (2) to investigate the damages in terms of agricultural machinery and farm management, and (3) to propose better scenarios of reconstruction for community-based agriculture. These approaches are called 'precision thinking" summarized by four steps as shown in Fig. 1.

The objectives of the paper is to apply this assumption to reorganizing our soil sensing practices for the last twenty years and then to explore the next stage of precision agriculture researches.

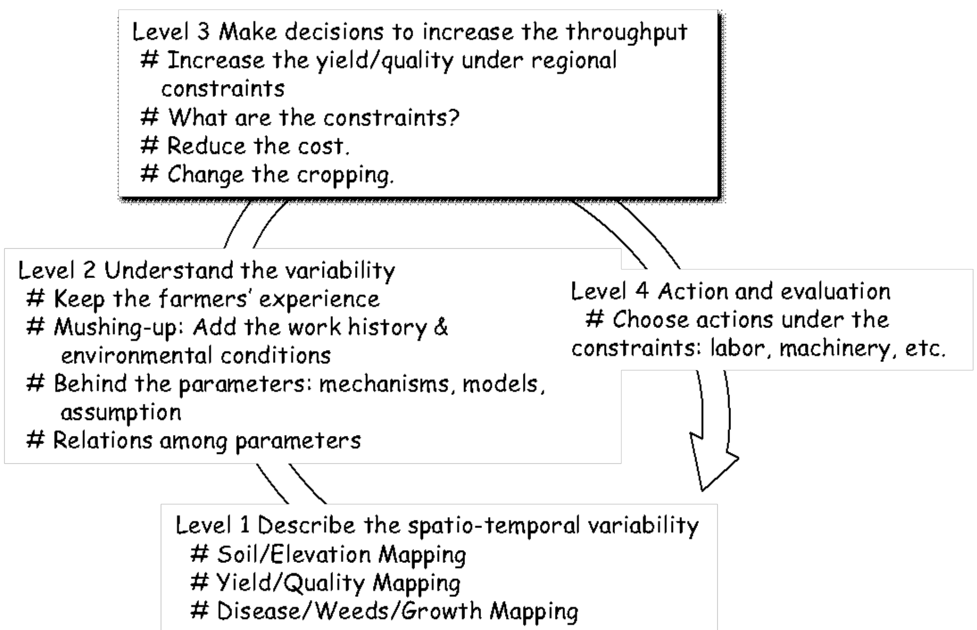


Figure 1. Four steps of precision management practices.

Describe the Variability

The first level or first step of precision management was visualization on the variability of the field. If no variability was found there was no need to introduce precision management, which induced critical discussion in 1990s of Japan. Shibusawa et al (1998) confirmed the within-field variability of a small field in terms of a few soil parameters with a soil-sampling and mapping method, as

