Contribution to the session "Integrating Physical, Ecological, and Social Perspectives in Watershed Management Through Green Infrastructure" organized by Futoshi Nakamura

Potential evaluation of wetlands for flood risk reduction using rainfall-runoff-inundation numerical model

Évaluation potentielle des zones humides pour la réduction des risques d'inondation à l'aide d'un modèle numérique pluie-débit-inondation

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RÉSUMÉ

L'objectif de cette recherche est d'évaluer quantitativement les effets de contrôle des inondations du Nbs, en particulier le potentiel de contrôle des inondations des rizières, et de proposer une méthode opérationnelle optimale pour le système de dérivation de l'eau de contrôle des inondations. La zone de recherche choisie est le bassin de la rivière Takasaki dans le système de la rivière Inba-numa dans la préfecture de Chiba, au Japon. Le modèle RRI a été appliqué à ce bassin en tant que simulation à l'échelle du bassin. La capacité de stockage de l'eau de chaque rizière a été déterminée à l'aide de données topographiques à intervalles de 5 m et d'un modèle d'écoulement instable en 2D. En ce qui concerne l'optimisation, un algorithme d'évolution complexe mélangé a été adopté pour examiner la méthode d'opération optimale pour les paramètres du modèle hydrologique à l'échelle du bassin versant et le stockage de l'eau dans le yatsu. En conséquence, une méthode d'exploitation optimale a été proposée pour exploiter efficacement plusieurs yatsu et réduire les niveaux d'eau des rivières. À l'avenir, nous prévoyons d'étudier non seulement l'optimisation des effets de contrôle des inondations des yatsu, mais aussi la méthode d'exploitation optimale qui tient compte de l'impact sur l'écosystème.

ABSTRACT

The aim of this research is to quantitatively evaluate the flood control effects of Nbs, specifically the flood control potential of rice paddy fields, and to propose the optimal operational method for the flood control water diversion system. The research area selected was the Takasaki River basin in the Inba-numa River system in Chiba Prefecture, Japan. The RRI model was applied to this basin as a basin-scale simulation. The water storage capacity of individual rice paddies was determined using topographical data at 5 m intervals and a 2D unsteady flow model. With regard to optimization, a shuffled complex evolution algorithm was adopted to examine the optimal operation method for the hydrological model parameters at the catchment scale and the water storage in the wetlands. As a result, an optimal operation method was proposed for efficiently operating multiple wetlands and reducing river water levels. In the future, we plan to consider not only the optimization of the flood control effects of wetlands, but also the optimal operation method that takes into account the impact on the ecosystem.

KEYWORDS

Wetland, water storage potential, optimization, numerical flood model, Flood Control System Operation

Zone humide, potentiel de stockage de l'eau, optimisation, modèle numérique d'inondation, fonctionnement du système de contrôle des inondations.

1 INTRODUCTION

The damage caused by flooding is still increasing in countries around the world, and efficient flood control measures are a matter of concern for the world. Flood control using large-scale hard measures is built into the master plan for river projects, but what is currently attracting attention is flood control using nature-based solutions. This makes it possible to take measures using the natural properties of nature. However, in order to implement these, it is necessary to accurately grasp the extent to which each of these small, dispersed measures has a water storage effect. In addition to the water storage capacity of the wetlands themselves, the timing of when water is drawn in during flooding is an important factor in the flood control effect of wetlands. Because the capacity of wetlands is fixed, it would be ideal to cut off the river flow at the peak of the flood, but it is difficult to time this. Therefore, the purpose of this study is 1) to construct a model that can evaluate the flood control function of multiple Wetlands in the basin while grasping the flood at the basin scale, and 2) to propose an operation that maximizes the flood control effect of Wetlands.

2 METHODOLOGY

2.1 Study area

The Takasaki River in Chiba Prefecture, Japan, was selected. It is part of the Inba-numa system, and there are many wetlands within the river basin (Figure 1)..

2.2 Numerical rainfall runoff model

The Rainfall-Runoff-Inundation model was used for the catchment scale simulation (Sayama, et. al., 2012). It can simulate both rainfall-runoff and inundation, however, rainfall-runoff was only simulated with kinematic wave model. The model used the following input data: (1) the MERIT hydro digital elevation model (DEM) with a resolution of 90 m used for the topographic data2）; (2) the observed rainfall data collected from radar/rain gauge-analyzed (RA) precipitation with hourly observations spanning 48 h; (3) the land-cover map from the MLITT with a resolution of 100 m. In this model, a Manning roughness coefficient value of 0.04 was adopted for the river channel. In the slope area, the values were 0.25, 1.0, and 0.03 for vegetated areas, urban areas, and water bodies, respectively. The soil depth of the vegetated area was assumed to be 0.5 m, whereas that of the other two areas were assumed to be 0 m. The permeability coefficient of the vegetated area was set to 0.18. The verification of the numerical analysis was carried out using the water level data from a Water Level Observation Station.

2.3 Unsteady 2D flow model

We used a two-dimensional unsteady flow model to accurately determine the water storage capacity of the river valley in accordance with the river water level. Topographical data was obtained from GSI data at 5m intervals. Topographical data was created for each wetland, set as the analysis boundary, and the water storage capacity, which changes in accordance with the river water level, was determined.

