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Evaluation of the Economic Effect of Climate Change on Rice Production in Japan: The Case of Koshihikari

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Climate change threatens global food security and farm management by affecting the quantity and quality of food. Our purpose is to accurately predict the effect of climate change on rice production in Japan. To estimate the rice quantity and quality under the future climate conditions, we simulated rice growth and quality models by three different scenarios of greenhouse gas (GHG) emission. For assessing the economic impact of climate change, we exchanged the results of rice yield and quality to the price. We focus on Kosihikari, the most popular cultivar among consumers and widely produced in Japanese rice farming, although being vulnerable to heat stress. The estimated results provide two insights. First, an increase in the quantity of rice yield due to climate change has a stronger economic impact than the decrease in quality even under the future climate conditions scenario with the lowest GHG-emission. Second, the impact between eastern and western Japan is different. In eastern Japan, the rice yield would increase while in western Japan, quality would deteriorate. This means the Japanese will be faced with an oversupply of rice, and suggests that rice farmers in western Japan will be obliged to adopt new strategies to improve revenue.

Acknowledegment:

JEL Codes: Q54, C63

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The estimated results provide two insights. First, an increase in the quantity of rice yield due to climate change has a stronger economic impact than the decrease in quality even under the future climate conditions scenario with the lowest GHG-emission.

Second, the impact between eastern and western Japan is different. In eastern Japan, the rice yield would increase while in western Japan, quality would deteriorate. This means the Japanese will be faced with an oversupply of rice, and suggests that rice farmers in western Japan will be obliged to adopt new strategies to improve revenue. (199/200 words)

Keywords: climate change, rice production, Japan, quality effect

JEL codes: Q11, Q18, C54, Q15

1. Introduction

1.1 Research theme

Climate change threatens global food security and farm management by affecting the quantity and quality of food. According to the Intergovernmental Panel on Climate Change (IPCC) report, for major crops (wheat, rice, and maize) in tropical and temperate regions, climate change without adaptation will negatively impact production for local temperature increases of 2C or more above late-20th-century levels (IPCC 2014). Among the major crops, rice is the most important food staple in most Asian countries and some parts of African and Latin American countries. In developed countries, where even staple foods are differentiated and branded, the quality of food is an important factor for farm management. According to the projections of the Ministry of Agriculture, Forestry and Fishery

(MAFF) of Japan on the effects of climate change, climate change will decrease the quality of rice in Japan by increasing the risk of white immature kernels. The physiological responses of rice plants to high temperatures during the grain filling period result in chalky grains that has been severe in western Japan recently (Shimoda, 2011). The experimental research suggests that climate change will strongly affect the quality of rice grain in the future (Usui et al. 2016). Therefore, the evaluation of crop quality has implications for the economic impacts of climate change.

The aim of this study is to make a precise projection of the effect of climate change on rice production in Japan. As will be discussed in the literature survey, most of the previous studies in social sciences take a statistical approach in studying the effect of climate change, with the main focus on the quantity of rice production. However, farming methods and cultivar varieties are innovated to adapt to natural and social changes, resulting in improvement in the quantity and quality of rice in Japan. The fundamental shortcoming of the statistical approach is the difficulty tracing the history of such adaptation strategies with pooled time series data. Burke and Emerick (2016) point out the problem of previous studies that rely on short-run variations in weather when there is an adaptation strategy for climate change, and proposes an alternative long-term differences approach. This study takes an integrative approach, considering the previous studies in social and natural sciences, to evaluate the effect of climate change using a process-based approach. One of the advantages of a process-based approach is the ability to evaluate the effect of climate change on specific rice varieties with fewer experimental and field data.

This study focuses on the Koshihikari cultivar in Japan. Koshihikari was introduced in the 1950s and has spread quickly across Japan. Koshihikari has been the most popular rice variety among Japanese consumers. As shown in Fig.1 and Fig.2, Koshihikari is produced in most areas, excluding Hokkaido. In 2015, 36.1% of the paddy fields in Japan were planted with Koshihikari, followed by Hitomebore (9.7%), Hinohikari (9.0%), and Akitakomachi (7.2%). One of the shortcomings of Koshihikari is its vulnerability to heat stress, which affects the quality of the rice. Our process-based approach analysis simulates the effect of climate change for Koshihikari with the current production practices, while an analysis based on past statistics shows the association of climate variables with mixed varieties and different practices. The analysis of how climate change affects the quantity and quality of Koshihikari will reveal the need for further adaptation strategies in Japanese rice production, such as a transition to heat tolerant varieties and delaying planting dates.

This paper is organized as follows. In section 2, we summarize the prior research on climate change in Japan. In addition, the usefulness of the process-based approach, which is rarely done in Japan, is also summarized. Chapter 3 explains the climate change scenario and the method of calculating the harvest volume/quality and production value based on the scenario. The results of the simulation are summarized in Chapter 4. In section 5, based on the calculation results, the influence of climate change on the US policy of Japan and the strategy of agricultural management are examined. Chapter 6 concludes.