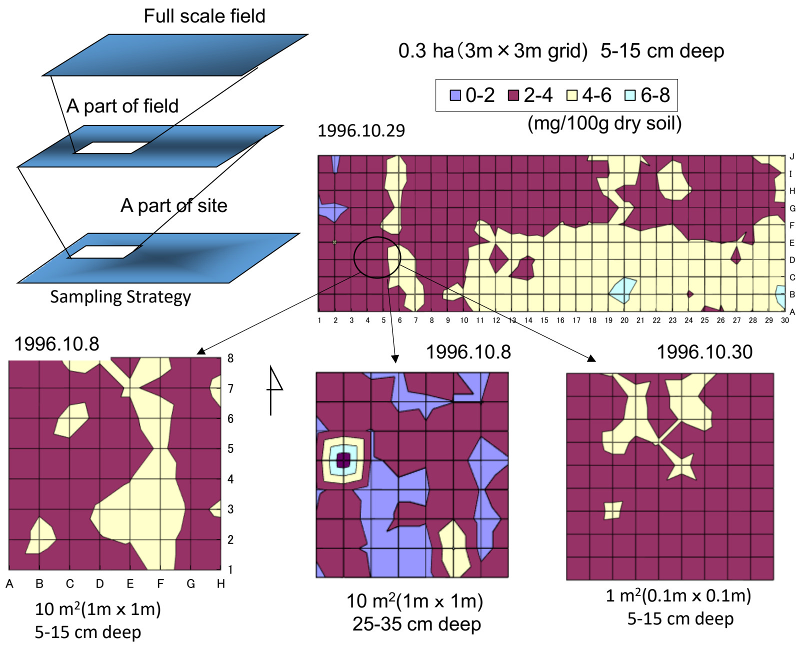


Figure 2. Soil-sampling and mapping of nitrate nitrogen of a 0.3 ha field in different scales

shown Fig.2. Soil samples were collected by 300 at the top soil of 5-15 cm depth in 3 m square grid sampling strategy across a 0.3 ha full scale field, by 300 in 1 m square grid sampling at three different depths of 5-15, 15-25 and 25-35 cm of a 10 m square site in the field, and by 300 in 0.1 m square grid sampling at three different depths of 5-15, 15-25 and 25-35 cm of a 1 m 1 square spot in the field. Results showed more than 4 times difference of soil parameter values in nitrate nitrogen, pH, electric conductivity (EC), and more big difference at the depth of 25-25 cm.

The evidence of visualized variability have derived the discussion on the need of precision management and on the need of effective methods for soil sensing such real-time soil sensing. Shibusawa et al (2001) developed a prototype spectrophotometer with a RTK-GPS, the soil penetrator to ensure a uniform soil surface under high speed conditions, and all units are arranged for compactness. Field experiments in a 0.5 ha paddy field resulted in detailed soil maps of moisture, soil organic matter (SOM), nitrate nitrogen (NO3-N), pH and electric conductivity (EC), using spectroscopy. While there were many approaches to soil sensing and mapping methods (Shibusawa 2006), a commercial version of real-time soil spectrophotometer was launched in 2004 and a soil analysis approach was developed as shown Figs 3 and 4 (Kodaira et al 2013).

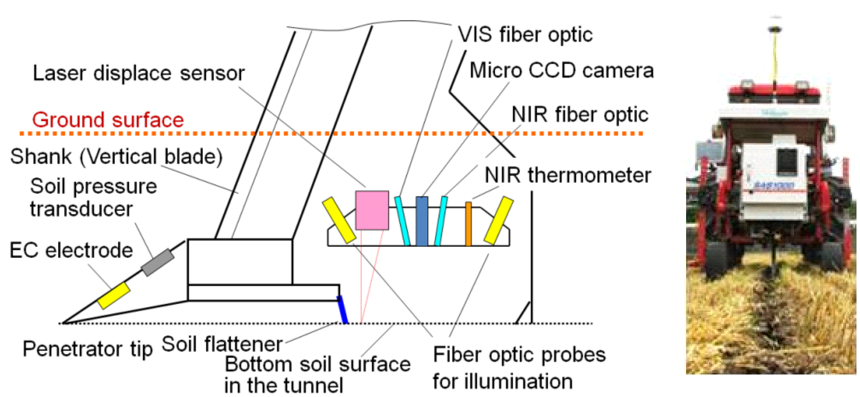
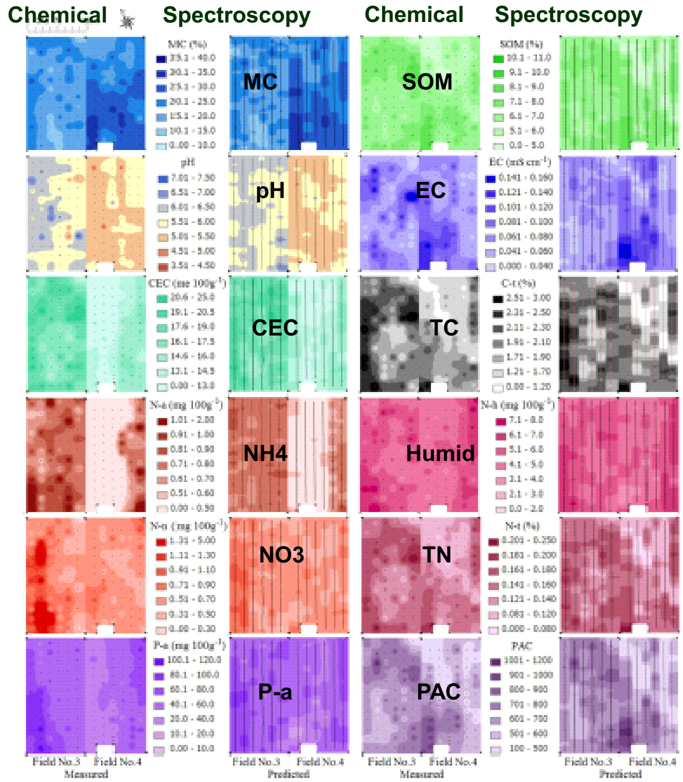