2.4 Optimisations

The optimization of the height of the water diversion plate and the start time of water diversion for the optimal operation of the model's hydrological parameters and wetlands was carried out using the Shuffled Complex Evolution Algorithm of Duan et al. (1994).

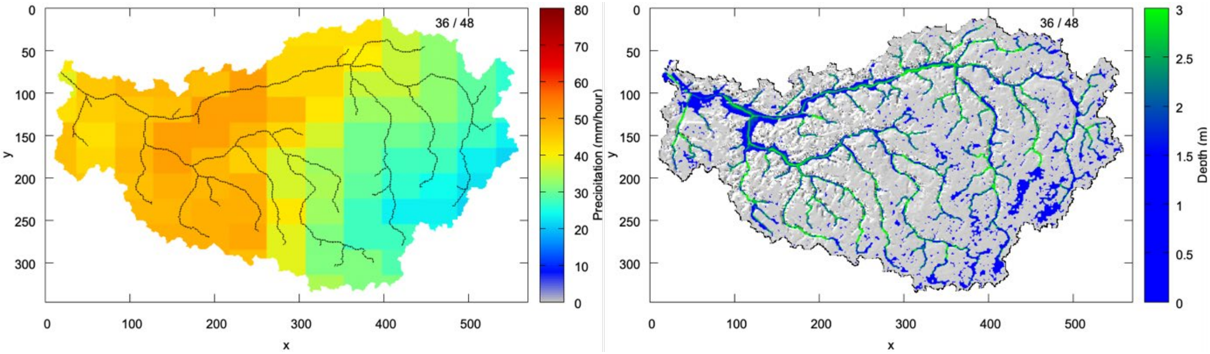

Figure 1. Study area (Takasaki River, Japan, left : Precipitation, right : result of numrical simulation)

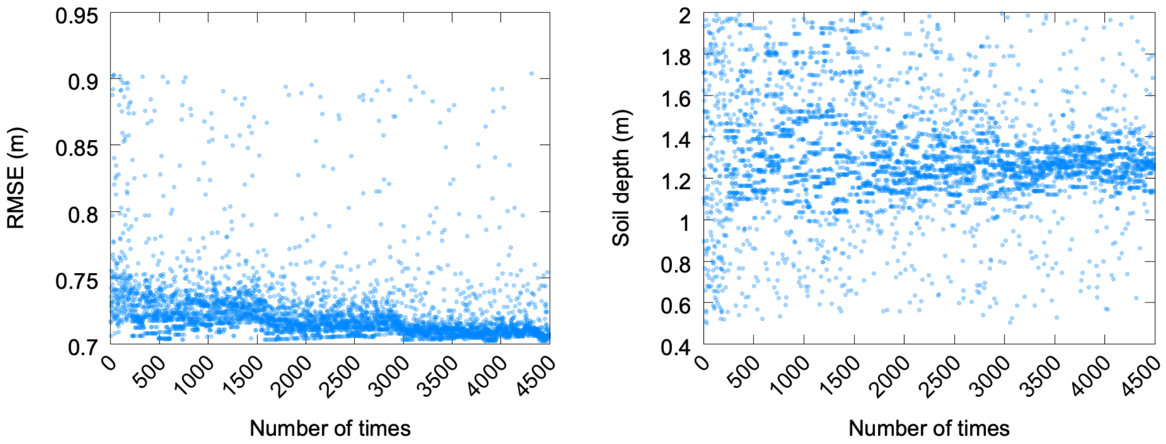

Figure 2. Results of optimization (left: RMSE of river water level, right: solid depth).

3 RESULTS

A system has been developed that can analyze the runoff of rainfall for the entire basin while taking into account the water storage function of wetlands. Figure 1 shows the results of the analysis of rainfall and runoff in the Takasaki River basin. The RRI model is a distributed rainfall-runoff model, and the water depth is calculated for each grid used in the analysis. As there are many wetlands in the Takasaki River basin, the amount of water stored in the wetlands is determined according to the river water level.

The amount of water stored in each wetland according to the river water level was accurately evaluated using a two-dimensional model. When multiple wetlands were used to control the river water level, the interaction between each wetland was quantitatively shown to change the overall performance.

The constructed model optimized the hydrological parameters using the river water levels of past floods (Figure 2). In addition, using the same optimization method, the height of the water diversion plate of the wetland and the start time of water diversion in the case of manual operation were optimized using the reduction rate of the river water level as the objective function. This showed the method of operation that maximizes the reduction of the peak of the river water level by storing water in multiple wetlands in the basin.

4 COCLUSION

We have developed a system that can evaluate the flood control potential of individual wetlands within a series of models for basin-scale rainfall runoff analysis. This system has enabled us to examine the flood control effects of the wetlands as a whole, the design of a water diversion system for effective operation, and the optimization of manual operations for water diversion. In the future, we will use more detailed topographical data to examine the flood control effects of the wetlands in more detail, and consider not only the optimization of the flood control effects of wetlands, but also the optimal operation method that takes into account the impact on the ecosystem.

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