PRECISION AGRICULTURE RESEARCH AT KYOTO UNIVERSITY -- Concept and objectives of the research

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ABSTRACT

One of the way of the preserving environment is the circulation of materials. Japan's cereal food self-sufficiency rate is less than 30%. Japan imports more than 30 million tons of food every year. Japanese are afraid of international food trade giving damages to environment. Advanced farm mechanization integrated with precision farming is an answer to solve these problems. Crop scientists, soil scientists and agricultural engineers at Kyoto University cooperate together in studying precision agriculture for paddy rice since 1996. Automatic follow-up combine and autonomous vehicle have been developed. Remotely sensing by using machine vision has been studied to measure nitrogen contents. Field map i.e. soil, growth and yield, in paddy field of 0.5 ha has been made. In this report the concept and objectives of advanced farm mechanization and precision agriculture research at Kyoto University are introduced.

Keywords: Food self-sufficiency rate, Preserving environment, Autonomous vehicle, Automatic follow-up combine, Remotely sensing

INTRODUCTION

In USA of 1960s a mixed farming and crop rotation turned to be a single crop farming with excessive chemicals. Since ground water contamination and soil erosion could not ignore in 1980s, the concept of Low Input Sustainable Agriculture (LISA) was proposed. After that the concept of Site Specific Crop Management (SSCM) was proposed (Goering 1992). The main objective of SSCM was to adjust the application of chemicals fit to the soil conditions every small section. To apply variably chemicals every section, measuring position of the fertilizer was required. Measuring position is one of key technology to SSCM. In 1990s the problem on measuring position was solved by using NAVSTAR-

GPS (Navigation System Timing and Ranging/ Global Positioning System), which was administrated by the US Air Forces. GPS has higher accuracy than the previous position measuring system. GPS enables to make a field map and to realize SSCM. Before using GPS large area data were only estimated from a few spot data. After using GPS, SSCM was called as precision agriculture or precision farming. In Europe the situation was similar to the US. Precision agriculture has attracted European researchers, too. In Japan however the situation is different from the US and Europe.

Meanwhile one of the way of the preserving environment is to circulate resources and materials we are using. If the materials would return to the original places, the damages to environment would be minimized. Japan's cereal food self-sufficiency rate is less than 30%. Japan imports foods and exports industrial products. The circulation of the materials is interrupted. If the food import were the cause of environmental pollution, Japan had to make an effort to reduce food production cost in order to increase food self-sufficiency rate. The method of precision agriculture is useful to calculate the circulation of the materials. Thus crop scientists, soil scientists and agricultural engineers at Kyoto University cooperate together in studying precision agriculture for paddy rice since 1996. In this report the concept and objectives of the advanced farm mechanization and the precision agriculture research at Kyoto University are introduced.

THE EFFECT OF FOOD TRADE TO THE ENVIRONMENT

German's and the United Kingdom's calorie supply self-sufficiency rate was still 60% and 50% in 1970, respectively. Today, however, they are more than 100% as shown in Fig. 1. European countries' rates are increased for last 2 decades. However Japan's calorie supply self-sufficiency rate was deteriorated from 79% to 46 % between 1960 and 1994 as shown in Table 1. It continues to decline. Though rice self-sufficiency rate is still about 100 %, but wheat and soybean are only 9% and 5%, respectively. While concentrate feed is

