C211

Evaluating the Effects of Rainfall Control on Runoff and Inundation in Catchments on Kyushu Island Using Simulated Rainfall Scenarios

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Introduction

Extreme short-term rainfall events, such as guerrilla rainstorms and line-shaped convective rainfall, have increasingly caused water-related disasters. To mitigate flooding, governments have built protective infrastructure like dikes, reservoirs, and improved drainage systems. However, climate change has intensified rainfall frequency and severity, challenging existing measures.

Traditional flood prevention methods are costly and time-consuming. As a complementary solution, rainfall control methods are gaining attention. These include altering wind patterns with green energy projects like wind turbines or using cloud seeding techniques to condense water vapor preemptively.

This study investigates rainfall-runoff dynamics under rainfall control scenarios. Using the 1-D kinematic wave model (1K-DHM) and the Inundation Model Coupled with the Rainfall-Runoff Model, we simulated controlled rainfall events in the Kurokawa River catchment, Kyushu. Results show that reducing rainfall by 8% decreases peak discharge by 19.31%–29.84% and shrinks inundation areas by 16.02%–24.99%. Simulations of historical extreme rainfall using similar reduction ratios suggest that rainfall control could significantly mitigate flooding impacts, demonstrating its potential to protect local communities.

Methodology

In this study, we simulated the inundation area using IMCR, which integrates local inertial equations for one-dimensional (1-D) river flow and two-dimensional (2-D) overflow modules. River discharge input was simulated using the 1-D kinematic wave model, 1K-DHM. The study area, shown in **Fig.1**, focused on the Kurokawa River in the Shirakawa River Basin, located in the Kyushu region, which was selected due to its significant impact from linear-shaped heavy rainfall events. Rainfall control events were simulated using the seeding core method based on the 2020 heavy rainfall event. Due to the limited number of case studies, we modified the rainfall latitude and longitude to create ensemble experiments. Table 1 shows the decreasing rate and the total decrease in catchment-average rainfall. The modified cases are named based on the number of grid shifts to the north (N) and east (E). The shifting distances are 0.031 degrees to the north and 0.0266 degrees to the east. Modified historical events were created using radar/rain Gauges. Data from the 2012 heavy rainfall event on the Kurokawa River were analyzed.

Results and Discussions

The inundation change results for scenario N7E4 and historical cases are shown in Figures 2 and 3. The inundation depths were based on the Ministry of Land, Infrastructure, Transport, and Tourism report. The results indicate an approximately 8% reduction in total rainfall can decrease the total inundation area by 17% using the seed core method. In contrast, applying a uniform reduction ratio to each hourly rainfall event based on historical data results in only a 1% decrease in the total inundation area. This smaller reduction may be due to the spatial variation of rainfall and its pattern, which significantly influence the inundation process.

When examining the decreasing rate of each water level due to rainfall control, it is clear that, although the total inundation area may not decrease significantly, the area with higher depths (over 1 m) shows a much greater reduction ratio across all scenarios.

Conclusion

The efficiency of rainfall control in mitigating flooding and inundation shows a clear decrease. However, even under the same conditions of reduced rainfall, the reduction in inundation still varies significantly, possibly due to the spatial variation of rainfall and the rainfall pattern. This study demonstrates the understanding of the rainfall control method in flooding response and evaluates its effectiveness in flood prevention. The results suggest that rainfall control methods can be one strategy for reducing the impact of flooding during short-term extreme rainfall events.

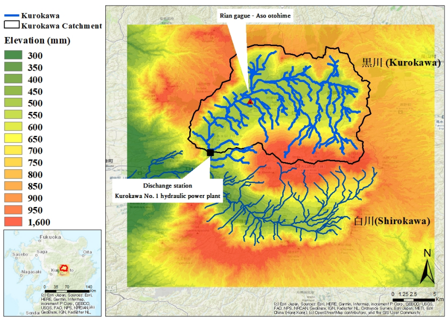

Fig. 1 Study area.

	N7E0	N7E1	N7E2	N7E3	N7E4	AVERAGE
1hr	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4hr	-4.03%	-4.42%	-2.04%	-2.56%	-10.69%	-4.75%
8hr	-28.38%	-25.83%	-22.16%	-18.23%	-13.59%	-21.64%
9hr	-8.51%	-2.95%	2.02%	5.17%	6.39%	0.42%
10hr	-2.89%	-0.74%	0.09%	0.71%	1.21%	-0.33%
11hr (Peak)	0.14%	0.33%	-0.11%	-0.61%	-1.46%	-0.34%
12hr	-13.24%	-16.57%	-19.95%	-23.68%	-27.86%	-20.26%
20hr	-20.92%	-16.70%	-12.64%	0.95%	41.34%	-1.59%
24hr	-19.72%	-10.70%	1.94%	15.67%	56.15%	8.67%
Total amount-Normal (mm)	310.05	318.57	321.24	317.02	307.50	
Total amount-control (mm)	285.53	292.69	294.77	291.30	283.42	
Decrease amount (mm)	24.53	25.89	26.47	25.72	24.08	

Table 1 Decreasing rates and total decrease amounts in basin-average rainfall under control scenarios.

Acknowledgment

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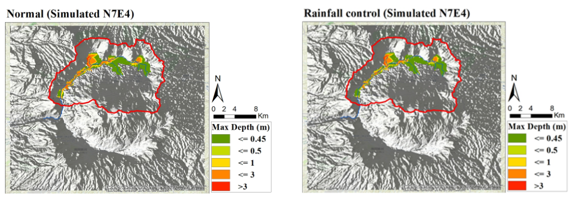

Fig. 2 Inundation areas before and after rainfall control in scenario N7E4.

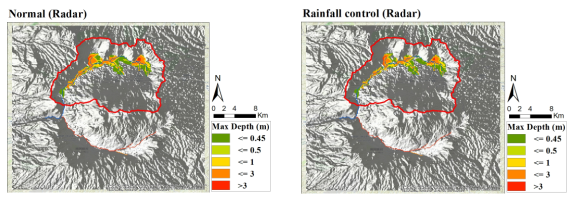

Fig. 3 Inundation areas before and after rainfall control in the Radar/Rain gauge scenario.

	Sim Normal	Sim Control	Radar/Rain gage Normal	Radar/Rain gage Control
0-0.45m	5.30	4.82 (-0.48)	5.28	5.99 (+0.71)
0.45m-0.5m	0.46	0.50 (+0.04)	0.72	0.66 (-0.06)
0.5m-1m	3.54	3.57 (+0.03)	5.03	4.69 (-0.35)
1m-3m	6.87	4.80 (-2.07)	9.47	8.64 (-0.84)
>3m	0.58	0.37 (-0.20)	1.51	1.05 (-0.45)
Total	16.75	14.07	22.02	21.03
Decrease area		2.68 (17%)		0.99(4.5%)

Table 1 Decreasing areas and rates at different depth levels for each scenario.