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Technological Innovation in Japanese Agriculture : Progress and Prospects

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Since the 2000s, compared with other countries, the rates of annual increase for Japanese rice, wheat, barley and soybean yields have been low. Stagnation of land productivity is a serious problem in Japanese paddy farming. On the other hand, the rapid expansion of core farmers' farmland is expected. In these circumstances, new farming technologies which utilize Information and Communication Technology, Robot Technology and Artificial Intelligence, so-called "smart agriculture" are expected. However, those technologies themselves do not convert the cultivation technology. Therefore, for the improvement of land productivity, it is necessary to develop a new cultivation system with the utilization of smart agricultural technologies.

Key words: technological innovation, smart agriculture, automatization

1. Introduction – Agricultural Development and Technological Innovation

1) Targets of analysis

The purpose of this paper is to analyze the progress of technological innovation in the 20 years since the establishment of the Basic Law on Food, Agriculture and Rural Areas (new Basic Law), and to comment on future issues and prospects of Japanese agricultural technology development. Improving productivity is a theme that should always be pursued in agricultural policy. However, there have been no major technological advances in Japanese agriculture over the past 20 years, indicating that some problems exist in agricultural policy.

In contrast, in the 2000s, the agricultural structure changed rapidly. In response to this, new farming technologies which utilize information and communication technology (ICT), robot technology (RT) and artificial intelligence (AI), so-called "smart agriculture" are expected. This paper also discusses the factors behind the stagnation of land productivity related to paddy farming in Japan since 2000 and the possible application of smart technology.

2) Development of agricultural technology

The development of agricultural technology is closely related to progress in agriculture and rural communities. Increasing food production was the most important issue before and after the Second World War, and rice yields were

improved through development of cold-tolerant varieties and diffusion of the protected semi-irrigated rice nursery. In the 1950s, with the development of heavy and chemical industries, production of fertilizers and agricultural chemicals expanded, and the input of these materials contributed to increases in crop yield and labor saving in weed control.

During the period of high economic growth, rice crop mechanization technology progressed in response to the migration of labor from rural to urban areas, and the relative increase of labor costs. In addition, as competition between rice production areas became severe, development and popularization of good-tasting rice varieties such as "Akitakomachi" and "Hitomebore" progressed. However, rice consumption decreased, and adjustment of rice production proceeded after the 1980s. Therefore, in the field of technical development in paddy field agriculture, the establishment of direct-seeding rice cultivation technology and the establishment of wheat, soybean, and forage production in paddy fields became important issues.

The direction of technological development that focused on labor saving, quality improvement of crops, and stabilization of production in upland fields converted from rice paddies has not changed since the 1990s. In these terms, individual technological developments such as marker-assisted breeding due to biotechnology have progressed, but

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there have been no major technological innovations.

2. Characteristics of Technology Policy in the New Basic Law

The concept of technology policy in the Basic Law on Food, Agriculture and Rural Areas (new Basic Law) affect the setting of (A) food self-sufficiency rate targets, (B) production effort targets in the basic plan for food, agriculture, and rural areas (basic plan), and (C) the basic research plan on agriculture, forestry, and fisheries. Table 1 shows the production effort target for each crop, the target cropping area, and target yield in the past three basic plans. For example, in the case of wheat, the target production amount was set at 1.8 million tons in the 2010 basic plan, but was lowered to 0.9 million tons in 2015. Similarly, for soybeans, the production target in 2015 was about half of that for 2010.

The basic plan in 2015 did not aim to establish cropping systems with a high land-utilization rate, such as by expanding the wheat crop area. With regard to the setting of yield target in the basic plan for 2015, wheat was 432 kg/10a, barley/naked barley was 358 kg/10a, and soybeans were 215 kg/10a – these yield levels were not high. In particular, the target yields for wheat, barley, and naked barley in 2015 were lower than in 2005. Historically, crop yields have generally improved over the years. However, in a basic plan that aims to improve the food self-sufficiency rate, it is unusual to set a yield target lower than for 10 years previously. Thus, the setting of yield targets for wheat, barley and naked barley in the basic plan have been quite restrained.

