Historical Changes in Urban Rice Production Systems in Tokyo, Japan

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Abstract: Historical changes in planting area, yield improvements, and production of both paddy and upland rice (Oryza sativa L.) in Tokyo and the whole of Japan from 1877 to 2003 were reviewed. The area of rice in Tokyo was at its peak (17,000 ha) at the beginning of the 20th century but dramatically reduced thereafter except for the period of 1950s, to 200 and 30 ha for paddy and upland rice, respectively, in 2003, due to urbanization. After the 1950s, the land-use efficiency rate in Tokyo was reduced from 180 to 100% and rice self-sufficiency rate from 4 to 0.1%. There was historical yield improvement of paddy rice in Tokyo particularly after 1960s in the Southern and Northern Tama regions, but the current yield level in Tokyo (ca. 400 g m\(^{-2}\)) is lower than that in the whole of Japan (more than 500 g m\(^{-2}\)) even though crop damage due to low temperatures is not serious. The reasons were discussed from the viewpoints of (1) less agricultural inputs and agronomic management, (2) declining rice research after the 1970s, (3) higher elevating air temperature (e.g. 1.4ºC for the last 40 years), in Tokyo, and (4) yield component differences. Upland rice in Tokyo has a planting area comparable with paddy rice (ca. 7,000 to 8,000 ha) during the 1950s, but yield improvement during the last 50 years is not noticeable (ca. 150 g m\(^{-2}\)) with no development of cultivars, and with greater fluctuation of crop situation index due to drought compared with paddy rice. This review paper discusses the importance of urban rice production system, along with a proposal of the alternatives.

Key words: Agricultural history, Paddy, Upland rice, Urbanization.
the production of vegetables, ornamental flowers, and fruits, or towards dairy farming, rather than focusing on the production of rice or crops (Lockeretz et al., 1987; Yeung, 1988; Mita, 1993; Midmore and Jansen, 2003). Rice production in Tokyo has been paid little attention. Documentation of the historical changes in rice production in Tokyo has been limited, despite the availability of good statistics. The analysis of historical changes in rice production may be helpful for future development of urban land use and food crop production, not only in Tokyo but also in other developed and developing countries, because such statistical data are not available in every country.

Tokyo is divided into 6 municipal regions, with the extent of urbanization different and geographical characteristics different. There may be regional differences in the process of changes in rice production. It would also be helpful to analyze the historical changes in the rice research topics of the Tokyo Metropolitan Agricultural Station during the process of urbanization, to clarify the technical problems and challenges for rice production in a given period. The objective of the present study was thus to provide an overview of historical changes in the rice production system in Tokyo from 1877 to 2003, with a focus on planting areas, yields, and production losses. Data on Japan as a whole are also presented to provide a contrast and a context for the urban changes.

1. Historical changes in land use, rice production and self-sufficiency rate in Tokyo

Changes in rice production in Tokyo from 1877 to 2003 were analyzed using the available statistical data. An earlier review article (in Japanese) is available on paddy rice production in Tokyo before 1960 (Ogiwara, 1961). The present paper deals with the production of both paddy rice and upland rice in Tokyo until 2003, in terms of the area of rice planting, the yield, and the amount of production. The results are then compared with the values for the whole of Japan (referred to as Japan hereafter) and with reference to regional variation within metropolitan Tokyo. The comparison with Saitama prefecture, a neighboring prefecture of metropolitan Tokyo with similar climatic conditions but with different extent of urbanization, is also conducted as for the changes in rice planting area, yield and production after 1950. Annual reports of agricultural, forestry, and fisheries statistics from the Kanto Agricultural Administration Bureau and from Japan's Ministry of Agriculture, Forestry, and Fisheries have been used to provide the statistical information on rice production in Tokyo and in Japan, respectively (Kanto Regional Agricultural Administration Office, 1954-2005; Ministry of Agriculture, Forestry, and Fisheries, 1926-2005). The statistical data of paddy rice planting area, yield and production in Tokyo from 1877 until 1926 were taken from Ogiwara (1961). For the statistics on Japan in the very early years, I used the statistical data of Japan from 1883 (Ministry of Agriculture, 1886). The old Japanese unit for rice production before 1956, the “koku”, has been converted into metric tons by multiplying the number of “koku” by 0.15. The old Japanese unit for area, the “tan”, has been converted into hectares by multiplying the number of “tan” by 0.10.

(1) Land use

I calculated land-use efficiencies in Tokyo and in Japan from 1950 to 2000 by dividing the total area planted (with the same area counted multiple times in multiple-cropping systems) by the total area of arable land (Fig. 1). Tokyo's land-use efficiency was about 180% during the 1950s, which illustrates a high level of adoption of crop rotation or double-cropping. The proportion of winter-cropped paddy fields was 26% (1,859 ha) and 37% (22,450 ha) of the total area of paddy fields and arable land, respectively, in Tokyo in 1953. Tokyo's land-use efficiency declined during the 1960s to less than 100% in 1975 and 1980, then apparently recovered thereafter to a level slightly
greater than 100%, probably due to the increasing cropping of vegetables for urban residents (Takao, 1995), which have a shorter growth period than rice and can be produced plural times a year, resulting in the apparent slight increase in land-use efficiency. In contrast, the land-use efficiency in Japan was more than 150% in 1950, but declined rapidly until 1970; thereafter, it remained stable at around 100%.

Nakausa (1961) investigated the cropping sequences in 1403 upland fields in Tokyo during the late 1950s, and classified them on the basis of planting times and crop species. There were 45, 1135 and 228 cases of sole, double and triplecroppings, respectively. Sole cropping of rice accounted only for 9 cases, while doublecropping of upland rice and winter cereals (wheat or barley) was most popular, accounting for 335 cases, followed by 328 cases of doublecropping with winter cereals and sweet potato. Doublecropping of winter cereals and fruits or root vegetables each accounted for 100 cases. Triplecropping of winter cereals followed by two vegetable plantings accounted for more than 100 cases. Triplecropping of winter cereals followed by upland rice and vegetables accounted for 34 cases.

(2) Rice planting area

In Japan, the area planted with paddy rice has averaged about 30 times the area planted with upland rice (Fig. 2a). The area of paddy rice increased steadily from 2.7 million to 3.1 million ha from 1897 to 1967, except during World War II. After 1970, the area of paddy fields decreased dramatically due to production adjustment imposed by the Japanese government, and reached 1.6 million ha in 2003. The area of upland rice in Japan increased nearly 300%, from 61,500 to 184,000 ha, from 1897 to 1960, again with the exception of World War II, and thereafter decreased to only 5,000 ha in 2003.