Figure 1. The share of Koshihikari in each Prefecture

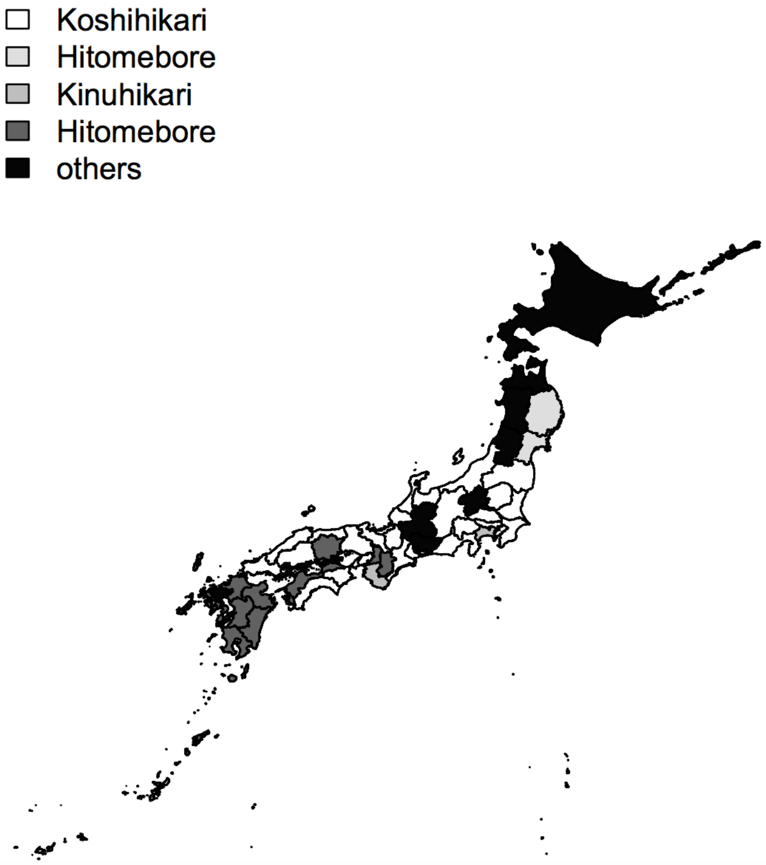

Figure 2. The distribution of Rice varieties in Japan(Share No.1 varieties)

2 Literature Survey

Past studies evaluate the influence of climate change on rice production in Japan using estimates of total factor productivity (TFP), computable general equilibrium analysis, and regression analysis.

Estimating the influence of climate change on total factor productivity (TFP) was introduced for Japanese rice production by Kunimitsu et al. (2014). They estimate a regression model to link rice TFP to climate factors via yield, quality, and flood influence using crop models, and then project future TFP levels. Kunimitsu et al. (2016) further develop this approach by using the spatial econometric model. Based on these results, Kunimitsu (2015) applied computable general equilibrium analysis to evaluate the regional impacts on rice production and agricultural income when the TFP level is affected by climate change. The remaining issues in this approach are how to construct the climate change variables, and how to interpret the linkage between rice TFP and climate conditions.

Akune et al. (2015) use the computable general equilibrium model to evaluate the economic impact of adaptation technologies to climate change. Based on past studies, they assumed different coefficients of high temperatures on rice production and quality for conventional rice varieties and high temperature-tolerant rice varieties. The remaining issues are the accuracy of the surveyed coefficients, and how to incorporate the non-linear effect of temperature changes.

Tokunaga et al. (2015) conduct a panel data analysis, using a function for agricultural products that incorporates labor and weather variables. They found that rising temperatures and precipitation, and falling solar radiation caused by climate change have reduced rice production. Tokunaga et al. (2017) predict the regional rice yield using panel data analysis, and examine the impact of global warming on regional economies with a computable general equilibrium model. Their estimation includes a quadratic specification of mean temperatures.

Kawasaki and Uchida (2015) quantify the economic impacts of climate change on agriculture through changes in both quantity and quality. Their novel contribution to the literature is that their model, partly based on Schlenker and Roberts (2009), controls for methodological issues regarding sample selection, aggregation, phenology, and nonlinearity. They find that warming improves yield but deteriorates quality, and the net effect on farm revenues is negative.

However, they ignored the potential adaptation to global warming through substitution of different cultivar and/or shifting the transplanting day, because their statistical model does not take the effects of changing farmer's choices on adaptation into consideration. In contrast, Ishigooka et al. (2017) conducted crop models across Japan combined with general circular models (GCMs) to reveal that the effect of climate change on the ratio of first-grade rice production, the highest quality of rice grain defined by MAFF, could be mitigated by cultivar choice and shifting the transplanting day. They showed the geographic distribution of the potential risk of quality reduction under future climate conditions, calculating the heat-dose (HD) index, defined as the cumulative temperature exceeding a threshold temperature during the grain filling period after heading (flowering) of rice plants. This index has been used as an indicator of heat stress intensity for assessing the effect of temperature on crop production or quality (Rane and Nagarajan, 2004, Farooq et al., 2011). Morita (2008) noted the white immature grain observed when the daily mean temperature averaged over the 20 days after the heading date exceeded around 26–27℃. Nagahata et al. (2006) reported that HD with a threshold temperature of 26℃ explained the generation of white immature grain using a growth chamber experiment with a japonica rice cultivar, Koshihikari, manipulating the period of exposure to high-temperatures (33℃ during daytime and 26℃ during nighttime). Ishigooka et al. (2017) utilized the HD index, fixing the exposure period as 20 days, for a simulation of crop models. However, according to Morita (2008), several meteorological factors can be candidates for the HD index; for example, the average daily maximum temperature during the grain filling period, solar radiation, and so on. Okada et al. (2011) estimated how the daily minimum temperature and solar radiation affect rice quality on a prefectural scale in Kyushu, western Japan, but ignored the cultivar’s characteristics. Thus, there is no predictable model for the relationship between the HD index and first-grade rice production if the cultivar is altered as an adaptation to climate change.