Figure 3. A tractor-mounted real-time soil spectrometer.



PAC: Phosphate Adsorption Coefficient

Figure 4. Soil maps by using the real-time soil sensor SAS1000.

The aims of were to develop calibration models of dozen-soil-parameter (DSP) based on visible and near-infrared (Vis-NIR: 305-1700nm) underground soil reflectance spectra collected using the Real-time soil sensor (RTSS) with a differential global positioning system (DGPS) in commercial upland field, and to appear high-resolution DSP maps for site-specific soil management on precision farming as a decision-making support tool for the grower. The soil parameters for DSP mapping investigated in this study were moisture content (MC), soil organic matter (SOM), pH, electrical conductivity (EC), total carbon (C-t), ammonium nitrogen (N-a), hot water extractable nitrogen (N-h), nitrate nitrogen (N-n), total nitrogen (N-t), available phosphorus (P-a), phosphorus absorptive coefficient (PAC), and cation exchange capacity (CEC) in the soil. The experimental site is commercial upland field with an alluvial soil that located in Hokkaido, Japan. Partial least-squares regression (PLSR) technique coupled with full (leave-one-out) cross-validation was used with the Unscrambler software Ver.9.8 software (CAMO Software AS, Norway) was used. Estimate values of DSP for the collected large number of underground soil reflectance spectra using the RTSS with a DGPS in commercial upland field were predicted by each calibration models. The predicted soil maps and the measured soil map of soil chemical analyses for DSP were drawn using ArcGIS Ver.10.0 software (ESRI Inc., USA).

Based on the high-resolution soil pH map, the grower found his miss work of over-supply of beet lime ($CaCO_3$) at some location and scattered correct amount of sulfur to adjust pH at the correct location before planting of potato. He memorized the miss work but forgot the location for several years, and he did not made decision without correct information.

Undersatnd the Variability

As mentioned above, growers could understand the soil variability when researchers provided correct information, but its inverse was not available. A paddy farmer requested a claim that one side of a small paddy field provided poor yield and the other side provided rich yield for years. He