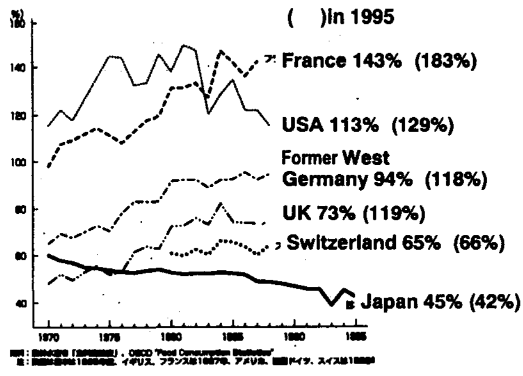

Fig. 1 Calorie supply self-sufficiency rate

produced only 25%. Japan's cereal self-sufficiency rate is less than 28% in 1996. Japan imports 30 million tons in food per year. The imported food takes away about 5 billion tons of water, 0.8 million tons of nitrogen and 0.2 million tons of phosphorus from food exporting countries. Feed changes into about 90 million tons of livestock waste (Kyuma, 1997). If the waste should return to the field, 5 million ha in area should be required. The area is nearly equal to all arable lands in Japan. It is difficult to carry the waste to the field and it is more difficult to transport them to the food exporting countries. The livestock wastes are being accumulated in Japan, so that it causes offensive odor and deteriorates water quality. Japan's food import is not only taking away soil nutrition from the exporting countries, but also preventing the circulation of the materials.

Korea's situation is similar to Japan. Korea's cereal self-sufficiency rate was more than 70% in 1980s. With high economic growth, the rate is deteriorated until 35% in 1996. Korea and Japan import organic matter as food and export inorganic matter. As a results the trade might prevent the circulation in the global eco-system.

Table 1 Japan's Food self-sufficiency rate

	1960	1990	1994	1996 (%)
Calorie supply	79	47	46	42
Cereal	40	30	33	28
(General) 91	67	62	63	
Rice	102	91	120	101
Wheat	39	12	9	7
Beans	28	5	5	5
Fruits	100	63	47	47
Meats	91	70	60	58
Hen's egg	101	98	96	96
Milk, dairy	89	78	73	72

CHARACTERISTIC OF JAPANESE AGRICULTURE

Paddy rice is a staple food in Japan. Rice is a nutritious crop. Thus a small paddy field, about 0.5 ha, enabled a family to live until the end of 1940s. Average farm size of a tenant was about 1ha, because it was the area in where a farm household could cultivate without farm machines. Rice producing countries' situations are similar to Japan. Just after World War II the improving food shortage was important. The traditional land lord system was considered to be an obstacle to improve it. The land reform policies was implemented by the allied occupation forces. At that time, all Japanese tenants became independent farmers who cultivated about 1 ha. The reform was very useful in the improvement of the land productivity.

In 1970s Japan's economy was highly grown. The high economic growth gave the farmers the employment opportunities. Japan is a mountainous island country, so that the plains are narrow, and factories were built in the vicinity of the field. A land is extremely valuable. Though employment opportunities were increased, most farmers did not apart with their fields. They became part time farmers. At the present about 2.5 million households are part time farmers and only 0.3 million households are full time farmers. As a result, the farm size was not changed.

Considering the environment, paddy field is surrounded by levees. Thus it is advantage for soil erosion. A section of the paddy field is between 0.1 and 0.5 ha, so that inside condition of a section is uniform. Japan's agriculture has been intensive. Someone said that the agriculture has already been precisely. In addition to that, the paddy has merits to preserve environment. For example, they are the function of purification of the water, the storage of water, temperature adjustment by evaporation from the paddy surface, nothing of continuous cropping injury and so on. Korea's situation also is similar to Japan's. Paddy rice is staple food. 59% of farmers have less than 1 ha. Average farm size is 1.3 ha. Introducing the precision agriculture into Korea and Japan, we have to give careful consideration to these conditions.

ADVANCED FARM MECHANIZATION

To keep the circulation of the materials, Japan's food self-sufficiency rate might be increased. We assumed to be 300,000 core farm households. In our concept the households may manage about 100 ha of field, handled by husband and wife using advanced farm machine and robot. Farm household of 100 ha is too large like a dream to Japanese. If the large size farm household could be realized, they might adopt precision farming to keep current precise operations. The concept of our advanced farming system consists of automatic follow-up vehicle system (Iida 1998 and 2000), and autonomous vehicle (Suguri 1999 and Morimoto 2000) as shown in Fig. 2. In Japan about two million part time farm households might be exist in the future. They need small farm machines. The machines may have been mass-produced in the future. Automatic

