WORKSHOP 04

Local Scale Simulations for Growth Diagnosis and Future Projections for Yield and Qualities by Using Various Type of Meteorological Database and Climatological Scenarios

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I. Introduction

Recently high quality rice is one of the major terms of the local economic development of Japan, but the local society strongly depends on their natural resources and are influenced by unusual (extreme) weather and/or climate change. For example, in Japan, influence of high temperature conditions during the ripening period of paddy rice have been frequent and it has already affected not only on yields of rice but also their qualities.

This research aims to provide future projections of rice yields and qualities by using a rice growth and yield projection model, which will help to develop adaptation strategies to avoid high-temperature injuries in Kochi Prefecture, located in the southern part of Shikoku Island of West Japan (Fig. 1). It might also promote and develop local economy, especially in hilly and mountainous regions with complicated topography and various land use. In addition, we introduce current experiment for rice growth diagnosis in situ by using image analysis and the numerical simulation model in view that local farmers have strong demands for the cultivation management, especially before ripening period.

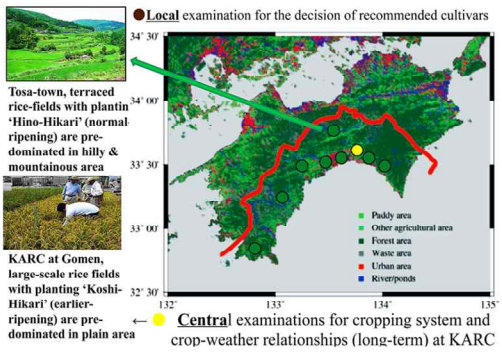

Fig. 1. Location of Kochi Prefecture (right panel), their local examination point for rice growth (yellow and dark circles) and the schematic features of paddy rice cultivation over the region (left two panels).

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II. Materials and Methods

2.1. Outline of the rice model

Current crop-growth simulations are operated using a rice growth and yield projection model (Hasegawa and Horie, 1997; hereafter H/H model). The H/H model has the reputation for incorporating basic responses to temperature and CO_2 conditions and used to estimate recent tendency of rice growth and yield in Kochi Pref. (Hasegawa and Sakata, 2008) and cultivar-based simulation in eastern Japan (Yoshida *et al.*, 2015).

2.2. Framework of simulation

Yield, heading date (is important to control crop management during ripening period), and protein contents (an index of eating quality) for two major cultivars, Koshi-hikari and Hino-hikari (most popular early- and normal- ripening varieties), and one recent recommended cultivars, Nankoku-sodachi (an extra earlier-ripening variety) in Kochi Pref. are currently estimated by using the MeteoCrop-DB (Kuwagata *et al.*, 2011; A crop-meteorological database over Japan) and the prefectural field examinations. The rice model was also run by the various climate change scenarios from the simple 'pseudo warming' data to other various downscaling scenarios based on General Circulation Models (GCMs) by applying Reginal Climate Models (RCMs) and statistical methods. In this text, we emphasized on the results from the pseudo scenario that is added +2°C, +4°C and 90% of solar radiation to observed average for seasonal change with current (recent unusual weather scenarios) and increased CO_2 (2050s and 2090s scenarios) conditions to project future rice growth, yield and quality and to estimate uncertainties for future projections.

III. Results

3.1. Climate change projection

At first, the reproductive simulations for the three cultivars were performed. The example for Koshi-hikari drawn in Fig. 2 showed good agreement with observed data though they grow under different management, soil and climatic conditions at multiple sites. The estimated error indicated by the RMSEs within 4 days for heading date and 80kg/10a for yield, and slight under-estimated (1%) for protein contents. Future projections by using simple warming scenario of them show advanced heading dates of earlier-ripening cultivars, especially under +4°C climate scenarios (Table 1) due to shortening of each growth stage.