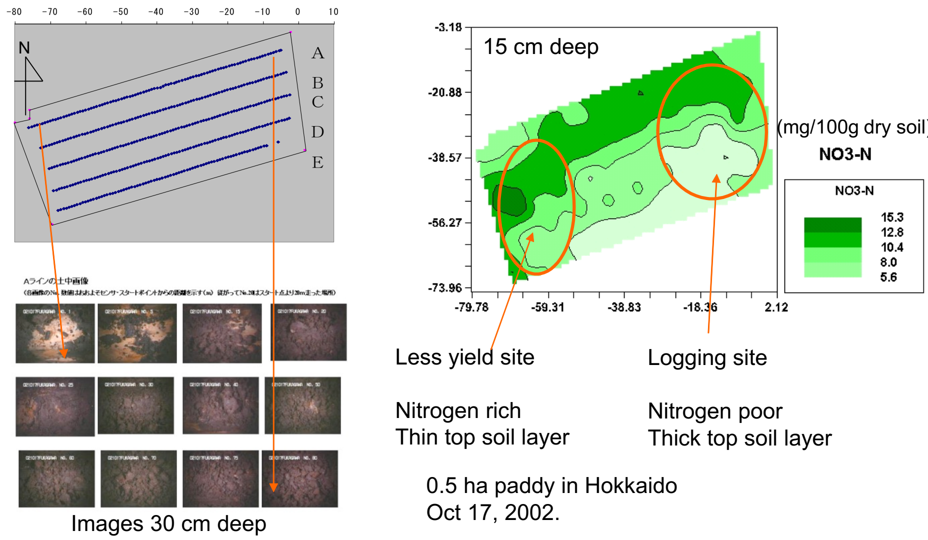


Figure 5. Reply to a farmer's question, why the rich soil made poor yield, in a double-depth sampling strategy.

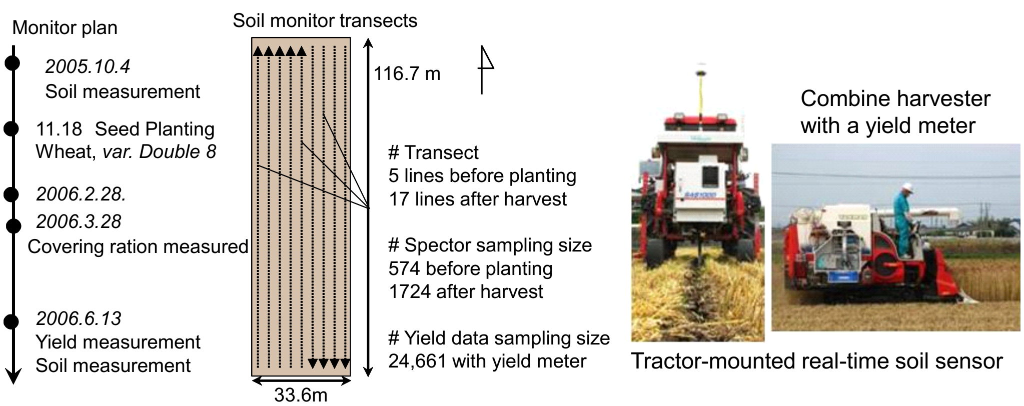


Figure 6. Experimental design for getting relationship of soil and yield variation.

changed amount of fertilizers applied corresponding to the yield. In 2002 the paddy field was monitored at different depths of 15 cm and 30 cm using the real-time soil sensor (RTSS) developed by Shibusawa et al (2001). The results showed that nitrate nitrogen was high on the less yield site and was low on the logging site on the map of 15-cm depth, and that a thin top later was found on the less yield site and a thick top layer on the logging site on the soil image map of 30-cm depth. The grower explained what happed in the land reclamation project more than 25 years ago and the effect of miss practices still remained at that time. There was no way to improve the layer of op soil.

Shibusawa et al. (2007) conducted a field monitor test to understand what happed in the field during a cultivation season of wheat as shown in Fig. 6. Two soil maps before planting (574 data points) and after harvest (1724 data points) were generated using the real-time soil spectrophotometer (RTSS) in a 0.3 ha field. A yield map (33,109 data points) was also obtained from the same field using a combine harvester with a yield meter. Evaluation of nitrogen balance at each grid resulted in attractive relationships between total nitrogen (TN) and yield, TN and protein content of grain, and nitrogen loss and yield, as shown in Fig. 7. The research team of the author thought that the yield map, nitrogen and its loss maps could provide a recommendation of fertilizing formulae, but a question of the growers was why the difference in nitrogen loss came