3. Materials and Methods for simulation analysis

3.1 Climate data

We analyzed Mesh-AMeDAS (Automated Meteorological Data Acquisition System) observations (Seino, 1993) for the present climate, and simulated the outputs of a global climate model, MIROC5 (Watanabe et al., 2010) for the future climate. The MIROC5 simulation was based on the three representative concentration pathways (RCP; Meinshausen et al., 2011), namely RCP 2.6, 4.5, and 8.5. Present and future climates were analyzed for two periods: historical (1981-1999) and the near future (2031-2049) climates. We conducted dynamical downscaling for the output of the MIROC5 model to the 20-km grid spacing that covers all of Japan using a regional climate model, JMA-NHM (Saito et al., 2007), because a horizontal resolution of the MIROC5 model (1.4º x 1.4º) was insufficient to resolve regional differences in meteorological conditions. From the downscaled meteorological conditions, we utilized the changes in mean state, and added them to the historical Mesh-AMeDAS observations to avoid biases caused by imperfections in atmospheric models. The horizontal resolution of the Mesh-AMeDAS observations (10 km) differs from that of the JMA-NHM simulation (20 km); therefore, we interpolated the downscaled outputs onto the Mesh-AMeDAS grid cells with the nearest four grid cells.

3.2 Rice growth simulation

Composed climate data was then inputted into the rice growth model, Hasegawa/Horie (H/H; Hasegawa and Horie, 1997, Yoshida et al., 2015). The H/H model simulates annual rice yields for given cultivar and meteorological conditions, including surface air temperature and downward shortwave radiation, accumulating biomass from daily photosynthesis. We first validated the performance of the H/H model by simulating the historical yield of 1981-1999 with the cultivars that hold the maximum cropping area in each prefecture, inputting the Mesh-AMeDAS observations. We then utilized the downscaled future variables to assess the impacts of climate change on rice growth. These analyses were processed for the grid cells where paddy fields in 2006 occupied more than 1 % of the 10-km grid cell.

3.3 The relationship between rice quality and the index of heat dose

For rice production in Japan, the standard of rice quality is determined by the contamination rates of damaged grains, chalky grains, colored grains, and foreign matter; the moisture of the grain; and reduced grain filling. These criteria are mainly derived from three categories; 1) growth of rice plants that produce damaged and chalky grains, 2) insect damage that generates colored grains, and 3) post-harvest work that results in grain moisture and contamination by foreign matter. First-grade rice must meet two standards: 1) immature grains are less than 30%, and 2) colored grains must be 0.1% or less of the test sample. According to the quality check tests in Japan in the past few decades, nearly 75% of second-grade ratings or lower resulted from the abnormal growth of rice plants, and about 20% was due to colored grains caused by insects. The reasons for second-grade or lower ratings in 2016 were contamination by chalky grains (about 25% of the total downgraded rice), and reduced grain filling (about 42%), both caused by abnormal growth. Although damage by insects might increase in the future because of climate change, we ignore this possibility to focus on the direct effect of climate change on rice plant growth resulting in chalky grains.

We modeled the relationship between the first-grade rice production ratio (hereafter FGRR) and the HD index utilizing statistical data (MAFF, 2015b), including the yearly first-grade rice production ratio on a prefectural scale. The prefectural crop calendar was also reported by MAFF (2010-2011, 2013-2015a). Following Ishigooka et al. (2017), we define the HD index as in equation (1).

$$HD_i = \sum_j \sum_{hd}^{xdays} max((Ta - Tb), 0) \; S_j / S_i \qquad (1)$$

where i, j, hd, xdays, Ta, Tb, S_j, and S_i represent prefecture, a grid within prefecture i, the heading date of prefecture i, the high-temperature exposure period, the daily mean temperature of the grid, the threshold temperature for heat stress, the land use ratio for paddy fields in the grid, and the total area of paddy fields in prefecture i, respectively. This HD index is calculated on a prefectural scale because the governmental statistics of FGRR are given at that scale. Then, we formulated the statistical model as follows.