After the Meiji Restoration in 1867, when Tokyo became the capital city of the new Japanese government, the area of paddy fields in Tokyo increased from 11,270 to 17,726 ha during the period from 1877 to 1897 (Fig. 2b). The maximum area of paddy fields in 1897 was about 8% of the total area of metropolitan Tokyo, and represented about 29% of the total arable land in Tokyo. The paddy field area in Tokyo decreased thereafter until the 1940s (the first period of urbanization), owing to the increasing inhabitants and development of new residential areas both in downtown Tokyo and in its surroundings (Sakai, 1956; Shimizu, 1968, 1972). From 1945 to 1955, the area of paddy fields increased from 5,918 to 7,924 ha, and it accounted for more than 20% of the total arable land in Tokyo. The area of paddy fields in Tokyo once again began to decrease from around 1955 onwards as a result of rapid urbanization and economic growth (the second period of urbanization) (Fig. 2b, Sakai, 1956). The income gaps between farming and non-agricultural sectors increased sharply, as is discussed later in the section of 2 (3). Shimizu (1972) showed that there were regional differences in Japan in the times when the areas of paddy fields and upland rice began to decline during the 1950s and 1960s. The area of paddy rice in the whole metropolitan Tokyo in 2002 is only 222 ha, which amounts to only 3% of the total arable land in Tokyo. The comparison between Tokyo
and Saitama prefecture showed that the reduction in planting area was started slightly later in Saitama, and considerable amounts of paddy fields (e.g. more than 35,000 ha in 2000) have been retained in Saitama prefecture (Fig. 2c).

Statistics for upland rice in Tokyo are available only for the period from 1926. The area of upland rice in Tokyo was about 50% of the area of paddy rice at this time, and gradually decreased from 1926 to the early 1930s, then slightly increased during the 1950s, and again sharply decreased during 1940s (Fig. 2b). Upland rice area sharply increased from 1945, and by the 1950s, the area of upland rice in Tokyo equaled the area of paddy rice (ca. 7,000 to 8,000 ha). The area of upland rice in Tokyo more than doubled during the 10 years between 1947 and 1956, from 3,427 to 8,560 ha, but decreased rapidly thereafter at a rate similar to that in the area of paddy fields in Tokyo, reaching only 29 ha in 2002. The average historical life span of paddy fields was longer than that of upland fields (including all upland crops) in every district in Japan (Shimizu, 1972). Shimizu (1968) estimated the average life spans, or remaining years of paddy fields for all of Japan except Hokkaido (the northern island of Japan) from the land reclamation, land abolition, and conversion between upland and paddy fields during the observation periods. The life spans of paddy fields were longer during the early 20th century, for instance 917 years during 1918-1925, but declined gradually by mid-20th century, for instance 315 years during 1938-1943. The life span of paddy field became higher during 1950s (e.g. 887 years during 1956-1958), but again declined during 1960s (e.g. 142 years in 1965-67). The corresponding values for upland fields were 330, 188, 607, and 115 years, respectively. The annual reduction in the areas of paddy fields and upland rice in Tokyo averaged 486 and 527 ha year⁻¹, respectively, from 1960 to 1970, and 29 and 9 ha year⁻¹, respectively, from 1975 to 2002 (Fig. 2b).

(3) Rice yield
The grain yield of paddy rice (on brown rice basis) in Japan averaged about 230 g m⁻² at the beginning of the 20th century, with year-to-year variations between 200 to 260 g m⁻² (Fig. 3a). The average grain yield increased steadily to around 310 g m⁻² by 1940, then increased more rapidly after the 1950s to exceed 500 g m⁻² in the 1990s. Statistics for the yield of paddy rice in Tokyo were not available for every year before 1910. From 1910 until around 1950, yield levels and long-term trends for paddy rice were similar between Tokyo and Japan as a whole (Fig. 3a, b). However, after the late 1960s, the yield of paddy rice in Tokyo started increasing faster than before (Fig. 3b), owing to the introduction of improved varieties and increasing use of chemical fertilizers, as is further clarified later in the section 4. However, the yield increment in Tokyo after the 1960s was smaller than in other parts of Japan. The yield of paddy rice in Tokyo by the end of the 20th century had reached about 400 g m⁻². This value is also lower than the yield in Saitama prefecture (Fig. 3c).

The grain yield of upland rice in Japan averaged about 120 g m⁻² at the beginning of the 20th century, with year-to-year variations between 100 and 140 g m⁻² (Fig. 3a). This yield slowly increased to more than 150 g m⁻² during the 1930s. During World War II, the yield of upland rice declined, but it started increasing slowly from the 1950s to reach more than 200 g m⁻² after 1990. Upland rice in Tokyo showed little yield increase from 1926 to 2002, with an average yield of around 150 g m⁻² (Fig. 3b). As is clarified later in the section 3, upland rice is prone to drought and fertilizer inputs are very much limited, which would be the primary cause for yield stagnation of upland rice in Tokyo over long time. In fact the evidence of research efforts to improve upland rice productivity in Tokyo...
Historical Changes in Urban Rice in Tokyo during 1940s and 1950s will be presented later in the section 5, but upland rice has been grown primarily for self-consumption rather than for the consumer market after the 1960s, and the separation from the marker system may have provided little incentive for Tokyo rice farmers to increase the yield of upland rice. Upland rice yield in Saitama prefecture is similarly low as in Tokyo (Fig. 3c), with little yield improvement after 1950.

(4) Rice production
The historical changes in the amounts of paddy and upland rice production (on brown rice basis) in both Japan and Tokyo were generally similar to the corresponding trends in planting area (Fig. 4a, b), although there were three marked differences between the two trends that resulted from differences in yield. The time course of rice production had large year-to-year variation due to yearly changes in yield levels. In addition, the rates of increase in production were greater than those in planting area (e.g., see the trend for paddy rice in Japan from 1900 to 1970), and the rates of decrease in production were less than those in planting area (e.g., see the trend for paddy rice in Japan after 1970) because of gradual increases in yield during these periods. Differences in the amounts of production between upland and paddy rice were also greater than the differences in planting area, because yield levels of paddy rice are more than twice the values for upland rice.

