FLOOD HAZARD EVALUATION FOR RIVERS IN TOYAMA PREFECTURE, JAPAN

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ABSTRACT

In Japan, typhoons and frontal rains cause severe water-related disasters almost annually, resulting in considerable damage to human life and property. Although multiple hazard and risk evaluations have been conducted in Japanese rivers, hazard evaluations of smaller rivers and tributaries managed by prefectures are unsatisfactory compared with those of the larger rivers managed by the national government. Several flood-related disasters occur in these small rivers because of insufficient data and risk analysis. This study primarily aims to evaluate the hazards and risks associated with all the rivers in Toyama Prefecture, Japan. In this study, a physical rainfall-runoff was utilized to evaluate flood inundation hazards in Toyama, Japan. For the rainfall runoff simulation, a physical distributed rainfall-runoff model was employed because it can simulate the hortonian overland flow in urban areas and the subsurface flow and saturation overland flow in mountainous areas. Flood inundations were simulated using input rainfall datasets, and the obtained results were compared based on a flood-vulnerability index of the rivers. The analysis showed that small rivers managed by the prefecture exhibited a shortage of capacity flows against large floods. These small rivers can easily be inundated when heavy rainfall occurs in the near future. Therefore, local residents need to be aware of this risk, and appropriate countermeasures should be adopted at the earliest.

Keywords: rainfall runoff simulation, flood, hazard evaluation, Toyama

1. INTRODUCTION

Severe water-related disasters occur in Japan almost yearly due to typhoons and frontal rains; these events often entail evacuation problems. Flood disasters are more likely to happen in small rivers than in large rivers. Because small rivers managed by the prefecture have less hazard evaluations than large rivers managed by the country. In addition, the river hazard map issued by the government is a flood inundation diagram that has caused multiple levee breaks, and it is unknown where the most dangerous. Determining which parts of rivers, including small rivers, are dangerous is important in river disaster prevention.

The main purpose of this study is to identify dangerous places where floods disaster occur among Toyama rivers including small rivers.

In this study, we created a dataset to calculate rainfall runoff for all rivers in Toyama Prefecture. Flood vulnerability was evaluated by comparing runoff rates, overflow, erosion and infiltration risks from the results of rainfall runoff calculations.

2. AREA OF STUDY

Toyama Prefecture is located in the central part of Honshu Island, Japan, as shown in **Figure 1**. Five main rivers named Jinzu River, Jouganji River, Kurobe River, Shou River, and Oyabe River flow into Toyama, and they are managed by the Japanese government as class A rivers. The study also focuses on some smaller rivers managed by the Toyama Prefecture as class B rivers, as depicted in **Figure 1**. Jinzu River, which is the largest, has a catchment area of 2,720 km^2 and river length of 120 km.

It should be emphasized that these rivers in Toyama have very steep channels. For example, the average river bed gradient in Jinzu River is about 1/50. Due to these steep river segments, flooding due to river-bank scouring and erosion are to be considered one of the most significant flood risks in Toyama.