$$\mathrm{logit}\,(FGRR_{\mathrm{i}}) = \mathrm{a}\,HD_{\mathrm{i}} + \mathrm{b}, \tag{2}$$

where i represents each prefecture, and a and b are coefficients of the statistical model. To determine the coefficients, we adopted the maximum likelihood method using Newton's method. We assumed FGRR follows a binomial distribution from the variable *FGRR* derived by our statistical model, and the model sampled 100 times for simplicity, because there is no information on how many times the quality check was conducted. We divided the prefectural FGRR data into two parts; one is used for calibrating the coefficients of the model (specifically, 80% of the total available data, randomly selected), and the other is used for validating the accuracy of the model (the remaining 20%). If Newton's method failed to calculate the coefficients, we then searched for another initial setting for Newton's method. After determining the coefficients a and b in our statistical model using the FGRR calibration data, we validated them, deriving the root mean square error (RMSE) value between the observed FGRR and calculated *FGRR* as the accuracy of the estimation using the remaining data. For the first step of this study, we focused on the major rice cultivar in Japan, Koshihikari. Table 1 shows the prefecture and years used in this study where the area occupies over 70% of the total production by this variety. We used the particle swam optimizing algorithm to search the optimal parameters (xdays and Tb) that could minimize the RMSE value of the validation data. As a result, the optimal parameters were (xdays = 25, Tb = 27.64), and the coefficients a and b in our statistical model were -0.105 and 1.766. Hereafter, we use these parameters and coefficients to project the rice quality under future climatic condition.

Prefecture	Data available year
Ibaraki	2010-2015
Tochigi	2010-2014
Niigata	2010-2014
Toyama	2010-2015
Ishikawa	2010-2015
Yamanashi	2010-2015
Nagano	2010-2015
Mie	2010-2015
Tottori	2010

Table 1. Koshihikari cultivating prefectures and years

As mentioned in the previous section, the *FGRR* on a prefectural scale under historical (1981-1999) and near future (2031-2049) climate conditions were calculated to reveal how climate change would change rice quality. The HD index for a certain grid was calculated using the H/H model, and then the prefectural scale index was derived by calculating the weighted average of the paddy field ratio of the grid using the prefectural yield. Given the HD index, the *FGRR* was estimated using equation (2). We calculated the rice quality of Koshihikari across Japan under historical and future climate conditions to reveal how climate change affects rice quality.

3.4 Economic indicators and calculation

We convert the changes in production volume and quality obtained in the previous section into economic value. First, we obtain the production amount by prefecture using the obtained production amount per 10a (kg/10a) and the 2010 cropping area, which is the base year of the simulation. Statistics from MAFF were used as actual values of production volume for comparing rice planting areas, relative trading prices, and simulation results.

Between first-grade rice and other grades, there is a discount with a fixed sales amount. However, the trade performance of second-grade or lower grades of rice is limited to a specific area, and it occurs only biennially. Also, in our simulation, since the past data are insufficient, we cannot provide proportions of quality other than for first-grade rice. Therefore, from the relative trading price of first-grade rice and the three remaining grades in the records from 2010 to 2017, the discount rate of the selling price due to lower quality was divided into three patterns, and we calculated the respective rates. The three trial scenarios use discount rates of 7%, 10%, and 15%.

4. Results of the simulation analysis

4.1 Changes in surface climate

Intensified surface warming became obvious with an increase of RCPs and elapsed periods, showing increases of 1.6 (RCP2.6) /1.7 (RCP8.5) ºC for the near future climate (Fig.3). The most intense surface warming simulated in the future climate of the RCP8.5 scenario fell within the range of estimation of Climate Model Intercomparison Project 5 (Kharin et al., 2013). Large surface warming was obvious in the northern area of the Sea of Japan side for all analyzed RCP scenarios. Similar geographical distributions and surface warming of daily mean temperatures were found for the daily maximum and minimum temperatures as well, except for slightly more warming in the daily minimum temperature. Although changes in downward shortwave radiation were less clear than surface temperatures, there was a larger decrease for western Japan in the future climate, with a regional decrease of 2.4 %.

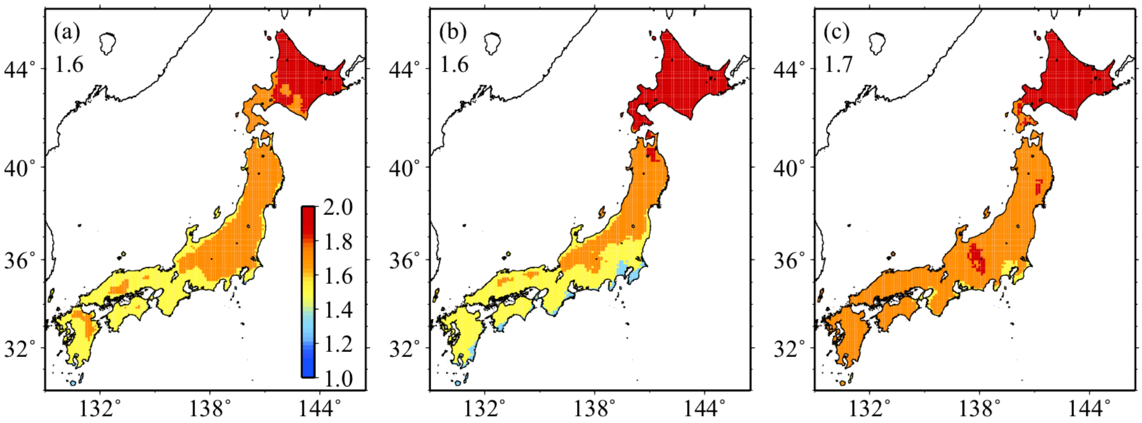

Figure 3. Changes in daily mean temperature relative to present climate (1981-1999) for near future climate (2031-2049) simulated with (a) RCP2.6, (b) RCP4.5, and (c) RCP8.5 scenarios (ºC). Values shown in each panel indicate regional average.