Before 1900, almost 50,000 t of paddy rice was produced annually in Tokyo (Fig. 4b), which is equivalent to more than 500,000 person-years of rice consumption. In contrast, the rice production in Tokyo in 2002 is less than 1,000 t year⁻¹, with 895 t of non-glutinous rice produced in paddy fields and 51 t of glutinous rice produced in upland fields. During the late 1950s, upland rice production in Tokyo accounted for nearly one-third of total rice production. Saitama prefecture used to produce more than 300,000 t of paddy rice in 1960 (Fig. 4c), which provides more than 3 million person-years of rice consumption. This value declined after 1960, but still Saitama prefecture produced 200,000 t of paddy rice in 2000, showing its greater food producing ability than Tokyo.

(5) Self-sufficiency rate for rice
Fig. 5 shows the changes in the self-sufficiency rate for rice consumption in Tokyo and Japan. The population levels of Tokyo from 1947 to 2002 were...
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derived from the Tokyo Statistical Yearbook 2002 (Tokyo Metropolitan Government, 2004). The amounts of per capita rice consumption were derived from statistics provided by the Ministry of Agriculture, Forestry and Fisheries (Ministry of Agriculture, Forestry and Fisheries, 1926–2005). I derived the rice

Table 1. Six agricultural regions of metropolitan Tokyo (1–6) and their geographical description, with comments on rice production in 1953 and 2000.

| Agricultural regions | Geographical description | Rice planting area (paddy/upland) and conditions of rice and agricultural production and rice cropping systems |
|----------------------|--------------------------|--------------------------------------------------------------------------------------------------|
| 1 Eastern Wards      | Alluvial lowlands along the Arakawa and Edogawa Rivers | 3133 ha / 40 ha Single cropping of rice in ill-drained paddy field 0 ha / 0 ha Highly urbanized, public agricultural park |
| 2 Western Wards      | Lowland / tableland border | 689 ha / 1,206 ha Rice cropping in ill-drained paddy field in inland valleys, more upland rice 0 ha / 2 ha Highly urbanized |
| 3 Northern Tama      | Musashino tableland 965 ha / 2,589 ha Single cropping of rice in ill-drained paddy field in inland valleys, 50% of paddies with winter-cropping, upland rice plus winter-cropping systems 63 ha / 8 ha Vegetable and flower production, urbanized |
| 4 Southern Tama      | Tama Hills or along the Tamagawa River 2,022 ha / 1,799 ha Single cropping of rice in ill-drained paddy field in inland valleys, 50% of paddies with winter-cropping along the Tamagawa River 153 ha / 23 ha Rice plus winter-cropping systems in dry paddies along the Tamagawa River, urbanized |
| 5 Western Tama       | Mountainous areas 386 ha / 1,188 ha Single cropping of rice in ill-drained paddy field in inland valleys, rice plus winter-cropping along the river, more upland rice 42 ha / 7 ha Rice cropping along the river Underpopulated |
| 6 Islands region     | Island areas 59 ha / 308 ha Rice cropping in ill-drained paddy fields at the foot of mountains, little winter-cropping 1 ha / 0 ha Underpopulated |
self-sufficiency rates for Tokyo and Japan by dividing total rice production by the total rice demand (equal to the per capita rice consumption multiplied by the corresponding population):

Rice self-sufficiency rate = Rice production / (Per capita rice consumption x Population)

Although the rice self-sufficiency rate in Japan fluctuated around 100% from 1945 to the present for Japan, that in Tokyo declined rapidly, from around 4% during the 1950s to 0.3% in 1975, and continued to gradually decline to around 0.1% in 2002.

2. Regional differences in Tokyo

(1) Municipal divisions and agricultural zones in Tokyo

Metropolitan Tokyo’s total area of 218,700 ha is divided into five municipal regions: The 23 wards ("Ku"); Northern Tama, on the Musashino Tableland; Southern Tama, in the Tama Hills or along the Tamagawa River; Western Tama, in a mountainous area; and the Islands region (Fig. 6). These five regions correspond to the five agricultural zones defined by Sakai (1954), who further divided the regions into 9 agricultural regions and 23 agricultural districts. Ogiwara (1961) divided the 23 wards in metropolitan Tokyo into two regions: the Eastern Wards, which are lowland areas along the Arakawa and Edogawa Rivers, and the Western Wards, which are on the border of lowland and tableland areas. In this paper, I have divided metropolitan Tokyo into six regions according to the system of Ogiwara (1961). These are the Eastern Wards (1), the Western Wards (2), Northern Tama (3), Southern Tama (4), Western Tama (5), and the Islands region (6) (Fig. 6, Table 1). The current agricultural zoning (four agricultural zones with three sub-zones) has been determined on the basis of the six agricultural regions mentioned above in accordance with the Tokyo Agricultural Promotion Plan, although some of the borders have been changed slightly to account for the effects of urbanization after the 1960s.

(2) Rice-growing land in Tokyo’s six geographical regions

In this section, I summarize the distribution of rice-growing land in each of Tokyo’s six geographical regions during the 1950s, before rapid urbanization began, and the historical changes thereafter until 2002. The types of paddy fields are characterized either
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as ill-drained paddy field, which is land with a high water-holding capacity and where only rice cropping has been practiced ("single cropping of rice"), or well-drained paddy field, which is land with higher permeability and where winter crops are planted after the rice harvest. Upland rice occupied a larger area than paddy rice (or a comparable area) in some parts of Tokyo, as discussed below.

In the Eastern Wards, 3,133 ha of paddy fields existed on alluvial soils along the Arakawa and Edogawa Rivers in 1953 (Fig. 7, Table 1). Single cropping of rice had been dominant in this area owing to the high water table, because farmers had not found suitable upland crops they could grow during the winter under these conditions. These paddy fields had been used to produce high-quality rice since the 19th century, and interestingly a substantial amount of the human manure collected from the city of Tokyo ("Edo" in those days) was incorporated into the paddy fields in this region as organic fertilizer, which shows sustainable suburban land use system for food production with recycling of resources.

In the Western Wards, 689 ha of paddy fields had been developed at the border between the tableland and lowland area by 1953, where natural spring or ponds are often located. They are ill-drained paddy field in inland valley (often called "yatsuda"), with a high water-holding capacity and low permeability, and single cropping of rice was practiced. Upland rice was grown in 1,206 ha in 1953 within cropping sequences such as upland rice followed by winter cereals or vegetables.

In Northern Tama, 965 ha of paddy fields had been developed by 1953; these were ill-drained paddy fields in inland valley (127 ha) without a second crop, paddies along irrigation canals (190 ha), and well-drained paddy fields along the Tamagawa River, where winter crops such as wheat, rapeseed, and vegetables were planted after the rice harvest (Ogiwara, 1961). On the tableland, upland rice was grown in large areas (2,589 ha; larger than the paddy field in this region) in 1953 within cropping sequences similar to those described for Western Wards.

