Global Warming and Changing Rice Cultivation in Japan
– An Analysis on the Acreage or Yield of Main Varieties of Rice –

Fumikazu ICHIMINAMI*, Meltem Okur DINÇSOY** and Enver Erdinç DINÇSOY***

In this study, we examined the change of rice cultivation in consideration of the global warming. In Japan, rice which is suitable for subtropical zone is grown even in an environment of cool-temperate climate. Since the rice varieties that resist of cold weather have been developed, rice cultivation spread to north parts of the country gradually. Land productivity of rice has also improved markedly. As a result, northern Japan became the main producer of rice. Now, taking not only crop production but also the landscape formation and preservation of the natural environment into account, we should think about the rural society from different aspects.

Key words: Global warming, rice cultivation, varieties, acreage, yield, Japan

1 INTRODUCTION

Global warming has been going on around the world, but the measure has not been fully implemented and favorable results may not come out. Agriculture is directly affected by the global warming. Since the viticulture in a traditional wine producing region becomes difficult due to the global warming, it is predicted that the wine production in European countries and so on will decrease remarkably in the near future. Regional appropriateness for viticulture will move north. Similarly, the production area of agricultural crops may change in Japan.

The purpose of the research is to explicate the relationship between global warming and agriculture focusing on the rice cultivation in Japan which has been mainly managed on a small scale by family. The fraction of farming of developed countries like Japan is changing and it is adapted to be produced in industrial facilities which are not affected by changes in weather. However, it is limited only to a small part, namely, the production of leafy greens such as lettuce and paprika with a shorter growing period and most agriculture still continues to be greatly influenced by the weather of the earth's surface. In the latter half of the 20th century, because the phenomena called “extreme weather” such as rising summer temperatures, water shortage due to drought, mild winter, torrential rain, and large typhoons come to occur so frequently, it may lead to serious consequences for agriculture.

In general, because it is said that the main cause of extreme weather events in recent years is a progression to global warming and so firstly the global warming is examined briefly.

2 CAUSES OF GLOBAL WARMING AND CHANGE OF ATMOSPHERIC ENVIRONMENT

2.1 Causes of Global Warming

Human beings have innovated technology and evolved civilization and economy to consume large amounts of fossil fuels such as oil and coal. As a result, greenhouse gases such as carbon dioxide (CO₂) and methane, etc. have increased. They wrap the whole earth, absorb the heat which has been previously released into space, and return it to near the surface of the Earth again. Since the heat emitted is confined close to the earth, the earth's temperature rises. More than 90 % of greenhouse gas emissions in Japan are occupied by a carbon dioxide. For other greenhouse gases, there are nitrous methane (CH₄), oxide (N₂O), hydro-fluorocarbons (HFC), per-fluorocarbons (PFC), sulfur hexafluoride (SF₆) and etc.

Livestock manure, belching of cows, rice paddies, and etc. are also sources that are responsible for generating methane. In addition, one of the causes of nitrous oxide is,
for example, over-application of fertilizer. Although agriculture is harmed by global warming, on the contrary, agriculture has become one of the sources of greenhouse gases. At present, a variety of national and local governments has set targets for the reduction of greenhouse gases. However, since there is not any compelling targets, noticeable results are not achieved in practice.

2.2 Change of atmospheric environment

It is also expected that the amount of rainfall and snowfall has declined due to the mild winter and rainfall runoff and snowmelt water flow into the river earlier than before in Japan. In addition, the flooding and its disaster caused by torrential rain come to occur frequently and severe drought also tend to increase. As a result, similar symptoms in the Asian monsoon region tend to occur.

Further, according to the prediction information on global warming like Japan Meteorological Agency, the condition of the end of the 21st century is predicted as follows;

a. Average temperature will increase 1℃ (degree Celsius) during the period of 2011-2030 years. Rise in the average temperature of the high-latitude region is enlarged. The frequency of abnormally high temperatures increases. In addition, hot days of 30℃ or more is followed by about four months and the frequency of hot nights becomes more than twice.

According to IPCC (2001), the global average surface temperature has increased over the 20th century by about 0.6°C. Several studies have also demonstrated that the rate of increase in daily minimum temperature was greater than that of the daily maximum temperature over the last few decades (Easterling et al., 1997; Peng et al., 2004).

