ESTIMATING THE DAMAGED HOUSES CAUSED BY TYPHOON HAGIBIS IN OCTOBER, 2019 USING AERIAL PHOTOGRAPHS IN THE CHIKUMA RIVER BASIN, JAPAN

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ABSTRACT: A flood often causes huge damage to human lives and properties. Strong typhoons and localized heavy rainfalls hit Japan during summer and autumn, and thousands of houses often inundated. It takes a long time to investigate the situation of damaged houses by local authorities. Therefore, we proposed the method to estimate flood extent and depth using aerial photographs. Although aerial photographs have the limitation that cannot be used in nighttime and bad weather, they can catch the clear situation of flood damage when an aerial photograph is taken timely. We applied the method to estimate the flood damage at northeastern Nagano City in the Chikuma River Basin. We also evaluated the damage by flood simulation. Then we compared the results with those of the flood trace survey by an academic research team and Nagano City. The result shows the proposed method using aerial photographs and DEM (Digital Elevation Model) is useful in estimating the depth of inundated houses. The difference between the method using aerial photographs (1,479 inundated houses) and the method using the flood trace survey by the academic research team (1,495 inundated houses) was 1.1 %. Furthermore, the proportion of the number of houses by inundation depth with using the proposed method was similar to that of the flood trace survey. Therefore, this method would contribute to reducing the load of local authorities.

1. BACKGROUND

When it comes rainfall season in Japan everywhere, the water quantity overflowing flood risk water level flows river channels and an overflowing or breaking levees have happening if levees are reinforced. Damages caused by river flooding have occured every year in urban areas. About 4,000 houses are flooded and broken with causing breaking the levee of Chikuma river in Nagano city, Nagano prefecture on October, 2019. Then many flooded news are reported. About 4,600 houses are flooded by breaking Kuma river in Hitoyoshi city and Kuma village in Kumamoto prefecture on July, 2020 and about 3,300 houses are flooded by breaking Rokkaku river in Takeo city Omachi town in Saga prefecture on August, 2021. On the other hand, to know damaged situation by flood disaster, water hazard statistic survey (normal properties damage, public civil building damage, public profit damage) are conducted every year and are opened on the web site E-stat which it collect various statistic information of Japan. The case of the investigation of normal properties damage, although local authorities which are damaged have to investigate the situations and count them, they need much time and human effort to investigate thousands of houses when extensive flooding events happen. It is essential to grasp the real situation rapidly. Geospatial information authority of Japan (GSI) has opened the map of flooded estimation for grasping flood extent and depth emergency after flood disasters happened. As other way of grasping flood extent, there are the way of using SAR (Sythetic Aperture Radar) images and SNS (Social Networking Service) images. However, the water hazard statistic survey in Japan have not been harnessing these remote sensing technologies. The flooded local authorities have taken a long time for the investigation and they have heavy loads. In this study, we conducted that the way of investigation the number of flooded houses preciously, easily and rapidly.

2. METHOD

The research object area is Northen and eastern Nagano city, Nagano prefecture, Japan. The city is hit by flooding Chikuma river and Tyhoon Hagibis on October 13th, 2019. We confirmed 18 points boundaries between inundatiton area and non-inundation area from the aerial photograph taken by GSI on October 13th AM 12 o'clock. Also, we utilized DEM on opening GSI web site. The DEM accuracy is ±0.3m relative to the vertical direction. After this, we call grand level plus flood depth a flooded water level. First, we got many flooded water levels from the photographs. Second, we regard the average water level as the standard value of flooded house estimation. Finally, we found that there are 1737 flooded houses in the flood extent. Besides, we compared among the way of inundation simulation, the way of flood trace survey and Nagano city official disaster report and confirmed the accuracy of the estimation results. We showed the image of flood depth estimation in Figure 1.

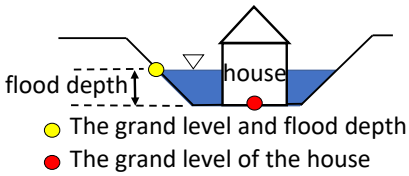

Figure 1. The image of the estimation of flood depth with aerial photographs.

2.1 Figure out water level from the aerial photographs and DEM

We confirmed 18 points water level which is the boundary between inundation water level and non-inundation water level with aerial photographs the peaking of flood depth flooding Chikuma river (Figure2. a, b). We show No4 and No18 examples of the boundary in Figure 2 (c, d). The boundary is identified with the basis of around buildings and roads. The red polygon and yellow × sign show flood extent and broken levee point respectively. It assumes that surface water slope is nothing and regard the boundary water level as average 334.2m is average water level. As whether there are houses inside flood extent and the positional information, we confirmed each house with optical satellite image on October 27th 2015 by Google earth Pro.

