Evaluation and Usage of the Flood-retarding Function of Low-lying Paddies in Basin-wide Flood Control

Akihiko Sawata [1*], Shinichi Goto [2], Takao Masumoto [3]

[1] Graduate School of Bioresource Sciences, Akita Prefectural University, Akita, 010-0444, Japan
[2] Nishikanbara Land Improvement District, Niigata, 953-0041, Japan
[3] Faculty of Bioresource Sciences, Akita Prefectural University, Akita, 010-0444, Japan
* Corresponding author. Email: d23g004@akita-pu.ac.jp

Abstract

To evaluate the contribution of rural areas to basin-wide flood control, we propose a method for calculating the storage capacity of paddy fields at the macro scale and examining their potential flood-retarding function. We also compared the economic values of strengthening drainage capacity and utilizing the storage function of paddies through a diagram of the relationship between drainage and storage capacities of paddies in the Nishikanbara region, an urbanized low-lying paddy region, during heavy flooding that exceeds the current drainage design level. We verified that the creation of retarding basins by using the storage function of paddies is an inexpensive and faster measure than strengthening drainage capacity. In addition, the flood-retarding function obtained potentially from low-lying paddies could be used in emergencies for basin-wide flood control.

Keywords: Urbanized low-lying paddies, Flood-storage potential, Flood-retarding Function, Standardized design level, Basin-wide flood control

1. Introduction

Agricultural lands composed mainly of paddies are said to have flood prevention functions and its public aspect has been recognized gradually and evaluated among residents of cities in addition to the drainage function of urban rainwater by the land improvement facilities such as drainage pumps in rural areas. In addition, if we equip land improvement facilities, such as drainage facilities, for disaster prevention functions, those design levels are expanded to 30-50 years of the rainfall return period, although basic levels are usually 10 years for those facilities. Recently, however, rainfall events over those extended design levels have been occurring frequently and it is difficult to catch up with the remarkable controls of regional flooding regardless of basin-wide flood control seen as the introduction and the trial of 'paddy field dam,' which reduces temporarily the peak flood from paddies by farmers. In this paper, in order to examine the concept of basin management in case of the occurrence of heavy rains and to evaluate the flood-storage potentials of paddy areas including land improvement facilities, such as irrigation and drainage canals, we report the results of the estimation of storage capacities of paddies and of economic values of those as an alternative in an urbanized low-lying region.

2. Target Area

The Nishikanbara region is situated in the middle of Niigata Prefecture and extends to three cities and one village, including Niigata City, of which the total basin size is 350km^2 with its main land use of 200km^2 of agricultural lands used mainly for paddies as Japan leading granary. One-third of the total area is below sea level (Figure 1), so the pumping drainage is essential even for the ordinary drainage by the drainage facilities installed by the National 'Nishikanbara' Drainage Project with its total pumping capacity of 529.9m^3/s (the Maximum: Shinkawa Drainage Pumping Station of 240 m^3/s).

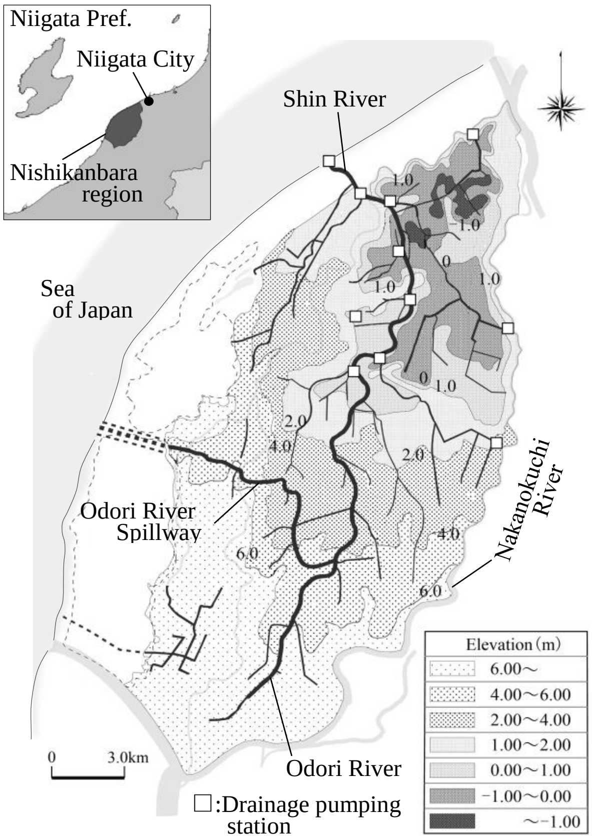

Figure 1. Map of the Nishikanbara region.

3. Methods

Runoff hydrographs to represent a symbolized whole basin are obtained by composing functionalized hydrographs from areas under different types of land use for design rainfall patterns, exponential curve fitting method (Masumoto and Kadoya, 1995). As for the derived runoff hydrograph (Figure 2), the sum of the runoff values above the maximum drainage capacity, *D*, is thought to be the flood volume, which is shown as the hatched area in the figure. Viewing this value at a basin-wide level, as the discharge capacity in the urbanized area would not exceed the maximum conveyance capacity of the river, low-lying paddies including drainage channels and rivers perform flood retarding functions as a buffer to store flooded water. In other words, flood volumes conform to storage capacity, *S*, in Figure 2. That is, the relationship between drainage (conveyance) amount in urban areas and flood prevention