Fig. 1 shows the trends in global average temperatures during the period of the past century. Average temperature denotes the average value of the near-surface air temperature and sea surface temperature. Average year value is the average value of the year 1961-1990. While repeating rising and falling, the average temperature is increasing gradually. According to Fig. 1, it can be seen that the average temperature has increased about 1 degree during about 100 years.

However, there are regional differences in the transition of the temperature trend. Although Japan's land area is small, climate zone extends from the subtropical climate zone in Okinawa to the cold zone in Hokkaido. Night temperatures in summer were also increasing not only in most urban areas but also in most rural areas in Japan (Fujibe, 2004; Tani and Wada, 2006).

b. The amount of annual or daily precipitation and its frequency has been changing a little. While the number of occurrences of heavy rain increases, the number of days without rainfall also increases. Moreover, while average annual precipitation increases excluding a part of southern Kyushu, the amount of precipitation is decreasing in many areas from winter to spring. If the accumulated amount of water is reduced as snow in winter, it may be impossible or difficult to secure the amount of water necessary for spring planting. In addition, the annual number of days without precipitation has increased except for some areas. Snowfall has decreased in all regions except for the Sea of Okhotsk coast.

<table>
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<tr>
<th>Year</th>
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<td>The average year value is the mean of the year 1961-1990.</td>
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<tr>
<td>1911</td>
<td>The difference between the average year (°C)</td>
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Fig. 1  Change in the mean temperature of the world (1906-2007)
Created by Ministry of Agriculture, Forestry and Fisheries in Japan based on Met Office Hadley Centre “HadCRUT3”
c. The number of occurrences of typhoon i.e., a large-sized tropical cyclone reduced in comparison to the past. However, because typhoon has been increased in size, the crops will suffer severe damage.

3 IMPACT OF GLOBAL WARMING ON AGRICULTURE IN JAPAN

3.1 Impact on agriculture

Because extreme temperature can affect the physiology and growth of crops, crop quality and yield generally decreases and the region suitable for cultivation moves. It is estimated, for example, if the temperature rises 3 degrees Celsius, the yield of rice increases in Hokkaido by about 13 %. In contrast, the yield of rice in the south of the Tohoku district will decrease around 10 %. In addition, almost the entire area of Hokkaido becomes suitable for apple cultivation and there are not suitable sites in the south of Kanto district no longer. Moreover, it has been estimated that the adaptability of mandarin Unshu (One of the varieties of citrus) will move north to the southern coast of the Tohoku district and a part of the current region under cultivation becomes no longer suitable sites. Furthermore, the measures which utilize water, breeding, adjustment of cropping season, and crop conversion, and etc. are required in order to mitigate the effects of changes in temperature and precipitation.

3.2 Manifestation of the effects of global warming

In recent years, abnormal weather has come to occur so frequently in many parts of Japan as well as other countries. For example, in August 2007, a heavy rain and localized high temperature occurred. These abnormal phenomena have various effects on farmland, water use, and agricultural production, etc. If we enumerate the major ones, they are as follows:

For rice, immature grain, white rice and body crack increase due to the effect of high temperature during the ripening period, and rice quality is reduced. Because weeds are too flourishing in levee and slope which is habitat of pests such as stink bugs, rice with spots might be more likely to occur (Yamamura, K. and Yokozawa, M., 2002). High temperature also reduces the yield of rice. When minimum temperature of the ripening period becomes higher, or daily range of temperature is reduced, accumulation of starch is reduced and ripening is inhibited.

For tea and fruit, because leaf sprouts grow so quickly in early spring due to rising temperatures, frost freeze occurs with decreasing temperature. For fruit such as oranges, apples, and grapes, failures such as sunburn, skin lifting, and poor coloration sometimes occur. The flooding damage and landslides on farmland slope also increase due to the frequent occurrence of torrential rains. The situation that limits the intake of irrigation water occurs due to severe drought.

Sugiura et al. (2012) elucidated many effects of recent warming such as phenomenological changes in many crops, increases in fruit coloring disorders and incidences of chalky rice kernels, and etc.

4 YIELD AND DIFFERENT VARIETIES OF RICE

Fig. 2 shows the acreage and yield of rice in the period between 1900 and 2012 in Japan. It should be noted that the time interval before 1990 is five years.

Numeric value is the sum of paddy rice and upland rice. Acreage or planted area is the area excluding the area for soiling. Yield of rice had been increased to 1975 in the long run except for the period of World War II, however, the trend has changed owing to the policy control and its conversion of rice production since then. Yield of rice had maintained for more than 12 million tons from 1955 to 1975.