3. Progress of Technological Innovation since 2000

1) Stagnation of land productivity

The core productivity indicator in land-use-type agriculture is crop yield level. Comparing the annual average increase rate in the yield of rice, wheat, barley, and soybeans in Japan with the world's major producing countries (Table 2), shows the annual average yield increase rates for other countries are 1.5–2% for all crops, while in Japan the annual yield increase rates for rice, barley, and soybeans are less than 1%.

Figure 1 shows the annual average increase rate for each of 3 periods: the 1960s to 1970s, 1980s to 1990s, and 2000s. The annual yield increase rate in the 1960s to 1970s was still high in Japan; however, since then the rate has declined. Notably, the rate in the 2000s was negative for barley and soybeans. In contrast, the yield growth rate in other countries

Table 1. Production effort target, cropping area, yield on basic plan for food, agriculture and rural areas

Basic plan		Setting of target on 12 years after		
		2005	2010	2015
Production effort target (ten thousand ton)	Rice (exc. Rice for rice flour and feed)	849 (100)	855 (97)	752 (88)
	Rice for feed		70 —	110 —
	Wheat	86 (100)	180 (205)	95 (117)
	Barley, naked barley	35 (175)	35 (159)	22 (122)
	Soybeans	27 (117)	60 (231)	32 (160)
	Forage crops	524 (149)	527 (121)	501 (143)
target cropping area (ten thousand ha)	Rice (exc. Rice for rice flour and feed)	165 (99)	158 (98)	139 (87)
	Rice for feed		9 —	14 (636)
	Wheat	19 (90)	40 (190)	22 (105)
	Barley, naked barley	9 (138)	9 (154)	6 (103)
	Soybeans	14 (93)	30 (200)	15 (115)
	Forage crops	110 (118)	105 (117)	108 (121)
target yield (kg/10a)	Rice (exc. Rice for rice flour and feed)	539 (103)	541 (102)	540 (102)
	Rice for feed		800 (136)	759 (149)
	Wheat	450 (122)	453 (107)	432 (114)
	Barley, naked barley	394 (109)	391 (102)	358 (113)
	Soybeans	197 (109)	201 (113)	215 (126)
	Forage crops	4,534 (119)	4,534 (114)	4,471 (125)

Source: Basic Plan for Food, Agriculture and Rural Areas -food, agriculture and rural areas over the next 10 years -, 2005, 2010, 2015.

Note: The numbers in parentheses in this table show how the indicator of the production effort target in 12 years after has been set compared to when the basic plan was formulated. Because the rate of increase in "Rice for feed" is an extreme number when the denominator is small, in those cases, we showed them as hyphens.

remained continued to exceed 1% in the 2000s. The rates of increase in yield of land-use-type crops were particularly small in Japan, especially in the 2000s.

2) Technical factors related to stagnation of land productivity on land-use-type crops

The stagnation of land productivity was due to various factors. First, in regard to paddy rice yield, the amount of fertilizer applied has been reduced to maintain the taste (Fig. 2). Many new good-tasting and high-yield varieties have been developed, but the area devoted to them remains limited. Furthermore, with the aging of agricultural labor, the decrease of operation time for water management, fertilization, and pest and weed control has led to decreases in rice yield.

The main reason that soybean and barley yields have not increased is that farmers aim more for quality than quantity in crop production. For example, barley yields have declined in recent years, because increases in amounts of fertilizer caused a greater degree of glassiness (i.e. decrease in quality) and, consequently, the amount of fertilizer was reduced and yield was suppressed.

In addition, cultivation of field crops in paddy fields always leads to problems of moisture damage. Seventy percent of soybeans are produced in paddy fields, and moisture damage has been a serious problem in many years.

Table 2. Comparison of annual average yield increase rate between Japan and other countries