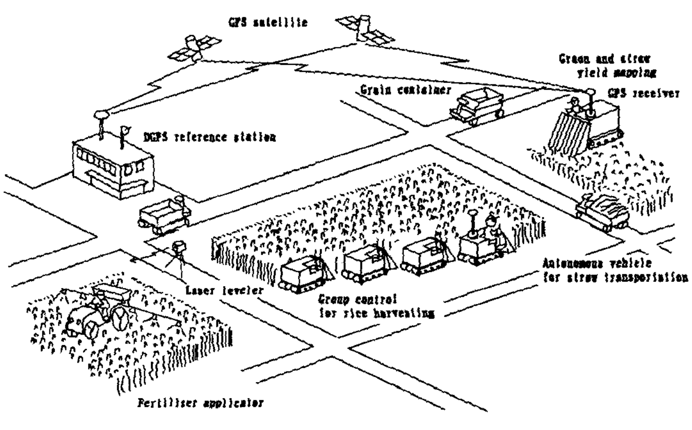

Fig. 2 Concept of Advanced Farm Mechanization

follow-up vehicle system also is called group control system. The harvesting of rice by group control combine is shown in Fig. 3. If a farmer would adopt the system, an operator could control two or three farm machines, so that a large farm could be managed by using mass-producing small farm machines. Meanwhile a person operates machines in the field and another person works in farmhouse. There is no person to drive a carrying vehicle. Therefore autonomous vehicle has been developed as shown in Fig. 4.

Besides watermelon harvesting robot has been developed (M. Umeda, 1998).

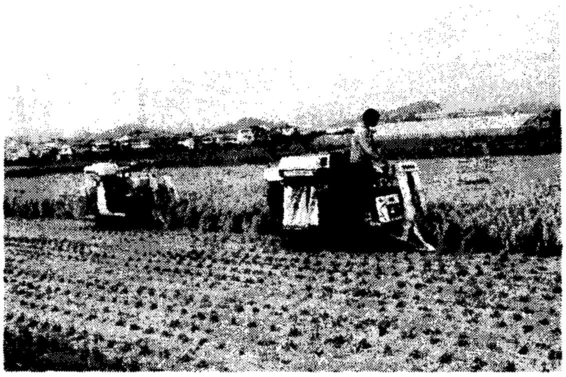

Fig. 3 Harvesting Rice by Group Control

Fig. 4 Autonomous Vehicle

CONCEPT OF PRECISION AGRICULTURE IN PADDY

The concept of precision agriculture in paddy is a saving nitrogenous fertilizer. There are 2 concepts to apply fertilizer. In cold region, the activity of microorganism in the early spring is not enough, so that design of basal dressing is important in order to get the numbers of stalks. Microorganism become actively and nutrition from soil are plentifully supplied at parnicle formation stage. Meanwhile in warm region, the activity of microorganism is enough even in the early spring. However nutrition from soil at parnicle formation is in short. Therefore the topdressing adjustment is important in order to control the number of grains i.e. glumaceous flower. Hokuriku Agricultural Experiment Stations (Joetsu in Nigata Prefecture) of Ministry of Agriculture, Forestry and Fisheries in Japan is studying precision agriculture and it is located in comparative by cold region. Therefore I heard that the design of basal dressing based on last yield map is important rather than the topdressing adjustment. However Experimental Farm of Kyoto University (Takatsu in Osaka Prefecture) is located in comparative by warm region.

In warm region, nitrogenous fertilizer demand is decided by following equation (JSSSPN, 1990)