In Southern Tama, 2,022 ha of paddies had been developed by 1953; these were well-drained paddy fields with winter-cropping along the Tamagawa River, and ill-drained paddy fields in inland valley with a rice monoculture. On the tableland or in the hills, 1,799 ha

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**Fig. 8.** Historical changes in the grain yield of (a) paddy rice and (b) upland rice in the six geographical regions of Tokyo from 1953 to 2003.
of upland rice were cultivated in 1953.

In Western Tama, there were 386 ha of paddy fields in 1953; these were well-drained paddy field along the Akiwawa River (160 ha), ill-drained paddy field in inland valley (221 ha), and others (5 ha). Upland rice was grown in 1,188 ha in 1953.

In the Islands region, there were 59 ha of ill-drained paddy field on Hachijo Island, and 308 ha of upland rice for the whole region in 1953.

(3) Effects of urbanization on rice planting

Figures 7 and 8 summarize the historical changes in the areas of paddy and upland rice and in their yields for the six geographical regions of Tokyo from 1953 to 2000. Only typical years without large crop damage were selected, at intervals of roughly 5 to 10 years. The Eastern Wards had the largest area of paddy rice in the 1950s, followed by Southern Tama, whereas upland rice was planted most in Northern Tama, followed by Southern Tama, Western Tama, and the Western Wards. The reduction in the area of paddy fields was most dramatic in the Eastern Wards. In the Eastern and Western Wards, areas of both paddy rice and upland rice declined during the 1950s, whereas the decline in the area of paddy fields started after 1960 in more remote regions (Tama regions; Fig. 7a, b). Conversion of rice fields to residential areas started earlier in the central parts of Tokyo (i.e. Eastern and Western wards) than suburbs (i.e. Tama regions), as is described by Sakai (1956). Paddy fields in Tokyo occupied only 242 ha in 2000, and more than half of them were located in Southern Tama (Table 1). The yield level of paddy rice was highest in Southern Tama, followed by Northern Tama (Fig. 8a), and in these two regions, the yield increase since late 1960s was more obvious than in the other regions, showing the importance of distance from the urban center and extent of urbanization on rice productivity. The yield of paddy rice in the Eastern Wards stagnated, and the yield level remained lowest in the Islands region. For upland rice, yield was highest in Tama regions, and lowest in the Islands region and the Western Wards (Fig. 8b).

I used population density as an index of urbanization, and examined its effects on the changes in rice planting areas (paddy plus upland rice fields) for all the 6 geographical regions in Tokyo. From 1950 to 2000, as the population density increased from 2,800 to 5,400 persons km$^{-2}$, rice planting area sharply and linearly decreased in whole Tokyo (dashed line in Fig. 9), and their changes were most dramatic during the 1960s (cf. Figs. 2b, 7). Increment of 100 persons per square kilometers apparently reduced 574 ha of rice fields. In spite of geographic differences from the center of downtown Tokyo and the wide variation in population density (258 persons km$^{-2}$ in Western Tama to 9741 persons km$^{-2}$ in Western Wards in 1950), rice planting area declined as the population density within the region increased in all the 5 regions except for Island region, with the slightly different decreasing rates (e.g. reduction of 37 ha (Western Wards) to 369 ha (Western Tama) of rice fields with increment of 100 persons per square kilometers). In Islands region, the population density for the last 50 years reduced to
three quarters of that in 1950 due to the depopulation problem, and consequently the rice planting area also reduced. It would have been true that rapid migration to urban Tokyo and increasing population density in Tokyo necessitate conversion of rice fields into residential areas. However, the analysis of Fig. 9 showed loss of rice fields in every different region of Tokyo in spite of large variation in population density. This indicated that perhaps the association between rice planting area and population density would be better interpreted by the changes in industrial structures; agricultural income of average farm household has become comparatively smaller during 1960s in Tokyo and during 1970s in overall Japan than off-farm income (Fig. 10a, b). Fig. 10a showed that for Japanese average farm household annual agricultural income shared more than 70% of total income in 1955 (256,000 and 103,000 yen, for agricultural and off-farm incomes, respectively) (Management and Coordination Agency, 1955-2000), but the proportion of off-farm income became equivalent to agricultural income by 1965, almost double the agricultural income by 1975, and 4 times larger by 1985. Clearly, the difference was far greater in Tokyo, with the off-farm income more than 10 times higher than the agricultural income in 1995 (Fig. 10b). The greater income and economic advantage of non-agricultural sectors attracted labors from agricultural sectors, reducing both full-time and total numbers of farm household (Fig. 11), and resulting in declines in rice fields in every region in Tokyo and Japan after 1960 (e.g. Fig. 2, 7). In order to maintain rice and agricultural fields in urban areas, appropriate political strategies, agricultural education and training programs, civic movement would have been needed in the past. During the 1960s and 1970s in Tokyo and Japan, however, they did not function well for this purpose. Besides, research efforts to improve rice production technology and to develop innovative land use in urban areas diminished after 1970 in Tokyo, as is described later in section 5.

3. Climate effects

Yield fluctuations from year to year are evident for both paddy and upland rice in Tokyo and Japan, but the extent of the fluctuations for paddy rice in Tokyo decreased after 1960 compared with that in Japan or for upland rice (e.g. Fig. 3). The crop situation index, which is the percentage of actual grain yield compared with the expected grain yield of the year supposing the normal weather conditions, is generally much more stable in paddy rice (cf. most of the variation between 90 and 110%) than in upland rice (cf. between 70 and 120%) (Fig. 12). In some years, the crop situation index for paddy rice in Japan had low scores, for example in 1971, 1980 and 1993, due to dominant cool summer weather. In such cold years, injury to crops
drastically reduced the average yield for Japan as a whole, but the yield and crop situation index of paddy rice in Tokyo did not reduce as much.

