APPLYING PADDY FIELD DAM MODEL USING RRI MODEL IN NARUSE RIVER BASIN FOR TYPHOON NO.10 IN 1986

Tohoku University Student Member ○Yikai Chai
Tohoku University Regular Member Yoshiya Touge
Tohoku University Regular Member So Kazama

1. Introduction

Flooding caused by Typhoon is one of the most devastating disasters in the world (Seemanta et al. 2017). In recent year, flood risks are expected to increase in the future, especially Japan which is prone to flooding. Hence, flood-risk assessments in those regions are crucial. The paddy field dam which is low material installation cost and high immediate effect with extensive address, is one of the flood mitigation measures during torrential rains (Miyazu et al. 2012). By artificially enhancing the flood control function of the paddy fields, the rainwater is temporarily stored in the paddy field during torrential rains, and the flood peak discharge of the paddy field is controlled to reduce the disaster.

In order to estimate the degree of inundation in the area affected by flooding, Rainfall-Runoff-Inundation model (RRI) is selected. One of RRI model advantage is the prediction of flood events development by considering the effects of river discharge and floods inundation. Therefore, the purpose is to analyze the flood inundation area caused by typhoon in Naruse River Basin and evaluate flood mitigation effect by paddy field dams installed in entire basin using RRI model.

2. Methodology

2.1 Study Area

For this study, Naruse River Basin in Miyagi Prefecture were selected as target area (Figure 1). In the basin, there are two first-class rivers, the Naruse River with a length of about 89km and converge into the Pacific Ocean with Yoshida River. Geographically, the Naruse River Basin area is approximately 1130km^2, surrounded by forest and hills in north south and west. The land use in the basin is with 22% in paddy fields, 72% mountain and forest, and 6% urban areas.

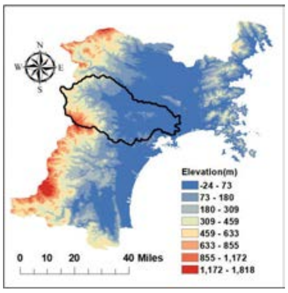


Figure 1. Naruse River Basin and River Bed Slope

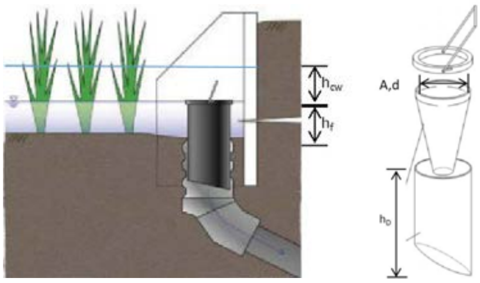


Figure 2. Runoff control device for free drain system (Miyazu et al. 2017)

2.2 Data collection and preparation

The flooding event caused by typhoon is occurred in 1986, this means that the method to obtain rainfall data only base on 12 observation stations in Naruse River Basin. For decrease the uncertainty, according to the one week rainfall data collected from observation station in Miyagi prefecture, interpolate the precipitation in entire Naruse River Basin by IDW and try to generate on hourly rainfall time series for longer. The 3 arc-second resolution DEM data and River discharge data download from USGS HydroSHED were utilized for more accurate representation of the floodplain. Moreover Flow accumulation data modified by ArcGIS.

2.3 Analysis method

2.31 RRI model

RRI model is a two-dimensional model that can simulate rainfall-runoff and inundation simultaneously (Sayama et al., 2012). At a grid cell in which river channel is located, the model assumes that both river and slope are located in the same grid cell and deals with slopes and river channels separately. The channel is discretized as a single line along the center line of the slope grid cell. The flow on a slope grid cell is calculated by the two dimensional diffusion wave model, and the channel flow is calculated by one dimensional diffusion wave model at the same time.

The RRI model equations are derived based on the following (1) mass balance equation and (2) momentum equations for gradually varied unsteady flow:

$$\frac{\partial h}{\partial t}+\frac{\partial q_x}{\partial x}+\frac{\partial q_y}{\partial y}=r-f \quad (1) \qquad \frac{\partial q}{\partial t}+\frac{\partial u q_x}{\partial x}+\frac{\partial v q_x}{\partial y}=-gh\frac{\partial H}{\partial x}-\frac{\tau_x}{\rho_w} \quad (2) \qquad \frac{\tau_x}{\rho_w}=\frac{gn^2 u\sqrt{u_2+v_2}}{h^{1/3}} \quad (3)$$

The second terms of the right side of equations (2) are calculated with Manning's Equations (3). Where h is height of the water from the local surface; q_x, q_y is unit width discharges in x and y directions; r is rainfall intensity; f is infiltration rate; u,v is flow velocity in x and y directions; g is gravitational acceleration; H is height of water from

Keywords: Paddy Field Dam Model, RRI, Naruse River Basin
Contact address: 6-6-06 Aramaki Aza Aoba, Aoba-ku, Sendai, Miyagi, 〒980-0845, Japan, Tohoku University Department of Civil and Environmental Engineering, Hydro-Environment System Lab Tel: 022-795-7455

the datum; τ_x, τ_y is shear stress in x and y directions; ρ_w is density of water; n is manning's roughness parameter.

2.32 Paddy field dam model

According to (Shimura et al, 1982), height of water level in the paddy field depend on the type of grain, and the standard of water level is 5cm. Therefore, we assumed that initial water level is 5cm, and the height of outlet is changed from 5cm to 10cm, 15cm, 20cm, 25cm, 30cm to see the water storage capacity by different outlet height.