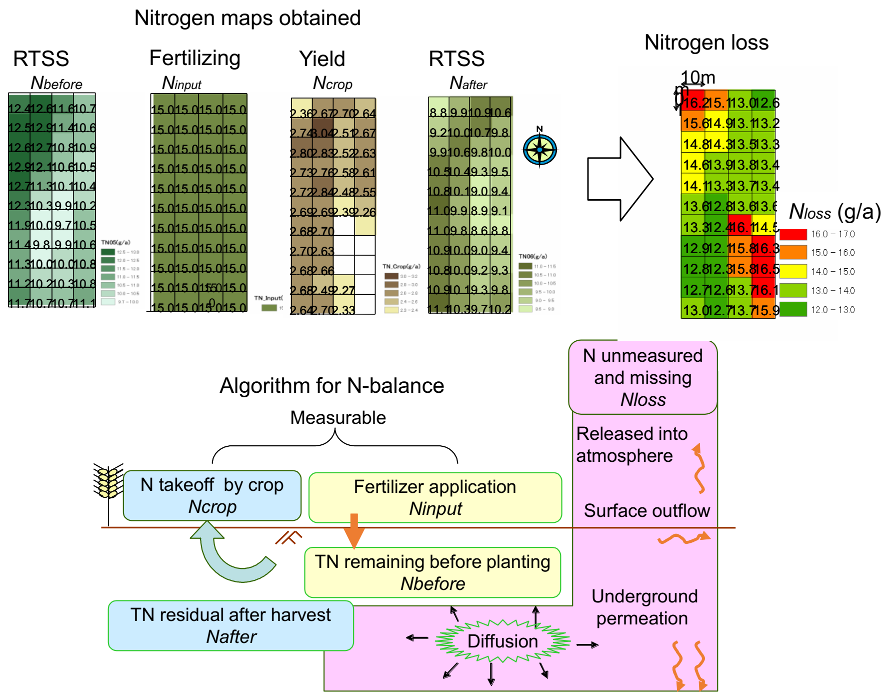


Figure 7. Algorithm for N-balance of the field using nitrogen maps.

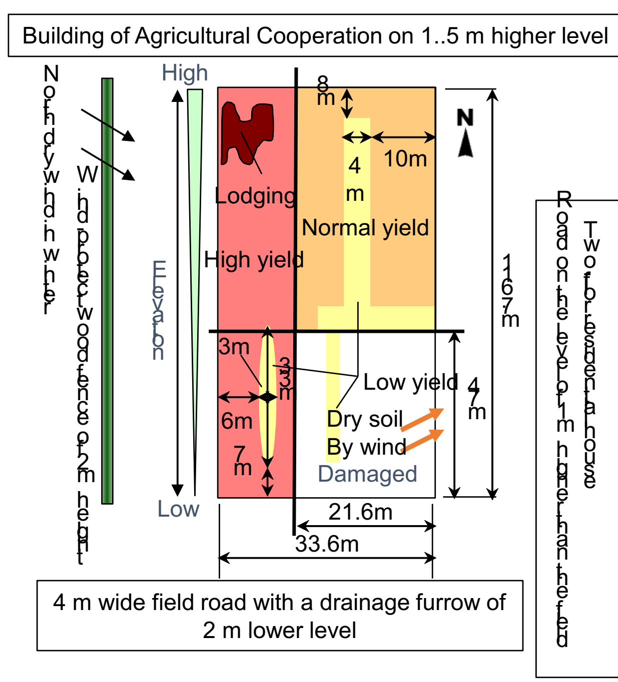


Figure 8. Yield variation in visual observation on the experimental site.

out. It was confirmed that only showing the detailed maps did not help the decision make.