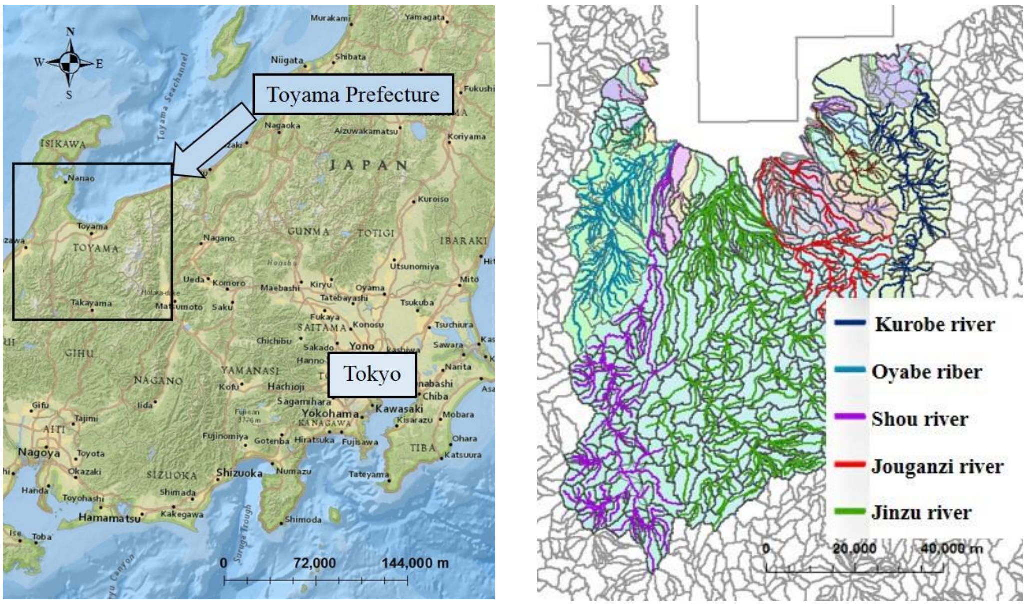

Figure 1. Location of Toyama Prefecture (left), and target rivers (right)

3. METHODOLOGY

3.1 Flood inundation model

For the rainfall runoff simulation, a physical rainfall-runoff model (Kure and Yamada, 2004, Kure et al., 2008, Moe et al., 2016a,b, 2017, Priyambodoho et al., 2018) was employed because it can simulate Hortonian overland flow in urban areas and, subsurface and saturation overland flows in mountainous areas, depending on the relationship between the soil and geological characteristics and the intensity of rainfall on a hill slope.

Reanalysis rainfall data based on radar and ground observation data provided by the Japan Meteorological Agency were used as input data for the simulation. The soil parameters used in the simulation were calibrated based on five land cover classes: forest, cropland, paddy field, urban area, and water body in the target area. The model calibration was conducted in the Kurobe River basin based on trial and error comparison of the observation and simulation results. The calibrated parameters are listed in **Table 1**.

For the conservation of continuity and momentum, Saint-Venant equations were used to model flood routing in the rivers and drainage. Manning's roughness coefficients of the river beds were set from 0.03 to 0.05 for river sections based on the results of our calibration.

Table 1. Model parameters and calibrated values

	Urban area	Paddy field	Water body	Forest	cropland
Soil depth [mm]	5	100	50	200	5
effective porosity	0.1	0.3	0.2	0.4	0.1
Saturated hydraulic conductivity[mm/h]	5	170	130	270	5
Surface roughness	0.04	0.03	0.03	0.05	0.03
Runoff coefficient	0.8	0.2	1	0.5	0.3

3.2 Dataset

A digital evaluation model (DEM), which is a raster dataset containing information about the topography of a region, and the J-FlowDir dataset (Yamazaki et al., 2018), was used in this study. Its spatial resolution is approximately 30 m, as presented in **Figure 2**.

The cross-section data for the rivers and drainage system in the target area were provided by the Toyama Office of River and National Highway, Ministry of Land, Infrastructure, Transport and

Tourism (MLIT). River networks, sub-basin, and land use/cover information were downloaded in GIS formats from the Geospatial Information Authority of Japan, MLIT. The land use/cover information is based on 12 land classifications, but the authors re-classified the land use into five classes for ease of model calibration, as depicted in **Figure 3.**

River discharge data for Toyama Prefecture was collected from the Water Information System and MLIT