4.2 Validation of the H/H model

Simulated rice yield driven by the observed Mesh-AMeDAS data reproduced historical yield variations, showing a 4 % overestimation for the whole period (Fig. 4a). When we aggregated prefectures that Koshihikari was cropped as the leading cultivar, the bias increased to 7% of overestimation (Fig.4b). The H/H model followed the abrupt drop of yield in 1993, when cold northeasterly winds from Okhotsk seriously damaged the northern area, which was simulated as an increase in cold sterility. While the 19-year average values and west-east contrast in yields were reasonably simulated throughout Japan, it tended to be overestimated in low elevation areas, and vice versa. The H/H model overestimated yields of Koshihikari for the most part of analyzed period (Fig. 4b). Cultivating technology had been improved for the observation but the simulation supposed to have high levels of cultivation as 2006 throughout the periods therefore the observed yield was overestimated in the early period.

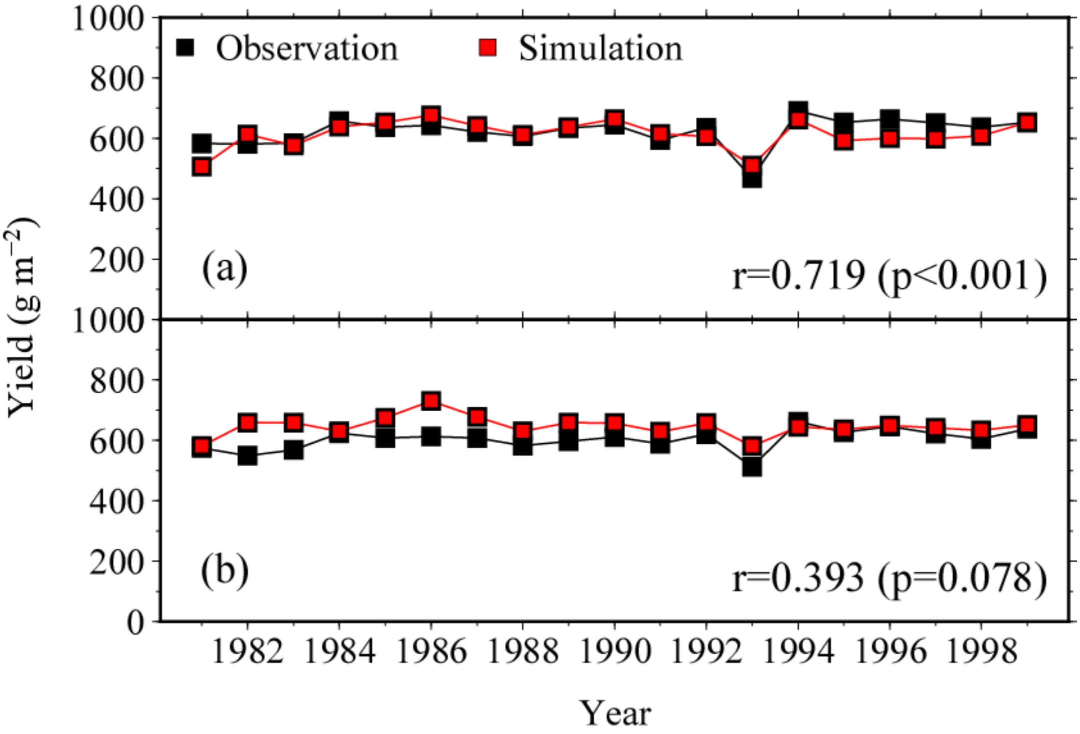

Figure 4. (a) Historical observed (red) and simulated (blue) yields for the period of 1981-1999 (g m^{-2}), averaged across whole paddy area. Parameter *r* and *p* indicate the Pearson's correlation coefficient and the p-value, respectively. (b) Same as (a) but averaged for the prefecture that Koshihikari is the current leading cultivar.

4.3 Climate change impacts on rice yield

An increase in yield was simulated, regardless of differences in RCPs and climatological periods (Fig. 5). The intensity of global warming corresponded to an increase in rice yield, showing the largest increase in the RCP8.5 scenario (21 %). Moreover, yield increases became more apparent in RCP8.5 than in RCP4.5. The increased ratio was enlarged 2-3 % in the case of homogeneous cropping of Koshihikari. For both type of cropping cultivar, more yield increase was found in northern area.