Acreage of rice had continued to increase until the 1960s, and it showed the highest value with 3.26 million hectares in 1965. But then, it has gradually decreased mainly due to the reduction policy on rice acreage, and acreage of rice shows almost half of the peak in the 2010s. Land productivity of rice (kg/10a) was only 200 or so up to the beginning of the 20th century and its regional difference was quite large. Then, land productivity of rice reached 300 in the 1920s, and it had more than 400 in the 1960s. Land productivity of rice continued to increase further, and it has maintained the level of 500 since the 1990s. As a result, land productivity of rice in Japan grew by more than 2.5 times in the last 100 years.

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Fig. 3 shows the change in the percentage of Koshi hikari on the total acreage of the non-glutinous rice. Koshi hikari was registered in Fukui prefecture in 1956 and it is the rice variety which has been grown over a long period of time in the widest area in Japan. The acreage has continued to be the first place since 1979. For a feature of Koshi hikari, its taste is good and stickiness is strong, however, it is easy to fall and vulnerable to diseases such as blast. Although the cropping ratio of Koshi hikari had been less than 30% up to 1995, then, the
ratio has been equal to or greater than 30% and it has continued to increase. After a peak of 38% in 2005, it tended to stagnates. While there are more than 300 varieties of rice, this ratio has continued to account for about one third of the total.

Fig. 4 shows the change in rate of acreage of 12 different major varieties excepting Koshi hikari rice. The rate of acreage of Hitome bore and Hino hikari holds the second or third place. These rates increased in the 1990s and they have been recently changed at a rate of about 10%. Acreage of Hitome bore was promoted to the second in 1994. Hino hikari was developed in Miyazaki prefecture and it was registered as a breed in 1989. Hino hikari has been designated as a variety encouraged by many prefectures and it is widely grown mainly in the Kyusyu and the west Japan such as the Chugoku, Shikoku and Kinki districts, and etc. Acreage of Hino hikari was only 1,797 ha in 1989, and then, it continues to increase steadily. Acreage of Hino hikari was increased to 133,248 ha in 1999.
Following these, the acreage of *Akita komachi* occupies the rank of fourth and it accounts for about 8% of the ratio. *Akita komachi* was adopted as a rice variety which is encouraged in Akita prefecture in 1984. *Akita komachi* is also widely cultivated in the Kanto, Chugoku, Shikoku, and Kyushu districts including the Tohoku. Acreage of *Akita komachi* increased to more than 0.1 million ha in 1991, or later, it has maintained its ranking from the second up to the fourth in the acreage. Acreage of *Akita komachi* is approximately 130,000 hectares in 2005.

*Kirara 397* is one of the varieties of rice from Hokkaido and it was registered as a breed in 1990. Planting of *Kirara 397* began in 1989. It is a breed that greatly changed the image of Hokkaido rice which had been generally thought as tasteless. It has grown into a breed that boasts the largest acreage in Hokkaido.

Cultivation of *Kinu hikari* started in 1975 and the breed was registered in Niigata prefecture in 1988. *Kinu hikari* is a breed that was adopted for the purpose of cultivation in the Kanto district; however, the main producing area in 2005 was in the Kinki district. Saitama, Shiga, and Hyogo prefectures have a large acreage of *Kinu hikari*. Acreage of *Kinu hikari* was 49,304 ha in 2005 and it holds the fifth rank thereafter.

*Sasa nishiki* was a popular breed which was once called “Big two” with *Koshi hikari*. Acreage of *Sasa nishiki* in 1990 amounted to 207,438 ha which was the peak. *Sasa nishiki* is hard to fall. However, *Sasa nishiki* is susceptible to blast as well as weather damage. The damage was extensive in the cold weather of 1993. Then, the planting of *Hitome bore* with greater durability against cold weather gradually spread. Acreage of *Sasa nishiki* has declined significantly since then.

Fig. 5 shows the change of acreage of the leading four varieties of rice. *Koshi hikari* has been planted for more than 50 years since the mid-1950s and it has gradually increased its acreage. Changes in acreage of *Koshi hikari* had been stagnant since the 1990s; however, the increase was slightly noticeable in the mid-2000s. *Akita komachi* began to be planted after the mid-1980s, the planted area was rapidly increasing, and it was more than 0.1 million hectares in 1991. *Hino hikari* began to be planted in 1989 and its area jumped in a short period of time as well. Planted area of *Hino hikari* was more than 100,000 ha in 1995, and more than 150,000 hectares in 2005.