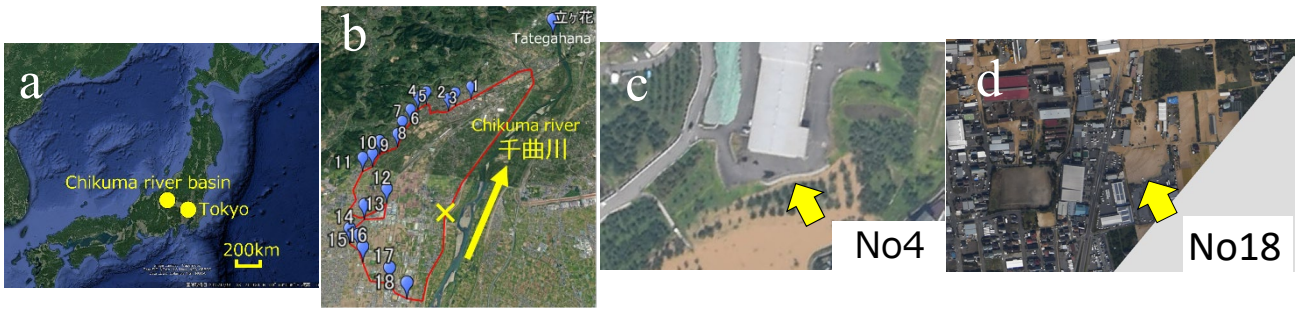

Figure 2. (a)The location of Chikuma river, (b)The 18 points boundaries and flood exetent estimation, (c, d)the boundaries of inundation area photo No4 and No18.

2.2 Inundation simulation

We conducted the calculation of unsteady two dimensional flows with inundation simulation software, iRIC (International River Interface cooperative) for estimating flood extent and depth. The calculation time is from PM 6 o'clock 12, October to PM 3 o'clock 13, October 2019, 21 hours. It is estimated that the biggest water quantity is 8300 m^3/s recording at AM4 13, October 2019 and we made hydro graph from the datum of the database of Hydro quality in Tategahana water level and water quantity measurement point. Then, the calculation mesh size is set 20m × 20m and the mesh numbers are 400 × 376. Next, the broken levee point is set at Chikuma river left side 57k because of the flood causing broken levee. The broken levee length is 80m and the broken levee width is 20m. We only gave the quantity main flow of Chikuma river to the inflow point of the calculation without considering the quantity of tributary flow Asakawa river and no precipitation. The roughness coefficients are reiver bed 0.03 and urban area 0.05. We show that Figure 4 is the flood extent and depth of the simulation result. The result shows that the biggest flood depth (m) display 50cm pitch and two dimensional contour lines, and the flood depth of the tributary near Asakawa river is deeper than near Chikuma river. The depth show yellow or red color 4.0m or 5.0m more over. The result is similar to the emergency estimation of the GSI (Figure 5).

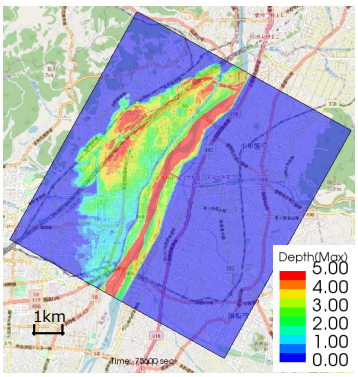

Figure 4. The result of inundation simulation in Chikuma river

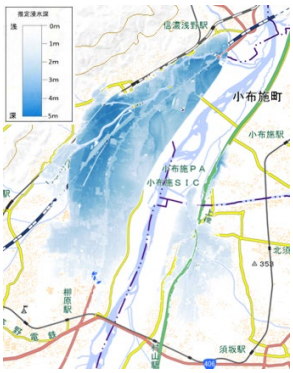

Figure 5. The estimation of the GSI

2.3 Flood trace survey

In this study, we confirmed flood depth of each 1737 damaged houses in the flood estimation extent in northern and eastern Nagano city referring to the report of Committee on Hydroscience and Hydro engineering team in Hagibis investigation. Also, we confirmed water level for the boundary of the flood depth against the distance from standard point of measuring Tategahana point to compare the boundary with the aerial photographs.