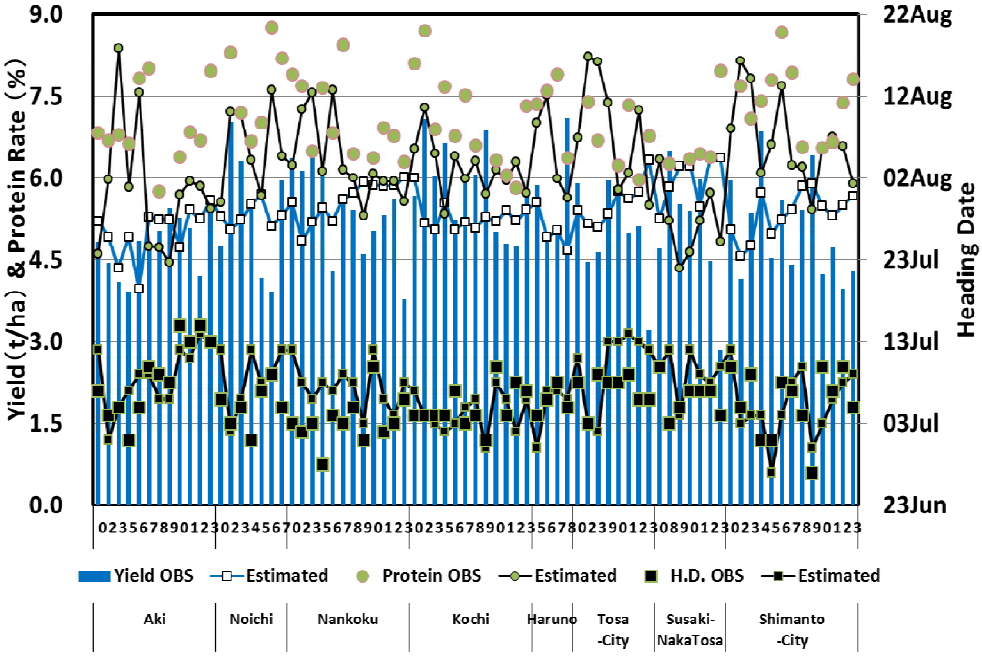

Fig. 2. Model validation and current estimation for Koshi-hikari based on local examination for recommended variety of rice, downscaled meteorological dataset and the H/H model.

The simulation also demonstrates decrease yield (Fig. 3) and increase protein content in recent very hot years, especially for two early ripening varieties, Koshi-hikari and Nankoku-sodachi. Such the effects were relatively small for Hino-hikari, a normal ripening variety.

Table 1. Changes of heading date of various paddy rice cultivars of Kochi Pref.

Cultivars (Ripening Type)	Base Exam. (No. of Sample)	OBS. Average (STD.) days	Projection Err. (RMSE)	+2℃(STD.) days	+4℃(STD.) days
Hino-Hikari (Normal)	Local (41)	19AUG (6.2)	-3.0 (5.0)	- 5.4 (6.0)	- 9.9 (7.0)
	Central (28)	17AUG (3.1)	-2.9 (1.8)	- 5.1 (1.9)	- 9.6 (2.1)
Koshi-Hikari (Earlier)	Local (75)	07JUL (3.4)	+1.4 (4.1)	-10.2 (4.5)	-18.5 (4.8)
	Central (32)	09JUL (15.0)	+4.4 (5.4)	- 9.3 (14.3)	-16.7 (16.8)
Nankoku-Sodachi (Extra-Earlier)	Local (36)	22JUN (3.1)	+1.8 (3.2)	- 8.2 (3.4)	-15.2 (3.6)
	Central (16)	20JUN (2.5)	+5.0 (2.1)	-10.0 (2.7)	-18.7 (3.6)