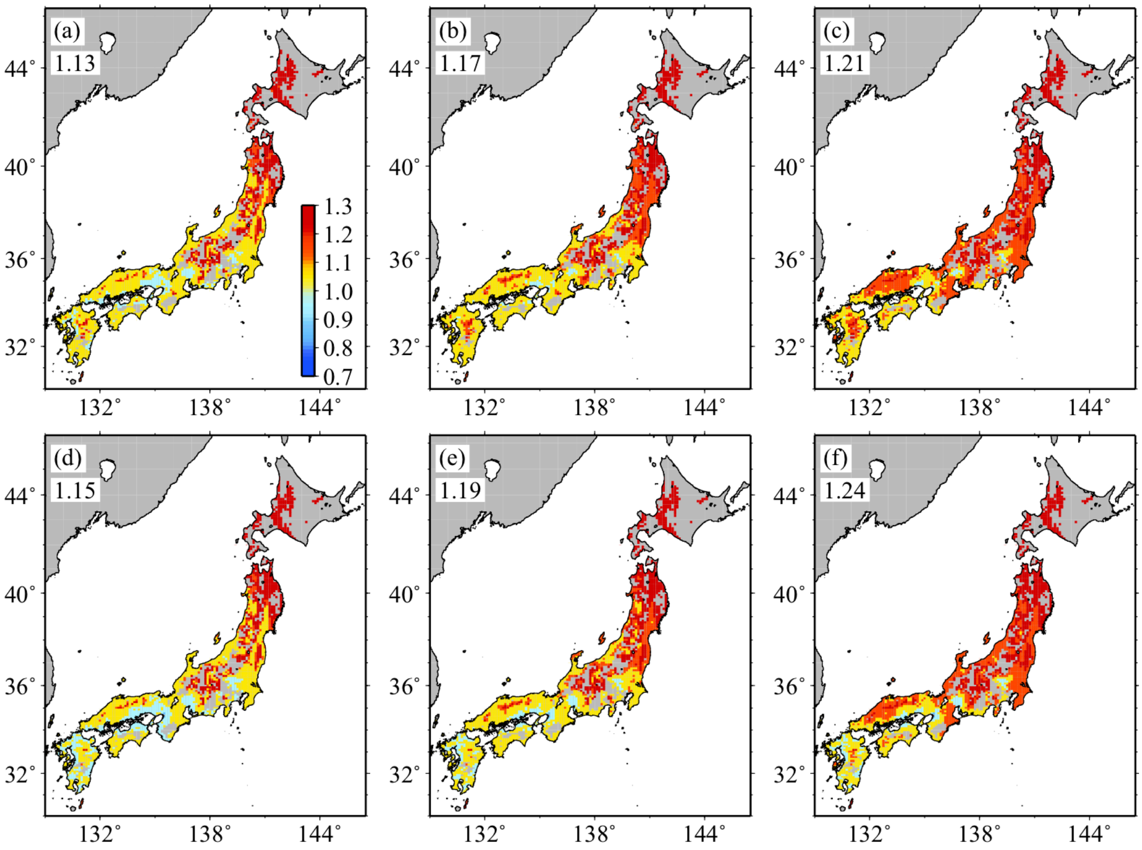

Figure 5. Same as Fig. 3 but for the changed ratio of yield relative to historical value for the period of 1981-1999 with (a-c) current leading cultivar and (d-f) Koshihikari.

4.4 Changes in rice quality

Fig. 6 shows the rice quality under historical and near future climate conditions if Koshihikari is cultivated in all paddy fields across Japan. As shown in Fig. 6a, the rice quality of Koshihikari is high under historical climate conditions, especially in north and northeast Japan. It should be noted that this does not indicate the actual results of the past crop quality tests. The difference of RCPs on rice quality is shown in Fig. 6 b-d. As a general trend, a decrease in rice quality was simulated regardless of RCPs, except for the two northeast prefectures. In contrast to the increasing trend in yield in the previous section (Fig. 5), quality decreases remarkably in the RCP8.5 scenario. The quality drops in every prefecture where Koshihikari was the leading cultivar in 2010, as shown in Fig. 2.