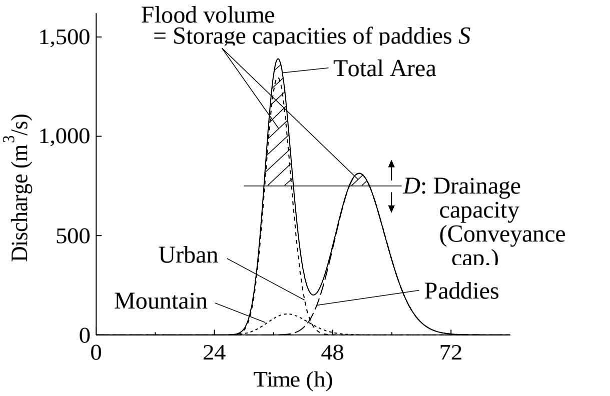

Figure 2. Discharge hydrographs in the Nishikanbara region. (Rainfall of 50-year return period)

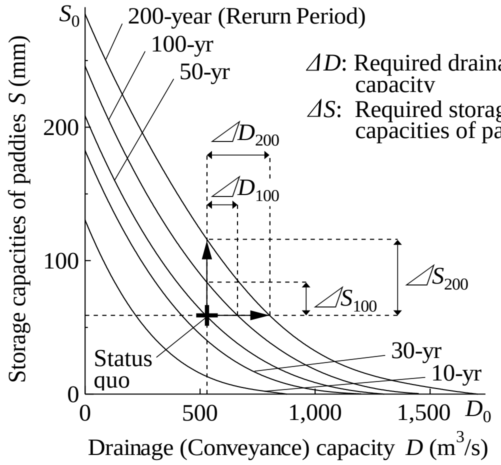

Figure 3. Relationship between the drainage and storage capacities of paddies in the Nishikanbara region

volume in low-lying paddies in the urban neighborhood is rephrased as that between drainage and storage capacities to reduce flooding. The relationship in terms of drainage capacity (D) and storage capacity (S) is expressed as; $S/S_0 = ((D_0 - D)/D_0)^u$, where D_0 (m^3/s) and S_0 (mm) are the maximum drainage and storage capacities, respectively, and u is a parameter of the curve (Masumoto et al., 2006).

Here, if we variously change the value, D, in Figure 2, the relationship between drainage (conveyance) capacity (D) and storage capacity (S) is depicted as a curve, resulting in graphs according to several return periods of design rainfall in Figure 3. Considering the present standardized design level (50-year return period) and drainage capacity of 529.9m^3/s, the plus mark (+) in Figure 3 represents the point of the status quo. At this stage, the storage capacity (S) and its volume evaluate to 59mm (converted in the whole basin size of 34.2km^2) and 20.1x$10^6 m^3$, respectively. In addition, in case of the occurrence of a 50-year probabilistic rainfall event, the design level of this basin allows flood storage on paddy fields. Based on Figure 3, we propose and compare two counter-measures against a rainfall event, which exceeds the present standardized design level (pumping capacity).

4. Results and Discussion

The counter-measures depicted as ΔD100 and ΔD200 in Figure 3, are the measures, called drainage capacity build-up, to maintain the present flood storage capacity by strengthening drainage capacities. When it comes to 100-year probabilistic rainfall, the necessary increments of ΔD100 and ΔD200 are 136.4m^3/s and 281.7m^3/s (Table 1), respectively. If we estimate the necessary construction costs for those increments in view of the National Projects (Total cost: 155.2 Billion Yen, Drainage capacity: 210.8m^3/s) of the past, for instance, we need 100.4 Billion Yen for ΔD100 and 207.4 Billion Yen for ΔD200. On the contrary, the counter-measures delineated as ΔS100 and ΔS200 are the measures, so-called the usage of flood-storage potential, to keep the present drainage capacity by storing floods in paddy areas. Responding to 100-year probabilistic rainfall, the necessary incremental differences are 26mm (storage volume: 8.9x$10^6 m^3$) as ΔS100 and 57mm (19.5x$10^6 m^3$) as ΔS200. If we estimate the necessary construction costs for those increments as storage functions in terms of the cost of a retarding basin construction project in the Kamisekigata Park (Total cost: 1.11 Billion Yen, Storage capacity: 0.409 million m^3), as an example, we need 24.1 Billion Yen for ΔS100 and 24.1 Billion Yen for ΔS200. Although this measure contains extra costs with the park construction, the cost reduces to one-fourth of the drainage capacity build-up measure. In spite of additional increases to maintenance costs in the drainage system improvement, the flood-storage potential usage measure would be an effective and realistic alternative. As a result, the usage of flood-retarding function, which potentially exists already in low-lying paddy areas and is of immediate use, should be introduced as a basin-wide flood control policy provided the agricultural side agrees under the urban side's understanding and support.

Table 1. Results of the evaluation of basin-scale storage in the Nishikanbara region

Measure	Required capacity	Required value			
		D	S		Construction cost
			Depth	Volume	
		(m^3/s)	(mm)	($10^6 m^3$)	(billion yen)
Strengthening drainage capacity	ΔD_{100}	136	—	—	100.4
	ΔD_{200}	282	—	—	207.4
Using the storage function of paddies	ΔS_{100}	—	26	8.9	24.1
	ΔS_{200}	—	57	19.5	52.9

D: Drainage (Conveyance) capacity, S: Storage capacities of paddies

5. Conclusions

The usage of the existing storage function of paddy areas is an effective alternative as a basin-wide flood control measure as well as the introduction of public cost sharing for drainage facility operation (Sawata et al., 2022) in urbanized low-lying paddy areas.

References

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