Several explanations for the differences in stability of crop situation index between Tokyo and Japan are possible. Firstly, climate effects differed in different regions; in 1993 with a cold summer, the damage was greatest in northern parts of Japan (Hokkaido and Tohoku regions), followed by Kyushu region, and then Kanto-Tozan region (where Tokyo is located). Secondly, cool weather affected almost all the paddy fields (i.e. more than 90% of the planted area) in Tokyo in 1971, 1980 and 1993 as in Japan, (see the proportion of damaged areas of the paddy fields in Table 2), but the damage in terms of production loss was smaller (i.e. less than 11% in 1993); this indicates that rice growth were affected but yield formation process was less affected in Tokyo. Unfortunately, statistical data for yield component in Tokyo are not available after 1966, and I had to use for the comparison the data of Saitama, a neighboring prefecture of Tokyo, with similar crop situation index as in Tokyo in the cold years (Table 3). Although the percentage of ripened grains of paddy rice

Fig. 11. Historical changes of total and full-time farm household numbers in Japan (open symbols, dotted lines) and in Tokyo (solid symbols, solid lines) from 1950 to 2000.

Fig. 12. Historical changes of crop situation index for paddy (a) and upland (b) rice in Japan and Tokyo from 1970 to 2002. Data of crop situation index for upland rice in Tokyo are available in only limited years.
substantially reduced in the cold years in Japan (80%), the extent was less in Saitama (91%). Total grain number and 1000-grain weight changed little in cold years compared with normal years. The third reason for the differences in stability of the crop situation index between Tokyo and Japan is that transplanting time and heading time of paddy rice in Tokyo were later than in other regions in Japan; an illustration is given in Fig. 13 which compared historical changes of peak dates of transplanting and heading for paddy rice from 1956 to 2002 between Tokyo and Tochigi; Tochigi was only 100 km north from Tokyo in the same Kanto region, and was chosen as one of the most popular rice growing prefecture as an example. In 1950s the transplanting date was 1 week later in Tokyo (late June) than Tochigi, but it was more than 1 month later in Tokyo (early to middle of June) in 2000 (Fig. 13a). The transplanting date became significantly earlier in Tochigi (e.g. about 1 month for the last 40 years) and many other regions in Japan, but the extent was much less in Tokyo (e.g. 9 days earlier for the last 40 years). As a result, heading date became earlier by 17 and 12 days in Tochigi and Tokyo, respectively, for the last 40 years (Fig. 13b). Quadratic equation was drawn only for heading date in Tokyo, as the coefficient of determination was improved by adopting quadratic equation than linear equation only in heading date of Tokyo. In short the planting schedule in Tokyo was more likely to escape development of reproductive organs from potential pre-summer cool weather in July when onset of summer season should delay. Fourth, because of the "heat island" effect (Levinska, 1987; Moriyama, 2004; Nichol and Wong, 2005) that occurs in highly urbanized areas due to the large emission of heat derived from the massive uses of energies inside the city (such as air-conditioning of buildings, automobile, and factories), reduced evaporation from the surface due to decreasing agricultural lands or green spaces, evening time emission of radiation from the buildings absorbed during day time, and so on (Saito, 1997), average air temperature has increased by 1.4°C in Tokyo over the past 40 years (Fig. 14). This increase was 1.8 times the increase in Miyagi Prefecture (0.8°C over 40 years), one of the most famous rice-producing regions of Japan, during the corresponding period. The heat-island effect may have mediated growth stagnation and injury to rice plants in Tokyo in cooler years. In general, the yield of paddy rice in Tokyo was lower than in other parts of Japan, but remained more stable after 1970.

In some years (i.e., 1937, 1941, 1947, 1964, 1971, 1973, 1975, 1978, 1984, 1990, and 1996), the yield of upland rice in Tokyo was less than 100 g m⁻² (Fig. 3b). The available data from 1957 to 1996 showed that the crop situation index of upland rice in Japan was negatively correlated with degree of drought damage on the basis of both area and production. About 35 and 44 % of variation in the crop situation index were explained by proportion of loss of production and area damaged by drought, respectively (Fig. 15a). Unfortunately in Tokyo, data of crop situation index for upland rice were not available for many years. As its substitute, I used grain yield of upland rice from 1949 to 1996 and also found a negative correlation with proportion of damage due to drought. Almost 50% of yield variation was explained by proportion of damage due to drought. As the drought damaged area increases by 10%, 9.4 g m⁻² of rice yield declines, and as the production loss due to drought increases by 10%,
7.6 g m$^{-2}$ of yield declines, as were evident from the regression coefficients.

Areas of crop damage and loss of production have been estimated for rice by frequent monitoring of farmers and by using empirical equations (Kanto Regional Agricultural Administration Office, 1954-2005). Damage caused by cool summers, lodging caused by typhoons, and rice blast disease were the main causes of lost production and yield reductions from 1945 to 2003 in paddy rice in Tokyo, whereas drought was the primary cause of yield reductions in upland rice in Tokyo. I estimated historical changes in the relative proportions of production losses in three categories: climatic, disease, insect damage (Fig. 16). The largest factor in paddy rice of Tokyo was disease (38%), followed by climate (30%) and insect...
(15%) damages, and insect damage has declined somewhat recently (Fig. 16a, b, c). The largest factor for production loss in upland rice in Tokyo was climate (67%), with much less diseases (13%) and insect (4%) damages (Fig. 16d, e, f). In Japan, climate damage was greatest (52%), followed by disease (35%) and insect (11%) damages for paddy rice (Fig. 16g, h, i), and for upland rice, greatest damage was climate (79%), with much smaller disease (16%) and insect (4%) damages (Fig. 16j, k, l). These analyses revealed that proportion of production loss due to adverse climate such as cold summer and typhoon was smaller in Tokyo than in Japan (i.e. 30% vs 52%), and that climate factors, presumably, drought, is identified as dominant factor for production loss in upland rice both in Tokyo and Japan.

4. Technological changes

(1) Rice cultivars

I compared the areas of different rice varieties in Tokyo for paddy and upland fields and for each grain type in 1953, 1960, 1980 and 1995 on the basis of annual food statistics (Table 4). In general, fewer varieties occupied a larger proportion of planting area as the time went from 1953 to 1995, particularly during 1960s and 1970s, and shorter height and higher yielding varieties, and with higher grain quality, were introduced for non-glutinous paddy rice (such as Nipponbare, Koshihikari, Akinishiki, and Kinuhikari) after 1970s. On the other hand there were less or little evidences of variety improvement for upland or glutinous rice. In 1953, about 90% of paddy fields in Tokyo were planted with non-glutinous lowland varieties, and the rest with glutinous lowland varieties (Table 4). Twenty-five non-glutinous
lowland varieties were listed with planting areas of more than 14 ha in Tokyo, which indicates large farm level genetic diversity of rice in 1950s in Tokyo. The dominant cultivars were improved varieties such as 'Norin-8', 'Tousan-38' and 'Norin-29', and these three occupied 48% of the fields. Ten traditional glutinous lowland varieties were listed in 1953 with planting areas of more than 2 ha, including 'Saitamamochi' and 'Aikokumochi'. About 60% of upland rice fields were planted with non-glutinous varieties, versus 40% with glutinous varieties in 1953. Fifteen non-glutinous upland varieties were listed, including improved varieties such as 'Norin-12' and 'Norin-24', and traditional varieties such as 'Hirayama'. Eight glutinous upland varieties were listed, including improved varieties such as 'Norinmochi-1' and 'Norinmochi-26', and traditional varieties such as 'Fujikuramochi'. The top 3 rice cultivars occupied 45 and 28% of the