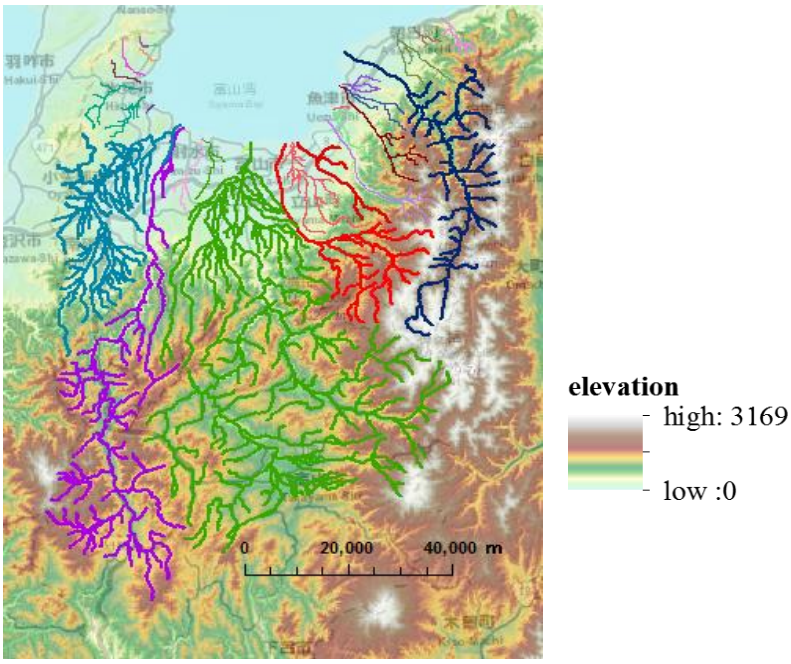

Figure 2. DEM (J-FlowDir) around study area

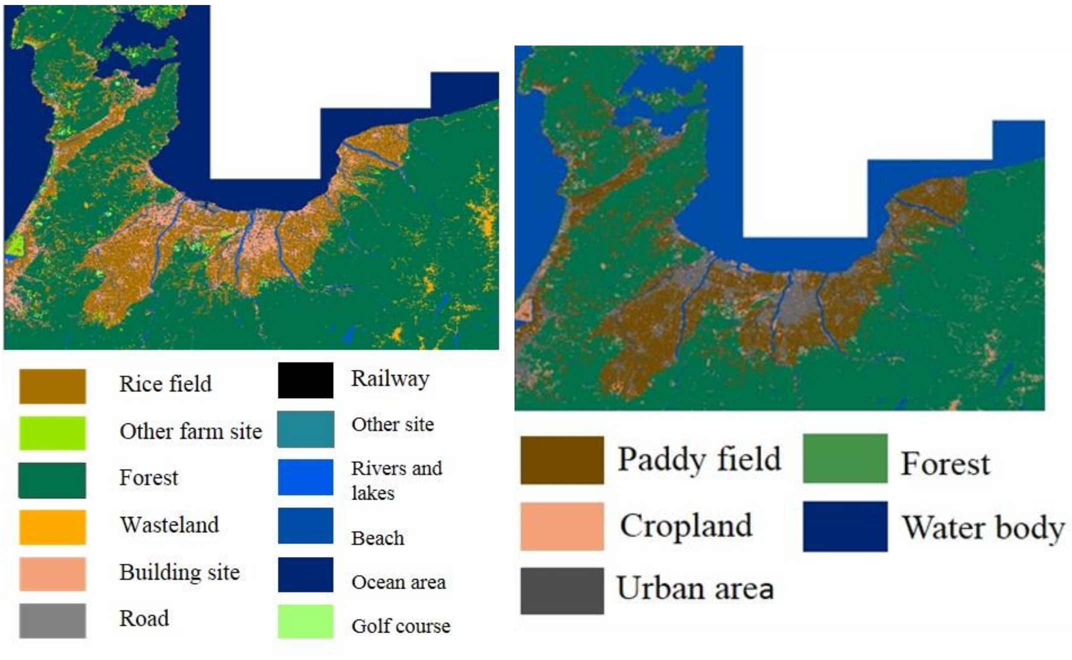

Figure 3. Land use/cover map around the study area (left: 12 class, right: 5 class)

4. RESULT

The calibrated model was applied to the other rivers for the flood event in 2015. This flood event was selected as the target, because observed river discharge data on the many rivers are available. **Figure 4** and **5** show the comparisons between the simulated and observed discharge hydrographs of the Kurobe and Oyabe Rivers as an example of the results. The simulated discharge was calculated based on the input of the reanalysis rainfall data. The simulation results matched the observed discharge reasonably. However, the simulation result in the Oyabe River, as shown in **Figure 5**, exhibits over estimation compared to the observation discharge. This is because there are many paddy fields and crop lands in the Oyabe River basin, and these areas were not taken into account in the rainfall runoff model used in this study. We need to improve the model to accommodate the paddy field and crop land for future studies in order to obtain better simulation results.

Additionally, simulations were conducted against small rivers managed by the prefecture as Class B. **Figure 6** shows a simulated discharge hydrograph of the Shiraiwa River, as we could not obtain the discharge data of these rivers. Therefore, **Figure 6** only shows the simulated discharge and rainfall data.