Then hearing was conducted to farmers and researchers managing the field. New findings were: (1) the field had been a test field for new variety plants a wheat for the right side and a yam for the left side, (2) yam cultivation tended to make rich residual soil and wheat cultivation to make poor residual soil, (3) fairly uniform fertilization management had been done and they expected less variability of the field, (4) the field surface had slightly inclined from the north to the south, (5) the field had the 2-floor big building of 1.5 m higher elevation on the north side and the drainage furrow of 2 m lower level on the south side, (6) the field had the 2 m high wood fence on the west side and the 1 m high traffic of road with two-floor dormitories on the east side, (7) the cold and dry wind attacked at the field surface and blew up in winter season. Water tended to move from north to south, and it could made wet in north and dry in south. Logging of wheat came out at the spot of north-west with rich nitrogen and wheat plants withered at the south east spot with heavy drought. That is why these portions showed relatively less absorption of nitrogen by wheat plants, and it could make high level of nitrogen loss.

This context information about the field and cultivation provided useful for understanding the soil maps. But they needed other evidence when they made decision.

Decision Making

For decision making support several data were set up as shown in Fig. 9 (Shibusawa et al 2007). The target yield was settled as 3.5 t/ha using the last 10 years average of the local area. Crop quality was evaluated as the amount of protein of higher than 13%. Formulas were relationships between total nitrogen of soil and grain protein content or yield or nitrogen loss to the environment. The protein contents decreased with the total nitrogen while the yields and the nitrogen losses increased with the total nitrogen. The critical value of total nitrogen was 2.7 t/ha of the field.

Then a suggestion could be keeping a value around 2.7 t/ha of total nitrogen. Decisions were on the side of farmers but the side of researchers.

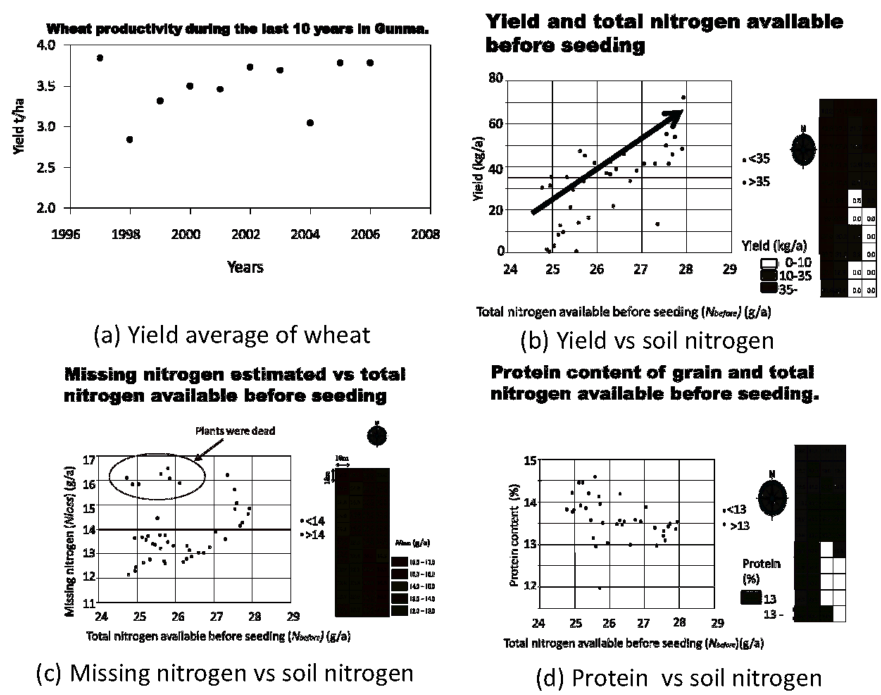


Figure 9. Results obtained for recommendations.

Action and Evaluation

Farmers' decision and action depended on profitability and productivity or sustainability. An agricultural corporation, Aguri Co., Ltd., has introduced a concept of precision agriculture and soil mapping strategy for more than 10 years, keeping an organic farming system as shown in Fig.10 (Shibusawa et al. 2012). Aguri farm was a 30 ha cultivation land of 400 small paddy fields. Hundreds of senior farmers asked them for cultivation but they wanted to keep the ownership of the land. Inevitably Aguri farm had to manage the number of fields without reforming and with less skills and knowledge. Aguri farm also had a concept of compact sustainability of the local community.