![Fig. 16. Historical changes of proportion of yield production loss (%) due to climate damage (a, d), disease damage (b, e) or insect damage (c, f) for paddy and upland rice in Tokyo from 1945 to 2003. The corresponding values for paddy and upland rice in Japan from 1952 to 2004 were also shown for climate damage (g, j), disease damage (h, k), and insect damages (i, l). The average values (%) during the period were also written.](image-url)
planted area of upland fields for non-glutinous and glutinous rice, respectively.

In 1960, the popular rice varieties were similar to those being cultivated in 1953 both in paddy and upland fields for both grain types, but the numbers of identified varieties were fewer in 1960, suggesting the evidence of selection of more adapted cultivars in rice production sector, and consequently the reduction in farm level genetic diversity of rice cultivars. For non-glutinous paddy rice, the rankings of the areas of the varieties had changed to some extent and a few new varieties, such as 'Tonewase' and 'Ginmasari' had been developed. In 1980, new recommended non-glutinous varieties with good grain quality such as 'Nipponbare' and 'Koshihikari' were adopted in paddy fields, 65% of the planted area being occupied by the top 3 cultivars.

Fig. 16(continued). Historical changes of proportion of yield production loss (%) due to climate damage (a, d), disease damage (b, e) or insect damage (c, f) for paddy(closed symbols) and upland(open symbols) rice in Tokyo from 1945-2003. The corresponding values for paddy and upland rice in Japan from 1952-2004 were also shown for climate damage (g, j), disease damage (h, k), and insect damages (i, l). The average values (%) during the period were also written.
In 1995, the most popular non-glutinous variety in paddy fields was 'Akinishiki', followed by 'Koshihikari' and 'Tsukinohikari', occupying 73% of non-glutinous paddy fields in Tokyo. In 2002, 'Kinuhikari' was the most popular paddy rice, accounting for about 26% of the total area of paddy fields in Tokyo (data not shown).

On the other hand, for glutinous rice, dominant varieties in 1980 and 1995 were those already released and utilized in 1960 or 1953, such as 'Mangetsumochi' (paddy fields) and 'Norinmochi-26' (upland fields). The area of non-glutinous varieties in upland fields decreased from 52% of the total in 1960 to 22% in 1980, and to only 14% in 1995. 'Norinmochi-26' occupied 57% of glutinous upland fields in 1995.

I presented the areas of different rice varieties in Japan for paddy and upland fields and for each grain type in 1961, 1980, and 1995 on the basis of annual food statistics (Table 5; Food Agency, 1980, 1996; Ministry of Agriculture, Forestry and Fisheries, 1958–2003). The percentages of planted area of the top 3 varieties of non-glutinous paddy rice increased (i.e. from 11% in 1961 to 35 and 43% in 1980 and 1995, respectively). Matsuo et al. (1997) also showed that the proportion of planted area of top 10 non-glutinous varieties in Japan increased from 27% in 1956 to 29% in 1961, 36% in 1966, 50% in 1971 and 54% in 1976. This also indicated the selection process of more adapted cultivars and the tendency of decrease in farm-level genetic diversity of rice cultivars in Japanese
paddy fields during 1960s and 1970s. Non-glutinous paddy rice varieties with a shorter plant height and higher yield potential and higher quality were increasingly developed thereafter. In the study focusing on a western region of Japan, the contribution of cultivar improvement to the farm level yield increase between 1960s and 1980s were estimated as 12 to 20% (Hasegawa et al., 1991; Hasegawa and Horie, 1995). Compared with the statistical data for non-glutinous paddy rice, fewer data are available for upland rice and glutinous rice varieties. The percentage of planted area of the top 3 varieties of glutinous rice increased from 1980 and 1995 (i.e. from 26 to 45% for paddy rice, and from 55 to 78% for upland rice). On the other hand, the apparent percentage of planted area of top 3 non-glutinous upland varieties dramatically decreased; this may be due to unavailability of statistical information for non-glutinous upland rice. Since there has been no breeding program for non-glutinous upland rice in Japan, it is assumed that non-glutinous paddy rice cultivars may have been planted as substitute in very small areas of upland fields. It may be interesting to note that as the importance of non-glutinous upland rice becomes smaller in production and in market (i.e. only 2% of planted area in total upland rice production in Japan in 1995), the drive to choose cultivars with superior traits (e.g. higher quality and higher yield) seems to have decreased, resulting in apparent diversification of rice cultivars.

(2) Agricultural input

I compared annual costs of fertilizers, agrochemicals (such as pesticides and herbicides), and agricultural machinery for an average farm household in Tokyo with the corresponding values for an average farm household in Japan at 5-year intervals from 1950 to 2000 to clarify differences in land productivity between Tokyo and Japan (Fig. 17). Total annual agricultural production costs per farm household in Tokyo increased from 58,200 yen in 1950 to 687,700...
and 1,938,100 yen in 1975 and 2000, respectively (data not shown). Costs were higher in Tokyo than in Japan during the 1950s and 1960s, but were higher in Japan than in Tokyo after 1970; current total production costs per farm household in Tokyo are about 80% of the costs for average Japanese farm household. Before 1955, the costs of fertilizers and agrochemicals were comparable or higher in Tokyo than in Japan, but after 1960 an average farmer outside Tokyo spent more on fertilizers and agrochemicals (Fig. 17a, b). During the 1980s, the costs of fertilizers, agrochemicals, and agricultural machinery for average Tokyo farm household were about 40%, 30% and 40%, respectively, of those in Japan (Fig. 17a, b, c). After the 1990s, the gap in production costs between Tokyo and Japan decreased to some extent, and the costs of fertilizers, agrochemicals, and agricultural machinery for average Tokyo farm household in 2000 were 83%, 44% and 81%, respectively, of the average for Japanese farmers. The data of amounts of each element of chemical fertilizer use (i.e. nitrogen (N), phosphorus (P) and potassium (K)) for paddy rice production were available only from 1954 to 1958 from Crop Statistics 1959 (Ministry of Agriculture, Forestry and Fisheries, 1959). It is clear from Fig. 18 that the amounts of application of each element increased in Japan during the 1950s, with the annual increasing rates being 0.33, 0.32 and 0.43 g m\(^{-2}\) year\(^{-1}\) for N, P and K, respectively (derived from regression coefficients), while there was no indication of increase during this period in Tokyo. The notably lower percentage of expenditure for agrochemicals in Tokyo indicates that urban rice farmers restrict the use of agrochemicals because of practicing greater caution for health of city residents and for conservation of urban natural environments. The evidence is presented as an example that numbers of spray of agricultural chemicals in 1965 were much fewer in paddy fields in Tokyo than overall Japan (Table 6). Although the data of Fig. 17 are for agriculture as a whole, rather than specifically for rice, resource inputs for production and plant protection