*Hitome bore* began to be planted in 1991 and it was increased rapidly in a short period of time as well. Planted area of *Hitome bore* was 57,493 ha in 1993 when...
extensive crop damage due to chilling injury occurred; the rice harvest in Aomori prefecture in the northern part of the Tohoku district was almost catastrophic. Planted area of Hitome bore nearly doubled to 115,384 ha in 1994 and it continued to expand the area since then, it was more than 0.15 million ha in 2004.

Fig. 6 presents the location and name of 47 prefectures in Japan. Fig. 7 shows the yield of rice by prefecture every 20 years. The yield of rice denotes rice yields per 10 are, that is, productivity of agricultural land. Since there are many varieties in rice, it means an average yield of rice in each prefecture. The average numbers of 47 prefectures, the yield of rice in 1950 was 315 kg. It was 434 kg in 1970, 506 kg in 1990, and it has reached
521 kg in 2010. Rice yield in 2010 was significantly increased to a level of about 1.65 times in 1950. Tabayashi (1983) presented the yield of rice by prefecture in the timing of the first half of the 20th century and the early 20th century. The average yield of rice was about 200 kg in the early 20th century and about 300 kg in the first half of the 20th century. Therefore, the average yield of rice increased to about 2.5 times in the last 100 years in Japan.

Originally, because rice is subtropical crop, high rice yields was realized only in the southwest Japan until the first half of the 20th century, the yields in the northeast Japan such as the Tohoku and Hokkaido districts was relatively low. Then, rice varieties resistant to cold weather had been gradually developed and high yields came to be realized even in the Hokkaido and Tohoku districts.

In 1950, some prefecture showed a relatively high yield in the Tohoku and Kyushu districts. Its maximum value was 399 kg in Saga prefecture. The lowest yield was 213 kg in Kochi prefecture and a very low yield was seen in Miyazaki and Wakayama prefectures. Regional difference in the yield of rice in 1950 was less than that of the other three years and the difference between the
highest and lowest was 186 kg.

Rice yield in 1970 increased more than 100 kg when it was compared to the rates in 1950. In addition, regional difference in yield also enlarged and the difference between the maximum and minimum was enlarged to 328 kg. The highest yield in 1970 was 574 kg in Yamagata prefecture. Aomori and Akita prefectures also gave a high yield of well over 550 kg. Tokyo experienced a minimum of 246 kg and Kochi prefecture also showed a lower yield of 293 kg. In 1990, the national average yield of rice was greater than 500 kg. Also, two prefectures indicating a yield of more than 600 kg appeared in Aomori and Nagano. Rice yield in Hokkaido and prefectures in the Tohoku, Hokuriku, and Tosan districts show a high score. On the other hand, the other prefectures of low yield were noticeable in the Shikoku and Kinki districts. The lowest was 284 kg in Okinawa. Nihei (2010) examined regional distribution of paddy rice production in detail by focusing on the development and adoption of new varieties of rice in the Tohoku district after the 1990s.

The average yield in 2010 further increased to 521 kg. Nagano prefecture showed more than 600 kg and the yield of the four prefectures in the Tohoku district was more than 550 kg. Okinawa showed the lowest value of 293 kg. In addition, the yield in Tokyo did not reach 400 kg. The yield of the prefectures in the Kyushu district except for Kumamoto has not reached 500 kg.

If the amount of solar radiation changes and the temperature rises, the rice yield in north Japan is assumed to increase. However, the yield of rice in southwest Japan will decrease or become unstable. Although rice yields are lower in the west Japan, the yield tends to be higher in Hokkaido, Tohoku, and Hokuriku districts. Such patterns have emerged since 1990. Disasters like typhoons improved varieties of rice and global warming have led to this pattern.

Table 1 shows acreage of Koshi hikari and Hino hikari by prefecture in 2005. Koshi hikari is cultivated in most prefectures. The largest acreage of Koshi hikari is 94,082 ha in Niigata prefecture, and the selling price of Koshi hikari produced at Uonuma is particularly expensive. Planted area of Koshi hikari is more than 4 ten thousand ha in Fukushima, Ibaraki, and Tochigi prefectures, respectively and it is also more than 3 ten thousand ha in both Toyama and Chiba prefectures.