As the first step of the hazard evaluation of the rivers, five large rivers (Class A) and four small rivers (Class B) were selected as shown in **Figure 7**, and the same rainfall data were used as the input data to the model in all basins, and the specific peak discharge was calculated and compared at each basin. These four small rivers were selected because among the small rivers in Toyama, the basin area was relatively large. **Table 2** lists the comparisons of the specific peak discharge in all the target rivers. The values in the small rivers were found to be higher than those in the large rivers. From this result, it may be concluded that small rivers are more likely to be affected by floods even at the same level of rainfall.

These small rivers may easily be inundated when heavy rainfall occurs in the near future. Therefore, local population should be made aware of this risk, and the counter measures against the aforementioned risk for these small rivers should be taken into account as soon as possible.

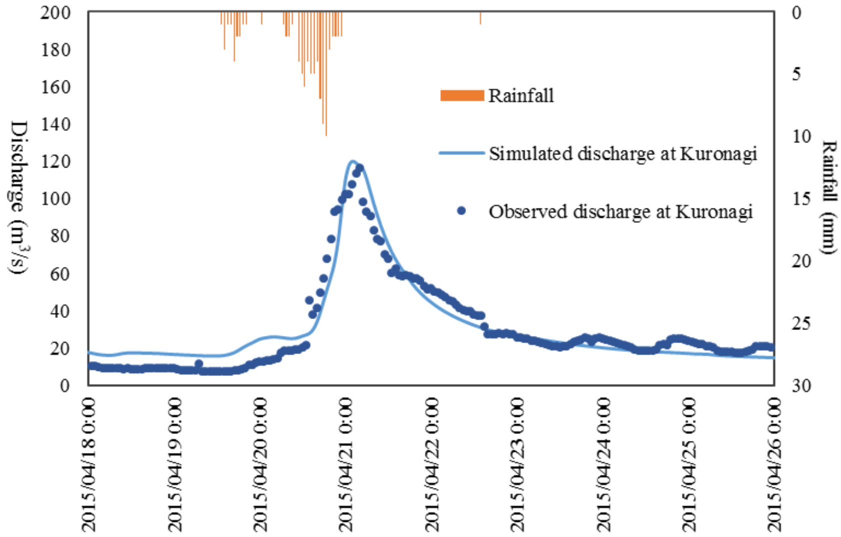

Figure 4. Comparisons between simulated and observed river discharge of the Kurobe river

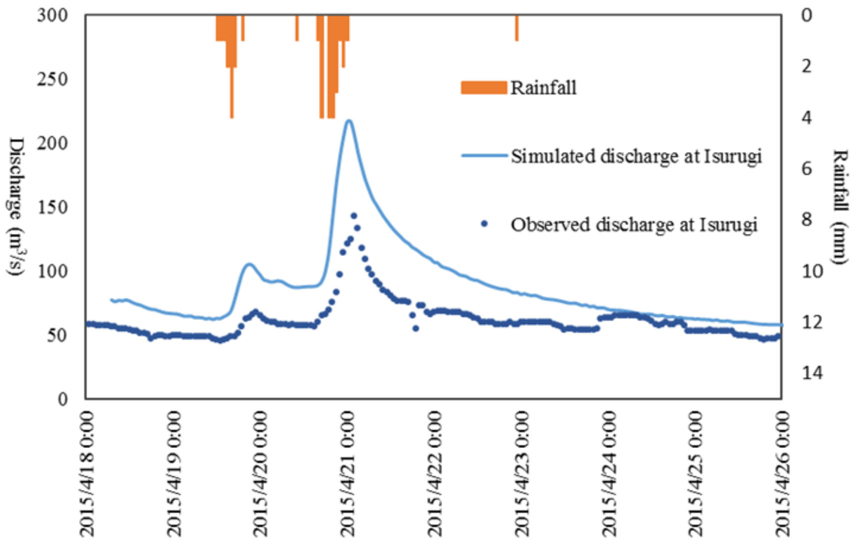

Figure 5. Comparisons between simulated and observed river discharge of the Oyabe river