	Japan	China	Korea	Indonesia	Thailand	Vietnam	India	Philippine	Taiwan	America	Canada
Rice	0.6	1.9	1.2	2.1	1.0	2.1	1.8	2.2	1.1	1.3	
Wheat	1.2	3.8	3.5				2.6		0.8	1.2	1.9
Barley	0.1	2.4	0.6				2.1			1.4	1.5
Soybeans	0.6	1.8	2.3	1.6	1.0	2.5	1.7	0.7	1.0	1.3	0.8
Tomatoes	1.8	2.3	3.5	4.5	3.8		1.8	2.7		2.3	2.0
Milk	1.5	1.7	3.7	1.4	2.9	2.4	2.4	1.0	2.5	2.1	2.2
	United Kingdom	Germany	France	Italy	Netherlands	Brazil	Paraguay	Australia	New Zealand	Egypt	average
Rice			0.5	0.5		2.4	2.1	1.0		1.1	1.5
Wheat	1.4	1.8	1.7	1.3	1.4	2.6	2.0	1.1	2.1	1.8	1.9
Barley	1.1	1.6	1.6	2.1	1.1	2.8		1.5	1.7	0.5	1.6
Soybeans				1.3		2.1	0.9	2.7			1.5
Tomatoes	3.2	4.6	3.9	1.8	3.6	3.1	1.3	2.4	2.3	1.9	2.8
Milk	1.6	1.7	1.4	1.5	1.2	1.6	0.4	1.9	0.8	1.7	1.8

Source: FAOSTAT(1961 - 2017).

Note: The numbers in the table are the average annual increase over the previous year of 5-year moving average yield from 1961 to 2017.

Figure 1. Trends of annual average yield increase rate in each period

Note: Source and calculation method are same as Table 2.

Improvement in cropping technology related to sowing methods or drainage measures has been attempted, but it has not led to substantial improvements. Small varietal changes concerning wheat and soybeans up until 2000 also delayed improvements in yield.

In wheat and soybean production, long-term land conversion between paddy fields and upland fields has reduced fertility of the soil in paddy fields. In addition, to avoid adverse effects on rice cultivation, drastic drainage measures and input of compost for paddy fields has been applied moderately, and this has caused reductions in soybean yields. These factors were well known, but not addressed earnestly.

3) Technological improvements related to production efficiency

The labor hours for rice, wheat, and soybean gradually decreased after 2000, but have changed little since 2008 (Fig. 3). We divided the working hours for paddy rice into machine-use operation and crop control work. The working hours have especially decreased for crop control work, and for machine work have remained almost the same. This is

Figure 2. Trend of fertilizer, compost and rice straw application in rice production

Source: Production Cost of Rice, wheat and Barley, Statistics Department, MAFF.

Note: Data was calculated by multiplying basic unit for fertilizer appreciation by composition of nitrogen, phosphoric acid, and potassium.

because the cultivation system did not change during this time.

The changes in production cost per 10a and per 60 kg (Fig. 4) show that the production cost of rice has decreased. This is due to the reduction of labor hours and land rent payment, not to improvement in technology. In particular, because

Figure 3. Trend of working hours for rice production

Source: Production Cost of Rice, Wheat and Barley, Statistics Department, MAFF.

Note: Crop control work includes seed preparation, rice nursery management, top dressing, weed control, water management, disease and pest control.

yields of rice did not increase during this period, there were no significant reductions in production costs.

4. Possibility of Smart Agriculture

1) Progress in an aging society with decreasing agricultural labor

In the 2000s, due to aging of the agricultural labor force and the decline in rice prices, the numbers of farmers who wished to rent farmland increased rapidly. If we assume that core farmers cultivate all of the land that they desire to rent, in 2030, the farm management area of core farmers is estimated to be 121 ha, about five times the current area. This is a very large expansion of farm size.

2) Current state of smart agriculture

The main technical theme in the current agricultural policy is promotion of smart agriculture. The government has a Key Performance Indicator of “most core farmers practicing agriculture that utilizes data by 2025”. Smart agriculture has become one of the major policy issues because of the rapid commercialization and practical application of equipment such as robotic farming machines, sensors, and software with the participation of various private companies.

Automatic tractors enable driving automatically by capturing satellite data concerning the position of existing tractors, programs that control automatic travel, and a steering device. Obstacle detection and automatic stop functions by image recognition are retained as safety mechanisms. The functions of automatic-driving tractors are the same as for existing tractors, but it is possible to go

Figure 4. Trend of the production cost of rice

Source: Production Cost of Rice, Wheat and Barley, Statistics Department, MAFF.

straight ahead with high accuracy and to turn automatically and, if the pre-programming is correct, the tractor automatically proceeds.

Similarly, automatic rice-planting machines can automatically run in paddy fields and transplant. Cultivation, transportation, and supply of seedlings must be carried out manually. However, the machine carries out the transplanting work, and the supervisor for machine can concentrate on seedling supply work, so that transplanting is a one-man operation.