![Fig. 17](image_url)  
**Fig. 17.** Historical changes of annual agricultural production costs for fertilizers (a), agrochemicals (b), machines (c) for an average farm in Tokyo and in Japan from 1950 to 2000.

![Fig. 18](image_url)  
**Fig. 18.** Changes of amounts of elements of chemical fertilizers (nitrogen (N), phosphorus (P), potassium (K)) from 1954 to 1958 in Japan and in Tokyo. The figure is made from the data of Crop Statistics (MAFF, 1959).
were clearly lower for urban farmers, many of whom are only part-time farmers (e.g. Fig. 11), and this was likely responsible for the difference in rice yield levels between Tokyo and Japan (cf. Fig. 3).

From the viewpoint of crop science, the primary cause for the different level of grain yield of non-glutinous paddy rice between Tokyo and Japan during late 1950s to 1960s was greater hill number per area and panicle number per hill in Japan that lead to greater total grain number per area (without changing much spikelet number per panicle) than Tokyo (e.g. 18.9 hills m\(^{-2}\), 16.9 panicle hill\(^{-1}\), 320 panicle m\(^{-2}\), 25,400 total grains m\(^{-2}\) in overall Japan vs. 15.7 hills m\(^{-2}\), 14.4 panicle hill\(^{-1}\), 226 panicle m\(^{-2}\), 23,600 total grains m\(^{-2}\) in Tokyo in 1965). Percentage of ripened grains was also higher in Japan than in Tokyo (74% vs. 47% in 1965).

Hill number per area, panicle number per hill, panicle and total grain number per area, and percentage of ripened grains increased further in overall Japan after 1960s (19.3 hills m\(^{-2}\), 21.9 panicle hill\(^{-1}\), 423 panicle m\(^{-2}\), 30,000 total grains m\(^{-2}\), 85.6% of percentage of ripened grains in 2000). Yield of paddy rice in Tokyo started increasing after late 1960s (e.g. Fig. 3b, 8a) but with a smaller extent than overall Japan, which is associated with increasing input for fertilizer after 1970s (Fig. 17a) and adoption of new cultivars (Table 4). In case of a western region of Japan, Hasegawa and Horie (1995) suggested a large contribution of increasing inputs of fertilizer to yield improvement for Japanese non-glutinous paddy rice, as well as cultivar improvement.

5. Changes in rice research over time
I analyzed the publications and papers of the Tokyo Metropolitan Agricultural Experiment Station that report previous studies of rice technology development in Tokyo, and grouped them by period and by category of research (Table 7). The three main periods were the 1940s, the 1950s (when rice production increased in Tokyo), and from 1960 to 1971 (when the area of rice declined drastically in Tokyo). The four main research topics were production, plant protection, agricultural engineering, and the environment. During the 1940s, seeding and planting methods of both paddy and upland rice were studied to stabilize yield against fragile environments such as drought (Momoumi, 1941a, b; Murata, 1941, 1943; Nagamata, 1941b). There are also studies on deep tillage and fertilizer application for paddy rice (Asai, 1941), utilization of rotary tiller (for land preparation), and post-harvest, f; agricultural meteorology, g; flood-prone or “akiochi” paddies, h; rice-based cropping systems, i; salt and acid damage, j; herbicides, k; insect resistance, l; rice blast, m; polluted water, n; cadmium.

were clearly lower for urban farmers, many of whom are only part-time farmers (e.g. Fig. 11), and this was likely responsible for the difference in rice yield levels between Tokyo and Japan (cf. Fig. 3).

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(i.e. shallow tillage of interrow spaces during crop growth) were studied in upland rice to increase its productivity during the 1950s (Umehara and Igarashi, 1955; Yamasaki and Tamura, 1956). New agrochemicals such as 2,4-D (2,4-dichlorophenoxy acetic acid) for weed control and organic mercury pesticides to protect against rice blast (Pyricularia oryzae Cav.) were also studied (Yamasaki, 1950; Yamasaki and Kato, 1953, 1954; Motohashi et al., 1956). Four papers studied crop rotation of upland rice (Tamura, 1953; Yamasaki et al., 1957; Nakausa, 1961) or rice paddy plus winter-cropping systems (Kasuya et al., 1953). For the 1960s and early 1970s, I found only two papers on rice research: one studied water pollution (Nakayasu et al., 1967) and the other studied cadmium contamination (Masui et al., 1971) in paddy rice in Tokyo, and no papers after 1971 on the rice production environment or technology in Tokyo, which suggests a diminishing interest in rice research and technology development for both paddy rice and upland rice in Tokyo after the 1970s.

In contrast, in Saitama prefecture, a neighboring prefecture of Tokyo metropolitan with similar climatic and soil conditions, which has also experienced urbanization but not as drastic as that of metropolitan Tokyo; I noticed provincial rice research activities, such as development of new rice varieties (e.g. Banbanzai by Tokura et al. (2002), Sakemusashi by Minoda et al. (2005)), and forage rice production (Kasuga et al., 2002, 2005).

6. Importance of urban agriculture

There has been increasing arguments to preserve or develop appropriate urban agricultural systems (Sriskandarajah and Dignam, 1992; Choguill, 1995; Sharp and Smith, 2003), and these authors discussed the multi-functional roles of urban agriculture and the requirements of efficient urban land use (i.e. inclusion of urban consumers for decision making), with the details different for each local situation (Bryant, 1986). For example, the Tokyo Agricultural Promotion Office (Tokyo Agricultural Promotion Office, 2005) showed that paddy fields near urban areas have many important functions. These include: (1) the production of a staple food to increase the food self-sufficiency rate, (2) an increase in populations of many living organisms and in biodiversity (also pointed by Eppink et al., 2004), (3) the improvement of water quality, (4) a decrease in air temperatures, (5) an increase in protection against flooding, (6) the provision of recreational, cultural, and educational landscapes (also pointed by Lee et al., 1998; Li et al., 2005), and (7) the provision of open spaces that would be useful during disasters such as fires or earthquakes.