$N_c = N_f/j = (N_{op} - h - N_s)/j$

N_c: Actual application of nitrogenous fertilizer

N_f: Demand of nitrogenous fertilizer

j : Available rate

N_{op}: Optimum nitrogen demand at earing

h : Nitrogen possessed at topdressing

N_s : Nitrogen supplied from the soil between topdressing and earing

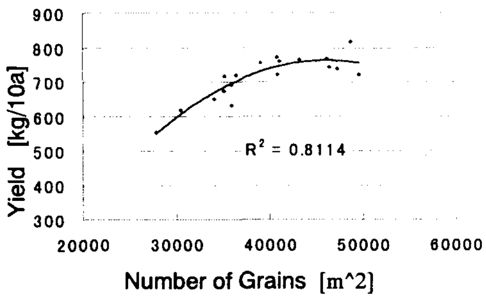

Fig. 5 Yield and Grain number

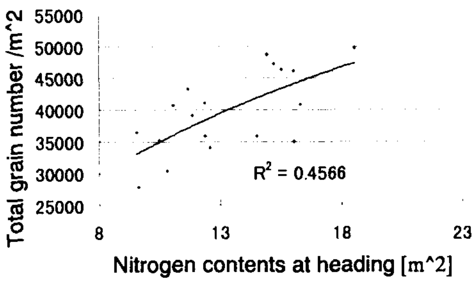

Fig. 6 N contents and No. of grains

The optimum nitrogen demand at earing is decided by the desired number of grains. The relation between yield and the number of grains is shown in Fig. 5. The relation between the number of grains and nitrogen contents is shown in Fig. 6. h is the crop possessed nitrogen at topdressing. It is calculated by the measuring leaf color. The color means the density of the crop chlorophyll contents. N_s is decided as follows. First soils sampled from the field are incubated at temperature 30 centigrade and for 4 weeks. Microorganism change inorganic nitrogen into mineralized nitrogen in the incubator. The nitrogen changed during 4 weeks is the criterion for soil fertility. The soil fertility is increased proportional to cumulative temperature. Thus N_s can be calculated by using the nitrogen and the Effective Cumulative Temperature Method (JSSSPN, 1990).

REMOTELY SENSING NITROGEN CONTENTS BY USING MACHINE VISION

Remotely sensing nitrogen contents is important technology to adjust chemicals at topdressing. In our laboratory, the relation between the leaf color and the nitrogen content has been estimated by using the normalized difference vegetation index (NDVI). NDVI based on algebraic combination of different wavelength bands i.e. 535nm (Green) and 800nm(Near infrared), or 670nm(Red) and 800nm(Near infrared). That called Green NDVI, and this called NDVI. In 1999 nine different experimental plots were made by combination of three different basal dressings 0, 3 and 6 ton/ha, and three different topdressings 0, 3 and 6 ton/ha. The combination is shown in Fig. 7. The scene of the measuring reflectance is shown in Fig. 8. The leaf area, the height of stalk and the diameter of a bunch are measured at five times between the panicle differentiation stage and the harvesting. Moreover the nitrogen content of stalks, leaves and panicles have been

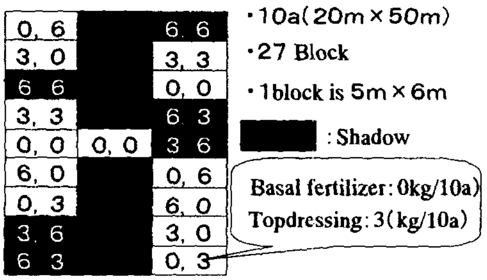

Fig. 7 Combination of Fertilizer

Fig. 8 Measuring reflectance of leaf color

measured by CN coder, respectively. The chlorophyll meter (Minolta SPAD 502) has been used, too. The experiment indicates that NDVI is useful to estimate nitrogen contents. In 2000, 7 combination at 8 plots has been tested.

Applying variably chemicals, smart fertilizing machine has been developed. The machine vision, RTK-GPS and the application program including the soil fertility map will be mounted on the machine. In August of 2000 chemicals were applied, but machine vision was not used. To compare the response of variable fertilization, chemicals were variably applied in only east half side at 0.5ha farm and were uniformly applied in west half side.

MAKING FIELD MAP

Field map consists of soil, growth, yield and so on. The soil map and yield map in the field of 0.5ha at Takatsuki Farm of Kyoto University have been made since 1997. Growth map by using SPAD 502 has been made since 1999. These however are reported in detail as other report for this conference, ICAME2000, "Field Mapping for Paddy Rice" [C. K. Lee, M. Umeda and et al]. Therefore the field map is omitted.

CONCLUSION

Concept and objectives of precision agriculture at Kyoto University are introduced. Japanese are afraid of the international food trade giving damages to environment. Advanced farm mechanization integrated with precision agriculture is an answer. The research has been continued for 5years. However there are many unknown factors. Therefore the research must be continued from now on.

The detailed method and result of the research are described in the reference of this paper.

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