Long/Short-term Research Visit
2023LS-06

Disaster Prevention Research Institute
Kyoto University

Development of a Flood Inundation Model for Evaluating Paddy Field Dams

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Detailed Flood Inundation Modeling for Paddy Field Dams

1. Purpose

The purpose of this project is to develop a detailed simulation model for flood inundation and drainage for paddy field dams based on unstructured mesh and hydrodynamics method. In addition, by comparing and evaluating the simulation results of the unstructured mesh model with field data and other simple structure models, we analyze the applicability of the model. Finally, to evaluate quantitatively the effect of the paddy field dams on reducing downstream flooding based on the numerical simulations.

2. Summary of Research Progress

In response to frequent heavy rainfall disasters, there is an increasing interest in utilizing paddy fields as an active rainwater storage and flood prevention measure. In Japan, the method is known as "paddy field dams", which involves installing boards in drainage weirs to control water outflow (Figure1). Recent efforts include practical experiments and numerical simulations to evaluate their effectiveness. However, the diverse characteristics of actual paddy fields require detailed hydraulic modeling for accurate impact analysis. This study applied a two-dimensional hydrodynamic model with an unstructured grid to simulate flooding in paddy field dams. The model performance was validated by comparing observed water depth in the field, yielding Nash-Sutcliffe efficiency (NSE) of 0.86. The flood mitigation effect was then quantitatively evaluated under different return periods (20-, 50-, 100-year events).

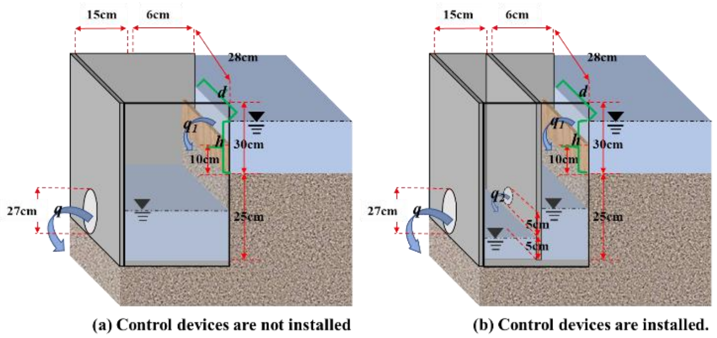


Figure 1 Paddy field drainage system.

Without control device

$$q = E_p \times \sqrt{2g} \times d \times (h - 0.1)^{3/2} \tag{1}$$

With control device

$$q_1 = E_p \times \sqrt{2g} \times d \times (h - 0.1)^{3/2} \tag{2}$$

$$q_2 = C_p \times A \times \sqrt{2g(h + 0.175)} \quad (3)$$

$$q = \min\,(q_1, q_2) \quad (4)$$

Overflow case

$$q = E_p \times \sqrt{2g} \times W \times (h - 0.1)^{3/2} \quad (5)$$

where, EP = 0.22, and Cp=0.65 are the flow coefficient of the weir (orifice) equation, A is the area of the orifice, and g is the gravitational acceleration, W is the width of paddy field block.. Other variables are indicated in Figure 1.

3. Summary of Research Findings

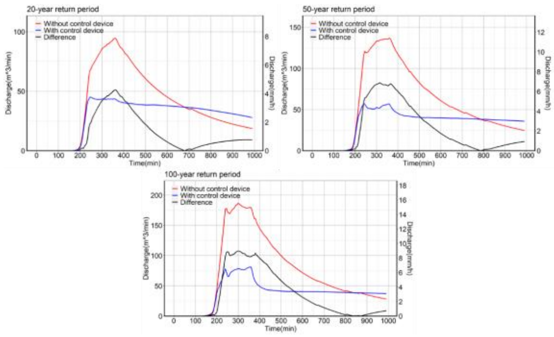
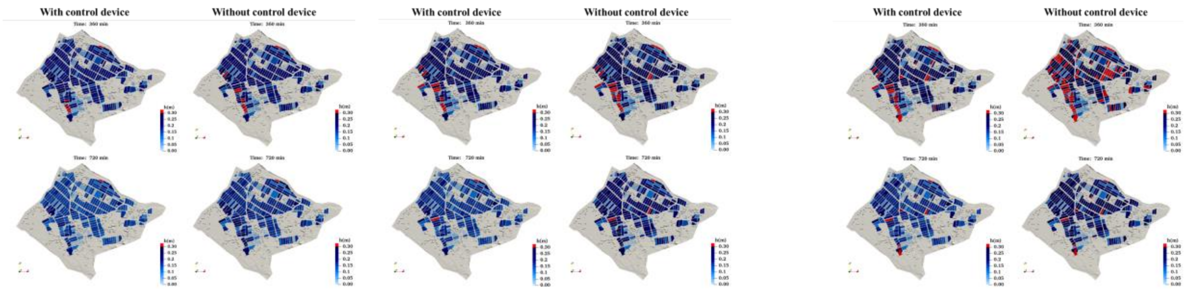


Figure 2 Paddy discharge



20-year return period 50-year return period 100-year return period

Figure 3 Surface inundation with and without runoff control devices.

The results demonstrated that regardless the rainfall return periods, the paddy field dams can reduce peak discharge by over 50 % and effectively slow down the drainage discharge after storm events(Figure 2, Figure 3). Furthermore, a simplified tank model was developed as a conceptual representation to compare against the detailed inundation model. While the simple tank model can capture general patterns, the detailed hydraulic model provides a more realistic representation of the paddy field dam, especially in cases involving inclined topography and variations in paddy size and ridge heights.