Fig. 8 shows the rate of acreage of Koshi hikari. The rate is a percentage of the overall acreage of non-glutinous rice. There are 6 prefectures which have the rate of acreage of Koshi hikari of 80% or more. High proportion is distributed together through the north Kanto district to the Hokuriku district.

Hino hikari has been cultivated from the west through the central area in Japan. There is a growing area of more than 1 ten thousand ha of Hino hikari in most prefectures of the Kyushu district, respectively.

Growing area of more than 5,000 ha is also seen in some prefectures. They are distributed in the Chugoku and Kinki districts. Fig. 9 shows the rate of acreage of Hino hikari. The rate of more than 40% is limited to the west of the Kinki district. The rate shows 82.1% in Oita prefecture, and a high percentage is observed in some prefectures in the Kyushu district. In addition to this, planting of rice varieties that produce high-quality even in conditions of high temperature have been carried out little by little.

5 GLOBAL WARMING AND RICE CULTIVATION

Nowadays, Hokkaido is the main producing area of rice which occupies the rank of second in 2010. However, the yield and quality tend to decrease under the influence of low temperatures in summer. Rice cultivation in Hokkaido began in 1693 in Hakodate located in the southern part of Hokkaido. In the mid-19th century, the rice breed of cold resistance was born in Sapporo for mutation. Since then, rice production has developed notably. National Agricultural Experiment Stations were also established at the end of the 19th century and they began the breeding of rice (Hatate, 1976). Therefore, for many years, efforts have been continued to develop or plant new varieties with higher yield and good quality.

Kirara 397 is closely related to the lineage of Koshi hikari and it has very good cold resistance. Kirara 397 was adopted as the excellent varieties of rice in Hokkaido in 1988. The reasonable price and stable quality were evaluated; it came to be distributed all over the country for business. Even then, cold resistance, disease resistance, and taste have been improved. As a result, Hoshino yume was born in 1996, Nanatsu boshi in 2001, Fukku rinko in 2003, Oboro zuki in 2005, and Tume pirika with very good taste in 2008 (Fig. 10). Table 2 shows recent acreage of main varieties of rice in Hokkaido. Since the rates of acreage of Nanatsu boshi and Kirara 397 were more than 30%, they have been already grown as major rice varieties in Hokkaido. In this way, the impact of global warming on rice cultivation in Hokkaido is already noticeable, and therefore the
measures have been carried out steadily. In the other prefectures, rice with a unique personality is produced in various prefectures, it is well received.

Table 3 shows the planted area of rice in the leading 5 prefectures in Japan. Beginning with Hokkaido and Niigata prefecture, it is clear that the northern part of Japan has extensive acreage of rice. Table 4 also shows the yield of rice in the leading 5 prefectures in Japan and tends to be similar to that of Table 3. Furthermore, Fig. 11 depicts the yield of paddy rice by prefecture in 2010 and rice is harvested everywhere in Japan. In particular, it is characteristic that large amounts of rice are produced in northern Japan whose climate is cool. Even if global warming progresses further, it is possible to accommodate to some extent in northern Japan. Rather, the larger issue is whether we can secure a sufficient number of farmers or farm organization in the future or not. Since it is almost certain that agricultural successors will decrease in number at least in Japan, the expansion of farming by non-family management such as a company or an association is inevitable.

In Kyushu, Hino hikari of high-quality rice forms about 60% of the planted area of rice. However, the high temperature during the period of maturity of rice has increased by warming of climate even in Kyushu. Kyushu is an advanced place of cultivation of the rice corresponding to warming. Deterioration of the quality of Hino hikari which is the prime brand has been serious because of warming in 1998 and afterwards.

Therefore, the rice varieties of a high-quality in which many crop yields is obtained even in a high temperature has come to be thought as important. The variety of Niko maru has such a character with its delicious taste. Niko maru was developed in Miyazaki prefecture in August 1996 by artificial crossing. The seedlings began to be distributed to farmers in 2002 and the breed was named

<table>
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<tr>
<th>Prefecture</th>
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<th>Hino hikari</th>
<th>Prefecture</th>
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</tr>
<tr>
<td>Aichi</td>
<td>7,185</td>
<td>-</td>
<td>Okinawa</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mie</td>
<td>23,402</td>
<td>109</td>
<td>- : No data</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture, Forestry and Fisheries in Japan: “The planting situation classified by different varieties of cereal crop”
Fig. 8  Rate of acreage of Koshi hikari in 2005
Source: Ministry of Agriculture, Forestry and Fisheries in Japan: “The planting situation classified by different varieties of cereal crop”