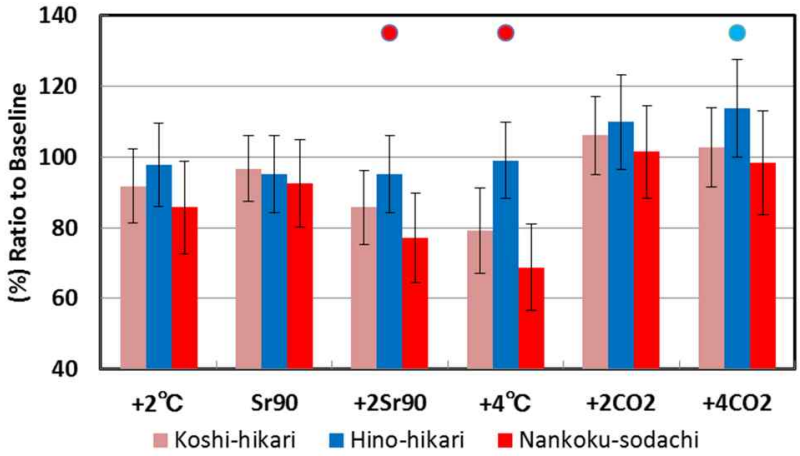

Fig. 3. Future projections for the yields (% ratio to baseline) of three cultivars in Kochi Pref. based on the local experiments. Red (blue) circle shows the significant negative (positive) effect for the yield.

IV. Discussion

4.1. Application for rice growth diagnosis

These results will contribute to develop adaptation strategies, which could possibly promote local industries by improving rice taste (protein contents) and reducing negative impacts of grain appearance quality. The model-based assessment also enables us to offer suggestions such as management of water temperature and application of fertilizers for the higher-quality rice grown in Kochi Pref. In addition, farmers are interested in the crop growth on the current season, more than future projections of crop yield and quality. To establish crop management or adaptation strategy on farmer's and one paddy field scales, we try rice growth diagnostic by using the crop simulation model and the diagnostic images taken by small flight vehicle like a drone (Photo 1). The result from image analysis would be integrated to the output from the rice growth model (Fig. 4).

4.2. Summary and Future Tasks

Current results show the decreasing of yield and increasing of protein rate near future (higher surface air temperature with current CO_2 condition). These results will be contributing to adaptation strategies and are possible to promote local industries from the viewpoint of rice taste (protein contents).

Fig. 4. A preliminary experiment for taking pictures over paddy field by a drone for rice growth diagnosis.

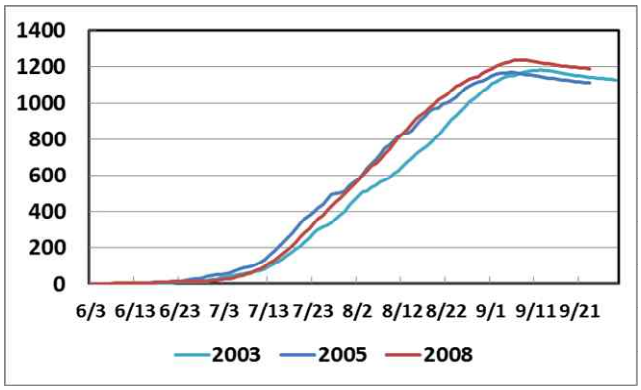

Fig. 5. Preliminary simulation of total dry matter weight of the Koshi-hikari under the current climate condition by using the H/H model.

Future tasks are to estimate uncertainties for future projections by using the various types of climate scenarios. It is also urgent task to simulate for Nikomaru, a rice cultivar with tolerance to high temperature and good taste, which is gradually introduced in hilly and mountainous area for the sales with higher price. Impacts of water resources, pest & disease and extreme events, not only heat wave but also typhoon-associated heavy rain and strong wind are also needed.

Acknowledgements:

This study was financially supported by the 'Research Program on Climate Change Adaptation (RECCA; FY2010-2014)' and the 'Social Implementation Program on Climate Change Adaptation Technology (SI-CAT; FY2015-2019)' of the Ministry of Education, Culture, Sports, Science, and Technology of Japan. The 'Development of technologies for mitigation and adaptation to climate change in agriculture, forestry and fisheries (FY2013-2017)' of the Ministry of Agriculture, Forestry and Fisheries of Japan was also cooperated.

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