The development of a cultivation management support system applying ICT is also progressing, and farmers can obtain weather condition data such as daily temperature, precipitation, sunshine duration, total solar radiation, and relative humidity within a 1-km mesh. Its system includes the predicted data of the following months, and can be used to support prediction of the season when the rice forms ears or harvest time, and judgment of topdressing by linking with the crop growth model.

In addition, utilization of unmanned aerial vehicles has rapidly increased in recent years, and it is becoming technically possible to implement sensing of crop growth and occurrence of pest damage, spraying of agricultural chemicals, and spot control that combines sensing and spraying functions.

3) Characteristics of smart agricultural technology

The aim of smart agriculture is to make established technical and scientific knowledge available to farmers as explicit knowledge. In this regard, smart agricultural

technology is the practical utilization of ICT, RT, and AI technologies. The possibility has arisen that employees who do not have sufficient cropping know-how can carry out intensive cultivation management that has been developed by expert farmers from careful observation of crops. Therefore, smart farming technology should function as labor- and also land-saving.

4) Technological innovation and reconstruction of paddy field utilization systems

However, smart agricultural technology itself does not entail changes in cultivation technology or farming system conversion. The work operation carried out by self-driving tractors and automatic-driving rice transplanting machines is no different from current tillage or transplanting work. If the cultivation system and applicable crop varieties do not change, the effects on productivity and profitability will be limited.

Since the formation of the medium-sized rice mechanization system in the 1970s, the framework of Japanese rice production technology has not changed. In terms of paddy field use, no substantial improvement has been made. Although production adjustment of rice has continued for more than half a century, the production structure centered on rice has not changed.

The relationship between the ratio of paddy field per land (paddy field rate) and the ratio of paddy rice crop area per paddy field (paddy rice crop ratio) in Ibaraki Prefecture is shown in Figure 5. The soil conditions vary from region to region, so there is a large difference in the paddy field rate. However, the paddy rice crop ratio is almost the same level in all locations except in the lotus root cropping municipalities. The paddy rice crop ratio being constant regardless of the paddy field rate, and being close to the production adjustment ratio of rice, show that farmers' consciousness that rice is the main crop in paddy farming is still constant even today when the profitability of rice production is almost the same as for wheat and soybeans.

However, the use of paddy fields should be considered according to local land conditions. For example, in low-moisture wetlands such as downstream of large rivers, continuous cropping of paddy rice is also possible, but in areas with relatively slanted and drainable upstream, paddy field crop rotation systems that do not assume the cultivation of paddy rice as one of rotating crops might be effective. In such crop rotation systems, it is desirable to construct a system incorporating field crops such as wheat, soybeans,

Figure 5. Paddy field rate and paddy rice crop ratio

Source: 2015 Census of Agriculture and Forestry, Statistics Department, MAFF.

Note: Data are the ratio of paddy field per land and the ratio of paddy rice crop area per paddy field in each city, town and village in Ibaraki Prefecture. An oblique line in this figure means 45-degree angle. Dots on the lower part of this figure are the mainly lotus root cropping municipalities.

forages, vegetables, and green manure while maintaining soil fertility and controlling weeds. For the methods to avoid moisture damage to wheat and soybeans, if the paddy field are used as drainage deeply plowed fields, the technical measures for these crops would be quite different.

How to change paddy field utilization, developing cultivation technology, and utilization of smart agricultural technologies should all be comprehensively discussed. If the small and scattered rice fields in mountainous areas can be used as plowed fields or grassland that do not require a ridge placed between rice fields, the available machinery systems and technologies will change drastically.

If the problem of stagnation in land productivity is to be solved given the rapid decrease in available agricultural labor, it is necessary to promote smart agriculture and develop new cultivation technology and cropping systems. Smart agriculture is a theme closely related to the future of local communities, and technological innovation in Japanese agriculture needs to be examined from various viewpoints.

References

- Uenishi, Y. and M. Umemoto (2018) Nougyo ni okeru Kaihatu Gizyutu no Fukyu ni kansuru Kenkyu no Doukou to Tenbou, *Bulletin NARO Agribiz Research* 1, 1-26.
- Umemoto, M. (2015) Tochiriyougata Nogyo no Tenkai to Kadai, in K. Horiguchi and M. Umemoto, eds., *Daikibo Einou no Keiseishi*, Nourin Toukei Kyokai, 509-540.