

# Climate Change and Anthropogenic Flood/Drought for Agricultural Water Use

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## Abstract

My research group has developed numerical models of distributed water circulation and agricultural production, which incorporate agricultural hydrology and water-use technologies, to support the development and management of basinwide water resources in monsoon Asia. Our success in modeling the complexities of human water use and water management in this region, where paddies are the dominant agricultural land use, has led to the development of a distributed water circulation model incorporating agricultural water use. This model has made possible innovative visualizations of water circulation, which are useful for assessing and predicting how extreme weather events caused by climate change will impact agricultural water use and drainage in low-lying areas; it has also led to proposals of “basinwide irrigation methods” that are based on sparse datasets of basic information such as rainfall and stream discharges. In addition, given the rising probability of abnormally heavy rainfall events in future years, we have developed risk assessment methods related to inundation in low-lying areas that make use of uncertainty evaluations. Our method has attracted strong interest from agricultural insurers and agri-business.

**Keywords:** Visualization, DWCM-AgWU, Extreme Events, Water Footprint, Irrigation, Flooding

## 1. Introduction

Paddy rice cultivation in Monsoon Asian includes not only high productivity, but also sustainable environments. Agricultural water use shares about 70% of the whole water use in the world, and the same goes for it in Monsoon Asia. On the other hand, Monsoon Asia has unique characteristics that varieties coexist, such as i) distinct wet and dry seasons including extremes (droughts and floods), and ii) various types of paddy irrigation and so on. In addition, agricultural practices are human activities, and it is essential to model anthropogenic practices for agricultural water use. In this paper, the first topic is “Modeling and Visualization” of water circulation, especially agricultural water use and the second is application of modeling and its expansion for sustainable strategies to the field of extreme events in agricultural hydrology and water resources research.

## 2. Methods and Materials

It is difficult to grasp the vicissitude of the the water use, but the visualization helps grapple with the routine of inside process.

### 2.1. Development of the DWCM-AgWU model

We selected the Mekong River basin and then the Seki River basin in Japan for the model development. The first process is the modeling of a basin-wide runoff, so called DWCM-AgWU model (Masumoto et al., 2009). In addition, reservoir management by an irrigation dam is modeled. By monitoring the river discharge at a diversion

weir, the dam is controlled to release water for irrigation. Once huge amount of irrigation water is taken from the river, the water is conveyed to the downstream and delivered/allocated

to paddy plots (Figure 1). These processes are all anthropogenic practices. In many runoff models, evapotranspiration (ET) and runoff mechanism are included, but our model features combining agricultural water use in the process, such as modeling of planting/harvesting time and areas, and modeling of paddy water use.

### 2.2. Impact assessment of climate change on agricultural water use by the visualization

The first expansion of the model is related to climate change. The input is data derived from General Circulation Model (so called GCM) after the bias correction. We are able to carry out quantitative approach at any time and space of all the cells. As a result, under various scenarios, we can estimate agricultural intake, planting/harvesting time/area, and so on (Figure 2).

## 3. Results and Discussions

Here are 3 applications and one further expansion.

### 3.1. Application of the model to basin-wide irrigation planning to the areas with scarce data

The first application is a trial to deal with a disordered development due to the lack of fundamental data in Cambodia. According to the civil wars there, hydrological and meteorological data are scarce, so that small ponds were constructed without any reasonable planning. As a result, once heavy rainfall occurred in the area, the dike of a small irrigation pond was destroyed, and it brought about severe damage in the downstream including houses. This type of floods take place every year. We proposed a new technology, so called “basin-wide irrigation planning method (Masumoto et al., 2016).” Our proposal closely relates to the analysis of experiments about

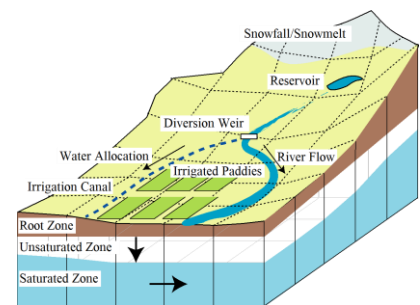


Figure 1. Illustration of the physical basis for the DWCM-AgWU model.

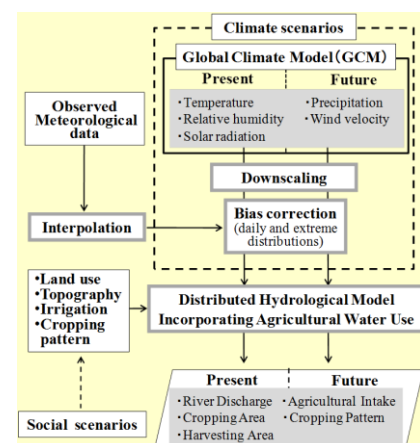


Figure 2. Procedures for evaluating the impact of climate change.

climate change. The input is extracted data from the GCM experiments. Through the assessment method based on our DWCM-AgWU model, we extracted the data at an important diversion weir point, for an example, daily discharges are obtained for 25 years, in the future as well as at present (Figure 3). This long-term daily estimation is regarded as quasi-observation data, and they are utilized for the planning of irrigation facilities.