Fig. 9  Rate of acreage of Hino hikari in 2005

Fig. 10  Main new varieties of rice, Nanatsu boshi and Yume pirika cultivated in Hokkaido
Source; Pictures taken by the author

Table 2  Recent acreage of main varieties of rice in Hokkaido

<table>
<thead>
<tr>
<th>Rank</th>
<th>Variety of Rice (Year named)</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nanatsu boshi (2001)</td>
<td>37,245 ha</td>
<td>35.2</td>
<td>42,407 ha</td>
</tr>
<tr>
<td>2</td>
<td>Kirara 397 (1988)</td>
<td>36,965</td>
<td>34.9</td>
<td>33,942</td>
</tr>
<tr>
<td>3</td>
<td>Hoshi no yume (1996)</td>
<td>18,771</td>
<td>17.7</td>
<td>13,171</td>
</tr>
<tr>
<td>4</td>
<td>Oboro zuki (2003)</td>
<td>6,069</td>
<td>5.7</td>
<td>6,253</td>
</tr>
<tr>
<td>5</td>
<td>Fakka rinko (2003)</td>
<td>3,385</td>
<td>3.2</td>
<td>4,245</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td>3,465</td>
<td>3.3</td>
<td>6,249</td>
</tr>
<tr>
<td>Sum of non-glutinous rice</td>
<td>105,900</td>
<td>100</td>
<td>106,267</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Survey of Hokkaido prefecture
### Table 3  Planted area (ha) of rice in the leading 5 prefectures

<table>
<thead>
<tr>
<th>Rank</th>
<th>Harvested Year</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Niigata</td>
<td>120,700</td>
<td>Niigata</td>
<td>116,900</td>
<td>Niigata</td>
<td>117,400</td>
</tr>
<tr>
<td>2</td>
<td>Hokkaido</td>
<td>116,000</td>
<td>Hokkaido</td>
<td>114,600</td>
<td>Hokkaido</td>
<td>114,400</td>
</tr>
<tr>
<td>3</td>
<td>Akita</td>
<td>94,100</td>
<td>Akita</td>
<td>89,000</td>
<td>Akita</td>
<td>89,700</td>
</tr>
<tr>
<td>4</td>
<td>Fukushima</td>
<td>82,600</td>
<td>Fukushima</td>
<td>81,300</td>
<td>Fukushima</td>
<td>80,700</td>
</tr>
<tr>
<td>5</td>
<td>Ibaraki</td>
<td>78,200</td>
<td>Ibaraki</td>
<td>77,400</td>
<td>Ibaraki</td>
<td>79,000</td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture, Forestry and Fisheries in Japan; “Yield of rice in harvested year 2011”

### Table 4  Yield (ton) of rice in the leading 5 prefectures

<table>
<thead>
<tr>
<th>Rank</th>
<th>Harvested Year</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Niigata</td>
<td>650,600</td>
<td>Hokkaido</td>
<td>647,500</td>
<td>Niigata</td>
<td>626,900</td>
</tr>
<tr>
<td>2</td>
<td>Hokkaido</td>
<td>603,200</td>
<td>Niigata</td>
<td>644,100</td>
<td>Hokkaido</td>
<td>543,400</td>
</tr>
<tr>
<td>3</td>
<td>Akita</td>
<td>549,500</td>
<td>Akita</td>
<td>535,800</td>
<td>Akita</td>
<td>508,600</td>
</tr>
<tr>
<td>4</td>
<td>Fukushima</td>
<td>445,200</td>
<td>Fukushima</td>
<td>438,200</td>
<td>Fukushima</td>
<td>436,600</td>
</tr>
<tr>
<td>5</td>
<td>Yamagata</td>
<td>419,500</td>
<td>Yamagata</td>
<td>417,100</td>
<td>Ibaraki</td>
<td>407,800</td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture, Forestry and Fisheries in Japan; “Yield of rice in harvested year 2011”

![Fig. 11 Yield of paddy rice by prefecture in 2010](source)

Source: Ministry of Agriculture, Forestry and Fisheries in Japan
Table 5  Planted area of the rice corresponding to global warming