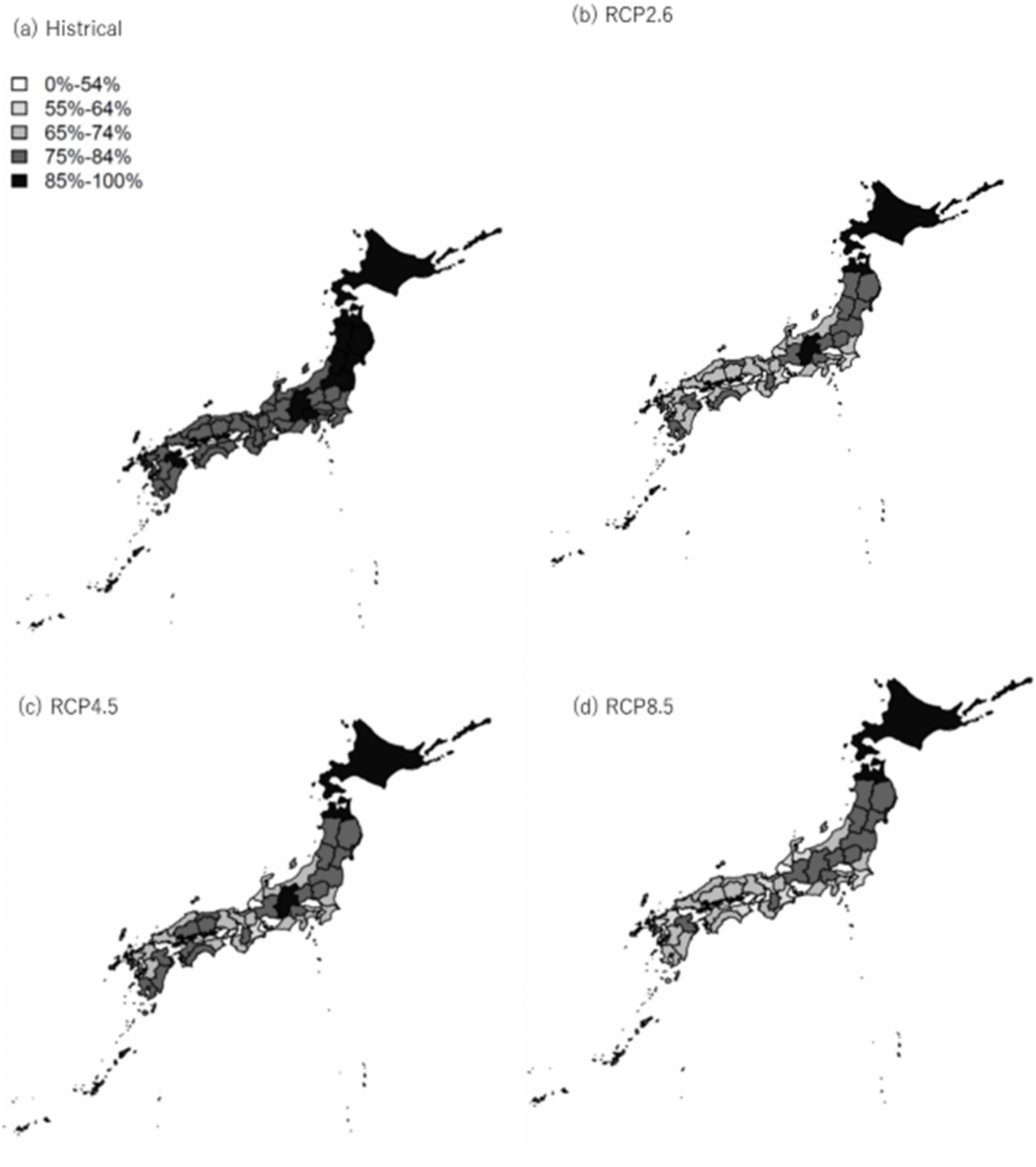

Figure 6. The distribution of the ratio of first-grade rice production

4.5 Changes in rice production value

There are regional differences in the effect of climate change (Fig, 7, Table 2). The difference in the gradation shown on the map due to the three patterns of discount rates shows the magnitude of the change in the forecast production value due to the ratio of rice that is less than third-grade. In accordance with the pattern where the proportion of rice below third-grade becomes higher from Fig. 7 (a) to Fig. 7 (c), the rice production value decreases.

Figure 7. The distribution of rice product values

	An average year-based	RCP2.6(2031-2049)		RCP4.5(2031-2049)		RCP8.5(2031-2049)	
	yield in 2010 (t)	(t)	2010/RCP2.6	(t)	2010/RCP4.5	(t)	2010/RCP8.5
Hokkaido	601,340	343,719	57%	386,206	64%	389,803	65%
Tohoku	2,231,643	2,853,587	128%	2,976,276	133%	3,121,803	140%
Hokuriku	1,056,471	1,409,507	133%	1,460,397	138%	1,538,019	146%
Kanto	1,326,277	1,655,631	125%	1,717,997	130%	1,792,411	135%
Tokai	518,311	635,526	123%	658,858	127%	684,630	132%
Koushin	240,592	277,617	115%	288,412	120%	306,138	127%
Kinki	554,992	659,614	119%	679,253	122%	703,754	127%
Tyuugoku	602,322	680,275	113%	702,038	117%	731,561	121%
Shikoku	279,150	315,293	113%	322,928	116%	329,910	118%
Kyuushu	949,035	966,770	102%	978,569	103%	990,853	104%
total	8,360,133	9,797,538	117%	10,170,932	122%	10,588,881	127%

Table 2. Simulation results of Koshihikari production

As a result, the total production value in Japan will change by 113% in the RCP2.6 scenario, with the least impact of climate change[1].This change can be decomposed into the effect of quantity and quality changes. The production quantity will be increased by 117%. The first-grade rice production ratio will be decreased (Fig. 6). Multiplying the quality effect by the assumed discount rate for the lower grade rice, we can estimate the effect of quality changes on the production value.

The projected quantity effect is greater than the projection by Kawasaki and Uchida (2016), 3.4%,

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[1] Discount rate is 15%.

while the projected quality effect is smaller than the projection by Kawasaki and Uchida (2016), 8.0%.