2.4 The comparison of damaged houses

The results are showed by Table 1 and Figure 6 comparing among the way of aerial photographs, the way of inundation simulation, the way of flood depth survey and Nagano city disaster report respectively. The water disaster statistic survey is separaded the damage level as 6 segmentations. They are flood below floor level, flood above floor level (1-49cm, 50-99cm and 1m above), half collapse and total collapse. In this study, the flood depth estimations with DEM are grouped in 6 segmentations and analysed. They are 0-0.49m, 0.50-0.99m, 1.00-1.49m, 1.50-1.99m, 2.00-2.49m and 2.50m above. Also, the object area is Naganuma, Toyono and Furusato district in Northen and Eastern Nagano city in Nagano city disaster report. Their places equal to the object areas of this study. The total damaged houses are counted aerial photographs -1.1%, inundation simulation +16.2% and Nagano city disaster report +11.4% respectively comparing flood trace survey measuring value. Comparing flood trace survey and the way of aerial photographs, it has a near trend not only total damaged houses but also each flood segmentation by Figure 6. And the total damaged houses in the way of inundation simulation is the biggest in the comparison objects. Next, we show the relationship among the each way of water level and the distance from the standard point, Tategahana to the boundary water level in Figure 7. The way of aerial photograph and the way of flood trace survey is close because it is within 30cm 10 out of 18 points, and the difference of average water level is within 20 cm. On the other hand, the way of inundation simulation is more than 2m away with the way of aerial photograph at 4th point from downstream and 2 points upstream side.

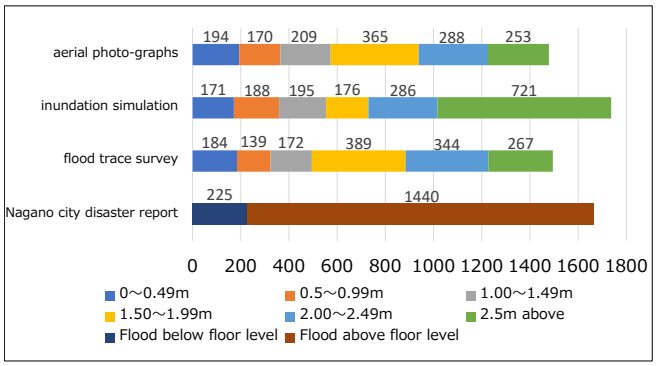

Figure 6. The comparison of the damaged houses total count

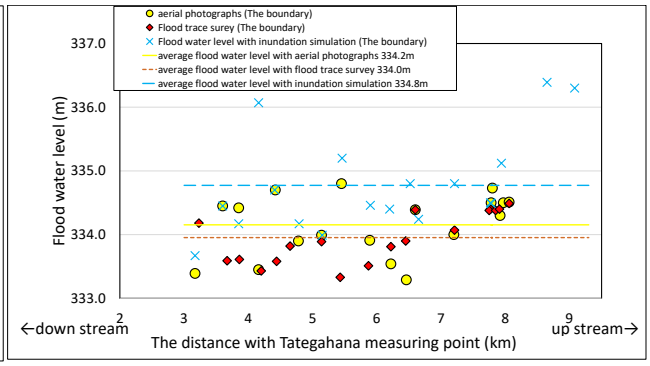

Figure 7. The comparison of the every method water level

3. DISCUSSION

With regard to the estimation of the number of damaged houses, although we confirmed that total damaged houses estimation is worked well and found that the difference is 1.1% with the comparison between aerial photographs and flood trace survey, the most effective factor is utilizing the aerial photographs pictured the nearest peak of flood depth. Afterall, it should be confirmed that whether photographs are able to utilize with bad situations in similar research. Furthermore, as confirming each flood depth segmentations in Figure 6, there are each 20 % differences between 50-99cm, 1.00-1.50m and 2.00-2.49m with flood trace survey. For the reason, we considered that the way of aerial

photographs is used average water level with no water surface grade when it is made out flood depth estimation, but the value of flood trace survey is used another water level every location of the house. Also, this 1.1% difference includes the DEM accuracy ± 0.3m. Hence, in the range of the DEM accuracy, we had might included that no flood depth houses regard as flooded houses in 0-0.49m and regard flooded houses as no flooded houses. However, the way of aerial photographs is effective approach for grasping water disaster situation rapidly and easily even if we consider this point.

Besides, when a hazard is happened, because local authorities have to issue official disaster certification for people damaged houses, they have difficult situation of investigating each house. Therefore, it is not easy to match the estimation of total damaged houses with disaster certifications, but we confirmed that the disaster situation is grasped easily using aerial photographs and an inundation simulation.

4. CONCLUSION

We found that the difference is 1.1% comparing between the way of aerial photographs and flood trace survey. Identifying the boundary of flood extent from aerial photographs and counting the number of total damaged houses from average water level are effective approach for grasping flood disaster situations. Both the way of aerial photographs and flood trace survey have about 10% difference with Nagano city disaster report. That is the limit of easier estimation in this approach. With regard to the way of inundation simulation, although we made a hydro graph from measured water quantities, it is bigger than flood trace survey as a result.

Table 1. The comparison of the damaged houses counts estimation

The way	Aerial photo-graphs	Inundation simulation	Flood trace survey	Nagano city disaster report
The total number of damaged house	1479	1737	1495	1665
comparison with flood trace survey (%)	98.9	116.2	100	111.4
difference (%)	-1.1	16.2	-	11.4
comparison with Nagano city disaster report(%)	88.8	104.3	89.8	100
difference (%)	-11.2	4.3	-10.2	-

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