<table>
<thead>
<tr>
<th>Prefecture</th>
<th>Variety of Rice (Year named)</th>
<th>Planted area (ha) in 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yamagata</td>
<td>Tsuya hime (2009)</td>
<td>2,500</td>
</tr>
<tr>
<td>Toyama</td>
<td>Ten takaku (2003), Tenko mori (2007)</td>
<td>4,830</td>
</tr>
<tr>
<td>Fukui</td>
<td>Aki sakari (2008)</td>
<td>347</td>
</tr>
<tr>
<td>Hyogo</td>
<td>Kinu musume (2005)</td>
<td>90</td>
</tr>
<tr>
<td>Fukuoka</td>
<td>Genki tsukushi</td>
<td>1,090</td>
</tr>
<tr>
<td>Saga</td>
<td>Saga biyori (2009)</td>
<td>4,360</td>
</tr>
<tr>
<td>Oita</td>
<td>Niko maru (2005)</td>
<td>622</td>
</tr>
<tr>
<td>Nagasaki</td>
<td>Niko maru (2005)</td>
<td>1,650</td>
</tr>
<tr>
<td>Kumamoto</td>
<td>Kumasan no chikara (2007)</td>
<td>1,230</td>
</tr>
<tr>
<td>Kagoshima</td>
<td>Aki honami (2008)</td>
<td>860</td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture, Forestry and Fisheries in Japan

Fig. 12  Main new varieties of rice corresponding to global warming

Source: Upper left; Image of the corresponding website. Upper right and lower left; Picture taken by the author
in 2005. Nagasaki prefecture began to grow the rice corresponding to warming firstly and then in 2006, it started to plant the variety of Niko Maru which was developed by the national agricultural research center for Kyushu and Okinawa Region. Oita prefecture also began to grow Niko Maru in 2008 (Table 5 and Fig. 12).

Four prefectures such as Saga, Fukuoka, Kumamoto, and Kagoshima develop the rice corresponding to warming uniquely in the research institution of each prefecture, respectively, and began to plant it in 2009. In a tentative way, Miyazaki prefecture grew from 2000 to 2009 "Nankai No. 166" which was uniquely developed in its own prefecture (Nagayoshi et al. 2011).

The change of the rice corresponding to warming is also progressing in the Tohoku district and Hokuriku district whose temperatures go up by a foehn etc. Yamagata prefecture gathered the seeds of "Tsuya hime" (Fig. 12) by artificial crossing in a agricultural experiment station in Yamagata prefecture in 1998, specified it in 2008 as the recommended variety, and planted it in 2,500 ha in 2010. Tsuya hime was specified as the recommended variety in Miyagi prefecture in 2009, in Oita prefecture in 2011, and in 2012 in Nagasaki and Shimane prefectures. Toyama prefecture developed two varieties, "Ten takaku" and "Ten komori" in the prefectural agricultural technology center. Fukui prefecture also developed "Aki sakari" originally in agricultural experiment station in Fukui prefecture.

Mori no kumasan was developed in Kumamoto prefectural agricultural research center. It was adopted to encourage variety in 1997 and it was registered as a breed in June 2000. Growing area of this breed was about 5,000 ha in Kumamoto prefecture in the 2000s (Fig. 12). It was chosen as the top in the flavor ranking of the rice of 2012 yearly outputs which was sponsored by the Japan grain inspection association.

As mentioned above, the varieties of rice corresponding to global warming have been developed first in Hokkaido. Although another kind of development had some types, the groups consisting mainly of Kyushu and Yamagata prefecture were explained in the study. Development of the variety of agricultural products takes too much time. Serious agricultural damages occur by abnormal weather, such as sudden local severe rain and a tornado. Moreover, it is required to be well adapted for a long-term climatic change.

5 CONCLUDING REMARKS

Rice is a staple crop as well as wheat or potatoes. There is also no obstacle in continuous cultivation of rice. If there is no effective measure, an abandoned cultivated land and uncultivated farmland will continue to enlarge in a tone so far in Japan. Therefore, it should be focused on not only crop production in farmland but also the landscape formation and nature preservation in the future. There is also a choice to expand the extensive cultivation of a variety of crops and trees to save the labor force. When you look at the landscape of the cosmos and buckwheat in the rural areas, people will feel calm. For the purpose of the windbreak and green manure, increasing the acreage of sunflower, rape, lotus, corn, Japanese millet, sorghum, clover, and so on should be recommended. Moreover, although the rate of forest area in Japan is high, the national concern about woods is not necessarily strong. We are likely to be better to increase the opportunity to act wisely on the significance of green and natural environment in rural areas.

References