Figure 7 shows the total effect of climate change on rice production value. In Tohoku and Hokuriku, the Northern areas of Japan, climate change will increase the production value of rice. This is because the quantity effect overwhelms the quality effect; the effect of increased yield is greater than the deterioration of quality. In Hokuriku, where Koshihikari is the dominant rice variety, the quantity effect is 128% in Tohoku and 133% in Hokuriku (Table 2, RCP2.6 scenario). Kanto, which is a vast plain area near Tokyo, also shows a 125% increase in production. As shown in Table 2, it is worth noting that in these three areas, which cover about half of the rice production in Japan, the output is greatly increased due to climate change.

On the other hand, the production value will be decreased in other areas in Japan, such as Koshin, Kinki, Shikoku, and Kyushu. As shown in Fig. 2, these include the prefecture in which Koshihikari has the largest proportion of paddy cultivation. For these prefectures, it will be necessary to review the strategies for future paddy field management. Also, except for Koshin, these areas are all considered part of western Japan. Despite the increase in the total amount of production, it can be confirmed again that climate change is a task that requires a wide-area response.

5 Discussion

There are two findings from the analysis results. First, the main impact of climate change is that the increase in production is expected to exceed the decline in quality. Second, the increase in the amount of total production is occurs mainly in eastern Japan; in western Japan, the Koshihikari production value overwhelms or declines over a wide area.

The first finding is confirmed from Table 2. This table summarizes Koshihikari production by climate change scenario and region using a 15% discount rate. In any scenario, production will grow by nearly 15%. In Japan, production of rice has exceeded the demand for 40 years, and the government has carried out a production adjustment intervention. As discussed in Takahashi (2012), the Japanese government has introduced an acreage control program for rice to support the price of rice by subsidizing the production of diverse crops, such as wheat, soybeans, and rice for animal feed. Because of the inelastic demand for rice, the increased production of rice due to climate change will sharply decrease the producer price. The increase in force majeure production due to climate change is likely to further increase the cost of such a price stabilization policy.

The second finding may influence farmers' strategies. The simulation analysis shows that the Eastern area of Japan may benefit from the increased yield with modest quality deterioration, while the Western area may be worse off due to the severe deterioration of quality. Focused on Koshihikari, East Japan farmers may see the increase in yield due to climate change as an opportunity. However, the expansion of production will probably result in a decline in rice price. The government would be forced to strengthen the acreage control.

On the other hand, rice farmers in the Western areas will be likely to give up producing rice and produce crops such as vegetables, fruits, and diverse crops in paddy fields. Koshihikari is no longer a high price crop. Because most of the western area of Japan has a mild climate, there are many areas where vegetables are produced as a rice crop backpack, and production rotations are organized with commodity crops such as fruits. It is possible that such areas will abandon paddy cultivation in paddy fields in the future, and undertake strategies to increase the frequency of use as upland fields.

In such a case, new land improvement investment may be necessary to utilize paddy fields for upland field creation. In Japan, an underground irrigation system called FOEAS, research on technology to control the groundwater level of paddy fields, and their use as upland fields is proceeding. Rather than relying on an expensive pricing stabilization policy, might it be possible that increased land improvement investment can contribute to an increase in farmer's revenue.

6 Conclusions

Our purpose is to accurately predict the effect of climate change on rice production in Japan. In this study, data was obtained by simulating temperature change data for 47 prefectures and the growth function of Koshihikari. The simulation demonstrates a change in the yield and quality of rice in Japan, which was categorized by region.

Intensified surface warming became obvious with an increase of RCPs, showing increases of around 2 ºC for the near future climate. The intensity of global warming corresponded to an increase in rice yield, showing the largest increase in the RCP8.5 scenario (21 %). Although other cultivars than Koshihikari are cropped in the northern Japan, the more increased ratio due to climate change was simulated for Koshihikari than current leading cultivars. The rice quality under historical and near future climate conditions was estimated if Koshihikari is cultivated in all paddy fields across Japan. The rice quality of Koshihikari is high under historical climate conditions, especially in north and northeast Japan while there are regional differences in the effect of climate change. With simulated future yield and quality, we estimated rice production value and found that regional differences in the value would be enlarged because of rice quality decreasing caused by climate change.

The estimated results provide two insights. First, an increase in the quantity of rice yield due to climate change has a stronger economic impact than the decrease in quality even under the future climate conditions scenario with the lowest GHG-emission.

Second, the impact between eastern and western Japan is different. In eastern Japan, the rice yield would increase while in western Japan, quality would deteriorate.

Process-based simulation results differ from conventional statistical inference. While comparing the two, it is necessary to think about meaningful changes and countermeasures. By arranging the data, it is possible to carry out a simulation on a process basis and use it for farming.

In this research, we could not consider the adaptation of agricultural management to climate change, such as appropriate selection of rice varieties. To consider that, it is necessary to carry out similar simulations using other rice varieties by region. In this simulation, we made assumptions to unify the production varieties of each prefecture to the variety with the largest share of production. However, in fact, there are prefectures in which the product varieties are unified, and there are prefectures in which there are multiple influential crop varieties. It will be necessary to change the preconditions of the simulation and consider more precise adaptation measures.

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