近世日本における大規模水田灌漑地区の渇水リスクの評価
Evaluation of Water Scarcity Risk in a Large Paddy Irrigation Scheme in Pre-Modern Japan

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1. Introduction

Japan's large paddy irrigation management system is universally acknowledged as a successful example of Participatory Irrigation Management (PIM) due to its effective and equitable water distribution by Land Improvement Districts (LIDs) and village communities (Mura).

Most irrigation schemes were established in the pre-modern era despite unstable water resources, but how they managed scarcity remains unclear.

This study explores how pre-modern irrigation has overcome these challenges, using the Okazeki scheme supplied by the Kokai River as a case study.

2. Methods and Materials

2.1 Study Area and Hydrological Settings

The Okazeki Irrigation Scheme was established in 1630 and covers approximately 1,900 hectares of paddy fields. It diverts water from the Kokai River through a weir and currently has a storage capacity of 2.9 million cubic meters.

After its establishment, many irrigation projects were constructed in the region. Some of these projects diverted water from the Kinu River, and the water drained from them was used to increase the water available to the Okazeki Irrigation Scheme.

2-2 How to calculate available water at Kawamata in the pre-modern Era?

The current flow data from the Kawamata measurement station was used as a reference to estimate the available water at Kawamata during the pre-modern era. However, adjustments were necessary to account for differences between current and pre-modern conditions.

First, since there were no reservoirs upstream in the pre-modern era, the influence of present-day stored water needed to be removed from the Kinu River. Second, the development of paddy fields was much less extensive in the past, meaning less drainage water from the Kinu River flowed into the Kokai River. Therefore, the effect of drained water from modern irrigation systems had to be excluded. Third, with fewer paddy fields in the pre-modern era, the amount of water lost through evapotranspiration was also lower. These considerations were incorporated to reconstruct a more accurate estimation of pre-modern water availability at the Kawamata measurement station.

The Okazeki irrigation scheme withdrew water up to the canal's maximum capacity, supplemented by rainfall. A 10-day moving average threshold was applied to assess water scarcity risk, evaluating water availability under three conditions: 20 mm/day, the Japanese irrigation standard; 5 mm/day, the minimum evapotranspiration requirement for rice growth; and July-August is the most critical period for water scarcity effects. During scarcity periods, a one-million cubic-meter reservoir, equivalent to

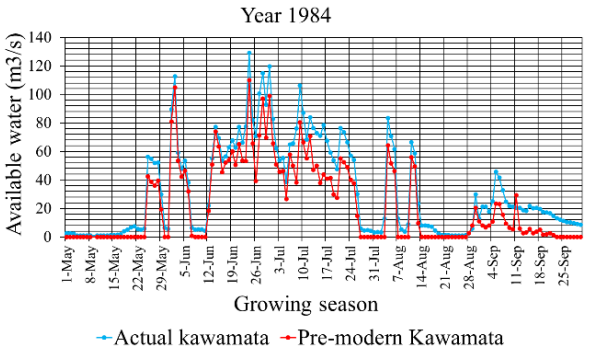

Fig.1 Actual and pre-modern Kawamata flow

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one-third of the current reservoir capacity supplements the water supply.

2.3 Materials

Actual flow data from the Kawamata measurement station were used as a baseline for estimating pre-modern water availability. 農業土木学会編、(1987) has provided insights into the paddy field network system. Rainfall data were obtained from AMeDAS. Previous reports and interviews with Land Improvement District officials were used to validate the network system model.

3. Results

3.1 Kinu-Kokai river system network's change

The hydrology of the Kinu-Kokai River system has changed over time due to infrastructure growth and shifts in agricultural water use.

Initially, water availability at Okazeki depended solely on natural flow and rainfall. After the scheme was built, upstream irrigation projects emerged, and their drained water was added to the supply, reaching Okazeki.

Today, four upstream dam reservoirs have helped regulate flow and reduce seasonal fluctuations, though this has changed the river's natural behavior, as seen in Figure 1. To assess water scarcity risks in the pre-modern era, the analysis excludes the impact of these dams and reflects conditions before large-scale irrigation development.

3.2 Water Scarcity Risk of Okazeki in 1630

The water scarcity risk for the Okazeki Irrigation Scheme in 1630 was assessed using two levels of water demand: 5 mm/day, representing the basic evapotranspiration requirement below which crop damage occurs, and 20 mm/day, the current

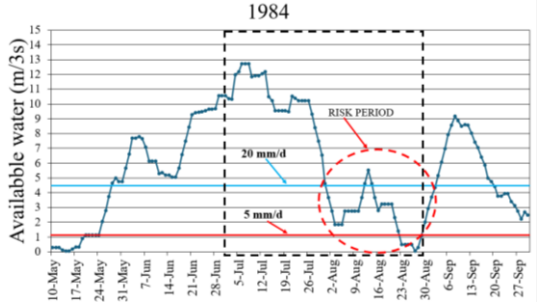

Fig.2 Water Scarcity Risk of Okazeki

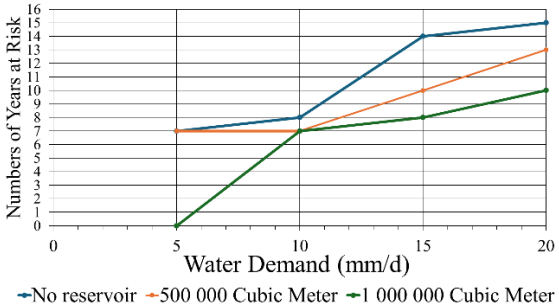

Fig.3 Water scarcity risk frequency

Japanese standard, below which intensive water management becomes necessary, as illustrated in Figure 2. The analysis revealed that water shortages occurred in 7 /16 years at the 5 mm/day level and 15/16 at the 20 mm/day level. With an estimated 1 million cubic meters of reservoir capacity, the Okazeki system could meet the evapotranspiration requirement. However, water shortages would still have occurred in 10/16 years at a 20 mm/day level.

4. Discussions

The evidence suggests that the Okazeki Irrigation Scheme was expanded as much as possible during its early development while focusing on providing a steady 5 mm/day water supply to meet evapotranspiration needs. The irrigated area was kept limited to avoid conflicts and maintain social stability. The priority was fair and reliable water distribution rather than maximizing crop production.

As shown in Figure 3, Okazeki frequently has a water supply close to 10 mm/day, which requires careful and intensive management. Government regulations will likely play a key role in ensuring fair water sharing and the sustainability of the irrigation scheme. These rules would have been essential to the scheme's long-term success and social stability.

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