The cultivation of winter crops or upland crops is also considered as important for urban agriculture; land conservation such as providing ground cover in winter that minimizes the dispersion of dust on windy days, and creating a landscape of flowering of winter crops in spring in response to increasing daylength and rising air temperature. The land productivity and economic evaluation were attempted by 12 different rice-winter crop rotation systems in a suburb of Tokyo (Kamoshita et al., 2007). Increasing numbers of school curricula lead teachers to take primary-school children on study tours to visit agricultural fields or to take part in rice production in urban agricultural fields, as part of “Shokuiku curriculum”, or food education curriculum (Field Production Science Center, 2007; Godo, 2006; Ministry of Agriculture, Forestry and Fisheries, 2007a, b). These tours also teach students about the environmental consequences of rice production. In urban agriculture, environmental pollution created by inappropriate use of agricultural chemicals should be avoided so as to harmonize with the lives of city residents. The amount of irrigation water that is used should be controlled and minimized to avoid competition with city and industrial uses of water (Kamoshita, 2003; Kamoshita et al., 2007).

7. Conclusions and future directions

From the literature reviews and analysis of the statistical data, I identified the following points as key characteristics of rice production in Tokyo from 1877 to 2003. Firstly, there were two periods of reduction in the area of rice in Tokyo, both associated with rapid urbanization and economically comparative disadvantages of rice production. The first period of decline was in the early 20th century, and lasted until 1940, a time when the area of rice in Japan as a whole gradually increased. The second period was from the late 1950s until 2003, with a more rapid reduction during the 1960s and a slower reduction thereafter; this reduction happened in the six geographical regions in Tokyo and associated with the increase in population density except in Islands region, which was driven by the increasing income gaps between rice farming and non-agricultural sectors, as well as by the decreasing numbers of total and full-time farm household. During this second phase of urbanization, not only total rice production but also land-use efficiency (e.g. from 180 to 100%) and rice self-sufficiency rates (e.g. from 4 to 0.1%) decreased in Tokyo.

Secondly, the yield of paddy rice in Tokyo increased slowly but noticeably in the first half of the 20th century, but was more remarkable after the 1960s. This change was driven primarily by improvements in rice yield in the Southern Tama and Northern Tama regions. However, the rate of yield improvement of paddy rice in Tokyo was smaller than in Japan, which was associated with smaller fertilizer input, less-intensive plant protection, and less agricultural mechanization, as well as declining inputs for rice.
research and technology development in Tokyo after the 1970s. Hill number, panicle number, total grain number per area, and percentage of ripened grains were smaller in Tokyo than in Japan, and hence, the current yield of paddy rice in Tokyo (ca. 400 g m\(^{-2}\) on brown rice basis) is lower than the average for Japan (more than 500 g m\(^{-2}\)). The primary cause of production loss of paddy rice in Tokyo in the last half century was disease damage (35%), followed by climate damage (30%), while climate damage (52%) was more disastrous than disease (35%) or insect (11%) damages in Japan. Crop situation index for paddy rice in Tokyo was less reduced than those in Japan in the years severely damaged by low temperatures after 1970 (e.g. 1993). The less yield reduction in Tokyo in cold years was associated with less reduced percentage of ripened grains, transplanting 3 to 5 weeks later (e.g. middle June) (i.e. possible escapes of reproductive organ development from pre-summer low temperature), and elevating average air temperature in the urban area (i.e. as large as 1.4ºC for the last 40 years).

Thirdly, crop situation index of upland rice fluctuated much more than that of paddy rice, and drought was identified as the most detrimental factor for production loss in upland rice both in Tokyo and Japan (e.g. worst yield less than 100 g m\(^{-2}\) in Tokyo).

Upland rice in Tokyo once shared comparable planting area with paddy rice (ca. 7,000 to 8,000 ha) in the 1950s, playing important roles for sustainable crop rotation and high land-use efficiency as well as food production. However, upland rice cultivation declined dramatically after the late 1950s because of rapid urbanization. Yield improvements of upland rice in Tokyo during the last 50 years were not noticeable (which remains at ca. 150 g m\(^{-2}\) on average) without any new cultivars successfully developed and adopted, whereas for Japan as a whole, the yield of upland rice increased slowly from 150 g m\(^{-2}\) to more than 200 g m\(^{-2}\) over the past 100 years.

From these 3 analyses, I suggest the following 2 points for future rice production systems in Tokyo. Firstly, urban paddy rice production system should not be considered solely from economic comparative disadvantages; externalities such as landscape and land use promotion, environment conservation, and minimum security of food production to improve extremely low food self-sufficiency rate should be considered whereas education and research activities for the use of rice land and rice production should be encouraged. Maintenance of paddy areas, yield increase, and accommodation of winter crops would be necessary for improving land-use efficiency in Tokyo. New and innovative rice-plus wintercropping systems should be established to meet the demands of current urban residents; we have been accommodating landscape winter crops (e.g. rapeseed, chinese milk vetch) in the system that attract urban residents in flowering times in spring and that would be incorporated as bio-fertilizer before rice planting (Kamoshita et al., 2007). We have been also advocating water-saving paddy rice culture, in order to alleviate competitive use of water with urban inhabitants.

Secondly, the alleviation of drought problems, managerial innovations, and development of improved varieties are necessary to increase productivity and stabilize production of upland rice. Upland rice can be alternative for paddy rice in the specific areas where water supply is favourable (e.g. frequent rainfall and high water holding capacity of soils) and when paddy water irrigation becomes costly. High land- and water-productivity for rice production in upland fields in Tokyo were demonstrated by Kato et al. (2006a, b, 2007). Upland rice production would be more effectively incorporated in rotation system with urban vegetable production; nutrient balances in soils should be rectified by including rice after continuous vegetable production. At the same time, I advocate use of flour made from rice grown in upland fields. Our project is ongoing to make flour of upland rice into bread or cookies for sale as well as for self-consumption.

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* In Japanese.
** In Japanese with English abstract or summary.
*** In Japanese with English title.
**** In Japanese. The title was translated into English by the present author.