Aguri farm had two bottleneck points for low-cost and high-output management: the one was web sales with advertising information on science-based non-chemical organic products and the other was uses of waste-composted organic fertilizer. The customers bought the rice by 50 % high price compared with the normal because of its high quality and evidence-based cultivation system. And Aguri farm got organic waste from city halls and livestock farmers with treatment charge or no charge because they had the license of industrial waste treatment, followed by composting it on the farm. The composts had various components and gradients, and they need correct information on the soil. They have accumulated soil maps using the real-time soil sensor for 13 years, and also accumulated the yield and quality data of each field. They have confirmed increases in total carbon of soil for the last decade.

With the experience actions of AGURI farm were: (1) keep soil mapping and look at total nitrogen and total carbon vs yield, (2) keep organic-based fertilizers, (3) get the needs of customers, (4) get the knowledge of scientists and professionals, (5) and toward carbon farming system with compact sustainability in customized approaches.

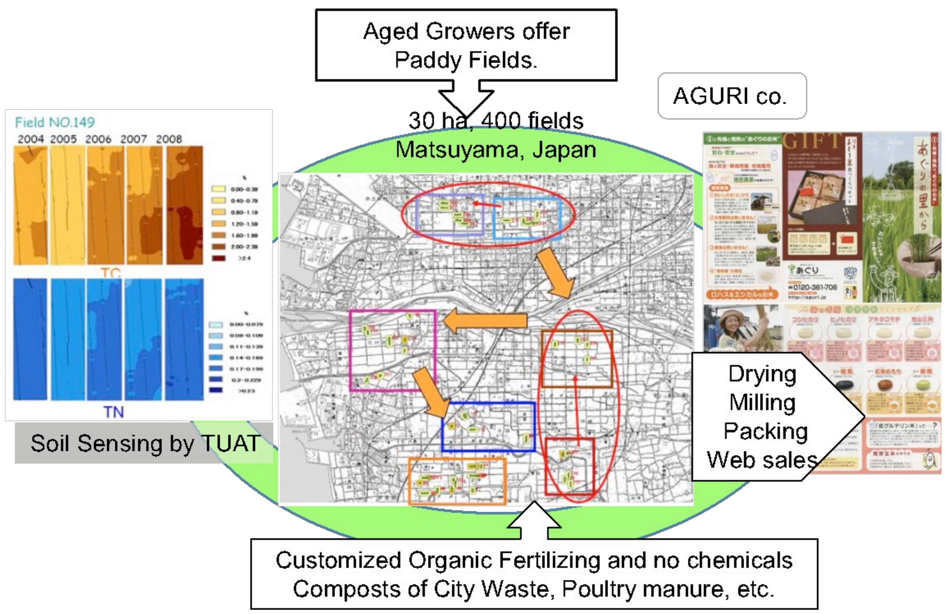


Figure 10. Actions driven by motivations of market requests and agronomic requests toward organic paddy management.

Conclusion

With the experiment and practice for the last decades in Japan, it was recognized the management involved four levels of knowledge in action. Level 1 was to describe the spatio-temporal variability of the fields, such as soil/elevation mapping, yield/quality mapping, disease/weeds/growth mapping, and then to recognize the evidence. Level 2 was to understand why the variability came out, with help of farmers' experience, mush up of date and memorized the work history and the environmental conditions, moreover to analyze behind mechanisms, models and assumption of the apparent results of parameters. Level 3 was to make decisions in order to increase the throughputs, looking at increases in the yield/quality under regional constraints, and reducing the cost, or change the cropping system. Level 4 was the action and evaluation, such as to choose actions under the constraints of labor, machinery, etc. One of the actions of growers was to introduce a carbon-farming concept.

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