Considering the size of orifice, calculate the outflow from runoff control device by using cylindrical weir equation (4) and orifice equation (5) to calculate the outflow from paddy field successively and choose the smaller outflow (Q) as the result (Figure 2). To obtain water level in the paddy field, according to equation (6), the water level of paddy field depend on the rainfall, water reduction depth and outflow from paddy field.

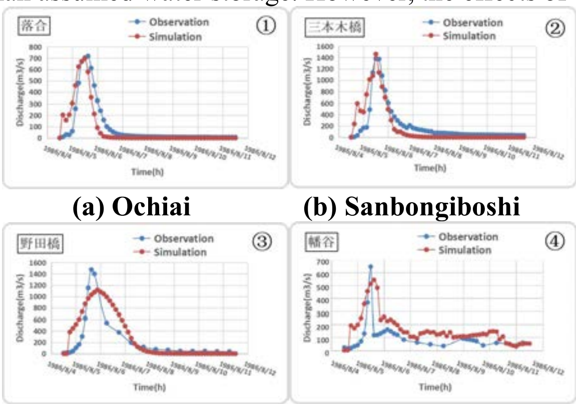
$$q_{PCW} = \sqrt{C_{PCW}\, g d^5 \left(h_{PCW} / d\right)^{1.5}} \quad (4) \qquad q_{\mathrm{PO}} = C_{\mathrm{PO}} A \sqrt{2\mathrm{g}\left(h_{\mathrm{CW}} + h_D\right)} \quad (5) \qquad \frac{dh_P}{dt} = -\frac{q_P}{A_P} + R - L \quad (6)$$

where C_{PO} is flow coefficient of orifice; C_{PCW} is flow coefficient of cylindrical weir; g is gravitational acceleration; h_{CW} *is* height from hole to water level; h_D *is* height of free drain; d *is* diameter of hole; A *is* area of hole; h_P is water level in paddy field; q_P is outflow; A_P is area of paddy field; R is rainfall; L is water reduction depth.

The DEM data resolution is 90 meter and land use resolution is 100 meter. Therefore, we divided the entire basin into many mesh and unit area of paddy field is assumed to be 90X90m and installed one paddy field dam in every paddy field mesh. The parameter of free drain utilized in this study is provided by S17(Miyazu et al. 2017).

3. Result and discussion

Figure 3 shows the result of comparison between observation and simulation data, station *a* and *b* are located in the upstream of river, simulation and observation result are nearly same, station *c* and *d* are located in the downstream of river, the peak discharge of simulation is lower than observation due to the overflow near station *c* and levee broken near station *d*. As shown in figure 4, paddy field dams can drastically reduce inundation volume, and as height of free drain increases, the inundation volume decrease, the flood mitigation effect is better, while storage volume of paddy field is higher than assumed water storage. However, the effects of evaporation and infiltration are currently not considered.



(a) Ochiai **(b) Sanbongiboshi**

(c) Nodaboshi **(d) Hataya**

Figure 3. Comparison of simulation and observation discharge in 4 stations

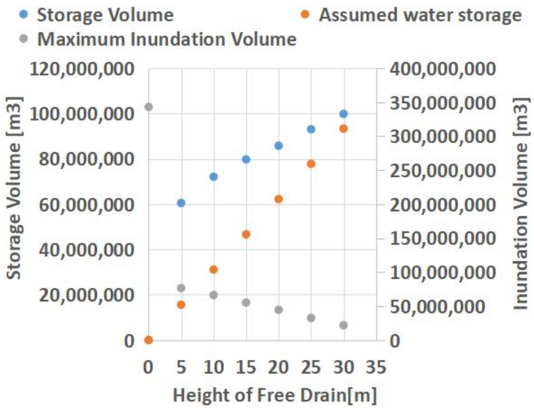


Figure4. Water storage volume in different height of free drain

4. Conclusion

(1)The results simulated by RRI model in 4 observation stations without paddy field dam are similar to observations and government predictions. It means that RRI model can be applied to simulate the inundation effect with paddy field dam.

(2)The flood mitigation effect of paddy field dam is significant, and the higher the height of free drain installed in paddy field is, the more water can be stored in the paddy field, while the smaller the inundation volume in the downstream of the Naruse River Basin.

Acknowledgment

This research was supported by Grants-in-Aid for Scientific Research (A), (16H02363 So Kazama).

References

Seemanta S. Bhagabati and Akiyuki. K., 2017. Consideration of the rainfall runoff inundation (RRI) model flood mapping in a deltaic area of Myanma Hydrological Research Letters Volume 11 Issue 3 Pages 15

Miyazu. M., Yoshikawa, N., Abe, S., Misawa, S., Yasuda, H., 2012. Development and Application of Evaluation Model for Interior Flood Damage Mitigation Effect of a Paddy Field Dam, Transactions of the japanese society of irrigation, drainage and rural engineering, No.282, pp.15~24.

Sayama T., Ozawa G., Kawakami T., Nabesaka S.& Fukami K. Rainfall–runoff–inundation analysis of the 2010 Pakistan flood in the Kabul River basin, Hydrological Sciences Journal, Volume 57, 2012 - Issue 2.

Miyazu S., Yoshikawa N., Abe S., 2017. Development of the Function-independent Runoff Control Device for the Free-drain Drainage System, The Japanese Society of Irrigation, Drainage and Rural Engineering Volume 85 Issue 2 Pages I_159-I_167