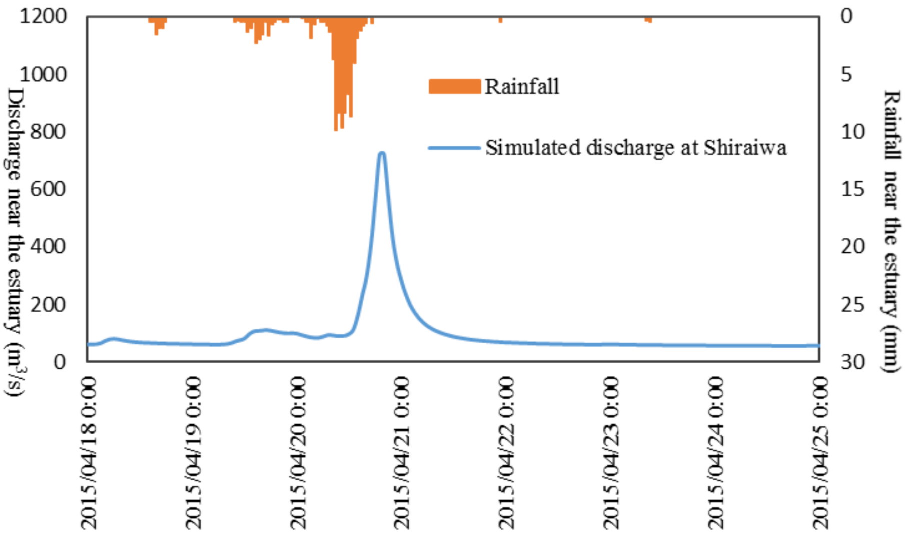

Figure 6. Simulated discharge at Shiraiwa river using model parameters

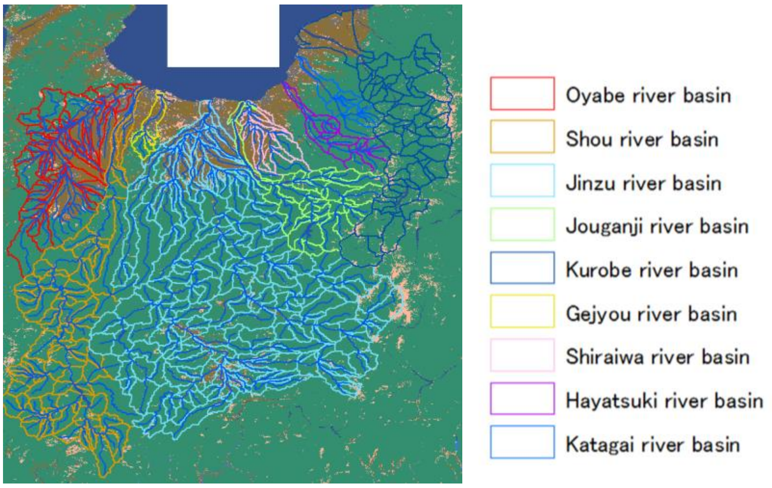

Figure7. 9 river basins in comparison

Table2. Specific peak discharge in Toyama rivers

River Class	River Name	Specific Peak Discharge [$m^3/s/km^2$]
A	**Kurobe river**	1.53
A	**Jouganji river**	1.30
A	**Jinzu river**	0.97
A	**Shou river**	1.00
A	**Oyabe river**	1.64
B	**Gejou river**	3.89
B	**Shiraiwa river**	1.40
B	**Hayatsuki river**	3.64
B	**Katagai river**	3.09

5. CONCLUSION

In this study, a physical rainfall-runoff was applied to rivers in Toyama Prefecture, and the characteristics and flood hazard of rivers were investigated.

The information and datasets necessary for the flood simulations were collected and integrated into the model. Our validation results, based on a comparison between the observed and simulated river flow discharge at several stations, confirmed that the applied model performs efficiently. However, the model needs to be improved to accommodate rainfall runoff processes in the paddy field and cropland areas to obtain significantly better simulation results.

The study found that small rivers are more at risk than large rivers. However, the part of the river with high risk zones and segments is still unknown. In the presentation, high risk points based on the flood vulnerability index of the rivers were related to the river embankment overflow, infiltration, and erosion due to high and fast flows during the flood event. The flood hazard evaluation for rivers in Toyama is conducted this way.

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