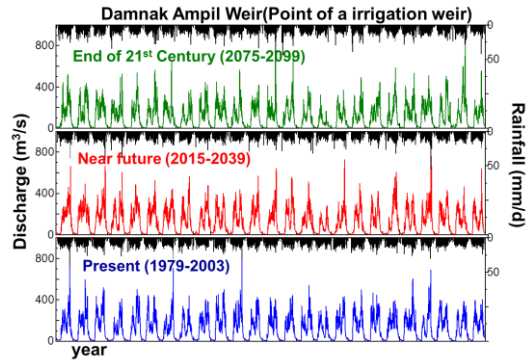


Figure 3. Generation of quasi-observation data for the Damnak Ampil weir on the Pursat River (Cambodia) using the DWCM-AgWU model.

### 3.2. Application of the model to the issues of water rights for agricultural use

It is not viable to estimate through the observations, as the system is too complicated. Yet, the model (DWCM-AgWU Model) provides us with the estimation of relevant water right. The procedure for it goes as follows: 1) Spotting an irrigation area (Figure 4), search for inflow points from residual areas (red circles ○), outflow points (blue circles ○) and; 2) Estimate return flow rate in an irrigation area by discharges calculated by the model. Seen in this example of the Seki River Basin (Yoshida et al., 2016), inflow-points stand at 33, and outflow-points reached 21. Without no doubt, it is impractical to observe all the points except for the model estimation. As for the estimated results of river return flow ratio, especially changes of the yearly values, regardless of the year and the area, they have about 0.5. The ratio is larger than expected, but it could be applicable to any river basin in Japan.

### 3.3. Application of the model to the nationwide map of the climate change impact

We generated nationwide assessment maps for the impact of climate change on agricultural water resources throughout Japan, by using climate scenarios derived from global climate models and the DWCM-AgWU model (Kudo et al., 2017). In addition, the study analyzed the uncertainty of the assessment maps, investigating the ranges of the assessment indices in 11 climate scenarios used. For the assessment of drought discharge, we generated them for two rice growth stages (puddling and heading) that are highly vulnerable to water shortages (Figure 5). The generated maps provide a framework for assessing the impact of climate change on agricultural water resources

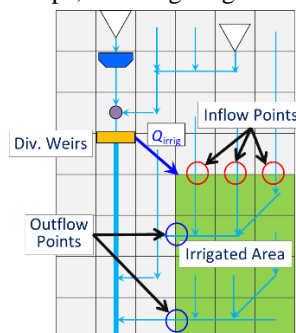


Figure 4. Estimation mechanism of the river return flow ratio.

and reveal the vulnerable regions to it.

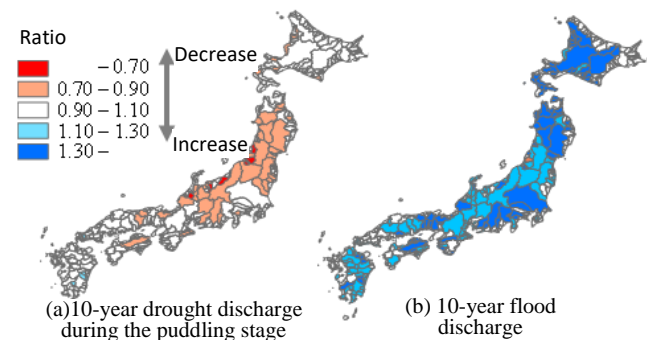


Figure 5. Nationwide maps of climate change impact in the 4.5 RCP scenario.

### 3.4. Further expansion of the model to the damage to rice production and to the agribusiness

We developed a method to evaluate regional drainage risk in low-lying paddy areas and its uncertainty (Minakawa et al., 2018). The results show that the mean value and peak position of the risk distribution increased, indicating that the flood risk would rise in the future. Additionally, the values of the expected shortfall (ES) for rice reduction with more than 50%, 90%, and 99% of each distribution were calculated to characterize each of them. The increase in damage risk was quantitatively evaluated by comparing the ES values with each other: the risk increased in the future and in the higher-order RCP scenario. By using this method, we can quantitatively evaluate the uncertainty of climate risk assessment.

## 4. Conclusions

The topic was elaborated on to tackle climate change and anthropogenic flood/drought problems through the “modeling and visualization” of agricultural water use. In addition, we did not apply our model to those problems by ourselves, but due to big events against agricultural water use occurred one after another, such as food shortage, climate change, energy crisis, and so on.

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