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► **To cite this version:**

Hidekazu Matsuoka, Ippei Kameda, Takuma Kiyosu, Isao Ideta, Ichiro Tamura. Quantitative Evaluation of Inundation Prevention and Mitigation Through the Introduction of Green Infrastructure. Novatech 2023, Jul 2023, Lyon, France. hal-04184087

HAL Id: hal-04184087

<https://hal.science/hal-04184087v1>

Submitted on 21 Aug 2023

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Évaluation quantitative de l'efficacité de la mise en place des infrastructures vertes en termes de prévention des inondations

Quantitative Evaluation of Inundation Prevention and Mitigation Through the Introduction of Green Infrastructure

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RÉSUMÉ

Au Japon, afin de lutter contre les inondations qui deviennent de plus en plus intenses et fréquentes en conséquence du changement climatique, les efforts sont déployés pour la « gestion des bassins fluviaux », dans laquelle toutes les parties concernées par un bassin versant collaborent pour mettre en œuvre des mesures contre les inondations.

Dans le cadre de la présente étude, nous avons mené une évaluation quantitative de l'efficacité des infrastructures vertes en termes de diminution du ruissellement des eaux pluviales, dans l'objectif de promouvoir la mise en place de ces infrastructures qui font partie des mesures tangibles mettant à profit au maximum les terrains.

La modélisation des infrastructures vertes a été réalisée à l'aide d'InfoWorks ICM, sur des squares, des terrains de sport, des routes et des parkings. Les résultats des simulations ont montré qu'après la mise en place des infrastructures vertes, le ruissellement des eaux pluviales diminué serait équivalent à 5,1 mm/h par rapport aux précipitations estimées (52 mm/h), et à 8,8 mm/h par rapport aux précipitations maximales enregistrées (91 mm/h). Ainsi, l'étude a révélé que dans les zones cibles, la mise en place des infrastructures vertes permettra de diminuer le ruissellement des eaux pluviales d'environ 10% par rapport aux précipitations maximales par heure.

ABSTRACT

In Japan, floods and inundation are intensifying and occurring with greater frequently due to the effects of climate change. Basin-wide comprehensive flood management is a concept being adopted in order to respond to such natural disasters, where all concerned parties related to a drainage basin work together on measures aimed at mitigating and controlling floods.

In this study, we quantitatively evaluated the stormwater runoff control effect of green infrastructure in order to promote the introduction of green infrastructure, a hard countermeasure that maximizes the use of land.

For the green infrastructure, InfoWorks ICM was used to model parks, athletic fields, roads, and parking lots. As a result of our inundation simulations, the stormwater runoff control effect after the introduction of green infrastructure was equivalent to 5.1 mm/h compared to the design rainfall (52 mm/h) and equivalent to 8.8 mm/h compared to the observed maximum rainfall (91 mm/h). Therefore, we found that the introduction of green infrastructure in the target area can be expected to reduce stormwater runoff by about 10% compared to the maximum hourly rainfall.

MOTS CLÉS

Développement à faible impact, Diminution du ruissellement des eaux pluviales, Infrastructure verte, Simulation d'inondation, Systèmes de drainage urbains durables

KEYWORDS

Green infrastructure, Inundation simulation, Low Impact Development (LID), Stormwater runoff control effect, Sustainable Urban Drainage Systems (SUDS)

1 INTRODUCTION

In Japan, the number of rainy days with a daily precipitation of 100 mm or more and the frequency of rainfall with an hourly precipitation of 50 mm or more are increasing every year. The frequency of rainfall with an hourly rainfall of 50 mm or more has increased by about 1.4 times over the last 40 years, indicating a significant impact from climate change.

Basin-wide comprehensive flood management is a concept being adopted in order to respond to these intensifying and increasingly frequent floods and inundation. All concerned parties related to a drainage basin work together on measures aimed at mitigating and controlling floods and inundation. With basin-wide comprehensive flood management, the goal is to achieve urban development that is highly resistant to flooding by working together on three ideas—reducing and mitigating floods, reducing the scale of damage, and reducing damage and enabling rapid recovery and rebuilding—through a combination of hard and soft measures.

In sewerage, the introduction of green infrastructure is needed as a hard measure that maximizes use of land. To promote the systematic introduction of green infrastructure in urban areas, it is necessary to clarify its effectiveness against inundation. The purpose of this study is to therefore quantitatively evaluate the stormwater runoff control effect of green infrastructure.

2 OUTLINE OF THE TARGET AREA

The target area is a drainage area of approximately 150 ha, as shown in Fig. 1. This area is flat with little undulation. The sewerage is a combined pump drainage area, and the current stormwater drainage standard is 47 mm/h (equivalent to a 7-year return period). Assuming the RCP2.6 scenario (IPCC-RCP2.6) based on future climate change, the target for stormwater drainage is expected to be 52mm/h (equivalent to a 7-year return period on future). In recent years, inundation damage has occurred due to frequent torrential rains. As considerable time would be needed to implement the hard measures necessary for sewerage systems, systematic and efficient inundation control measures are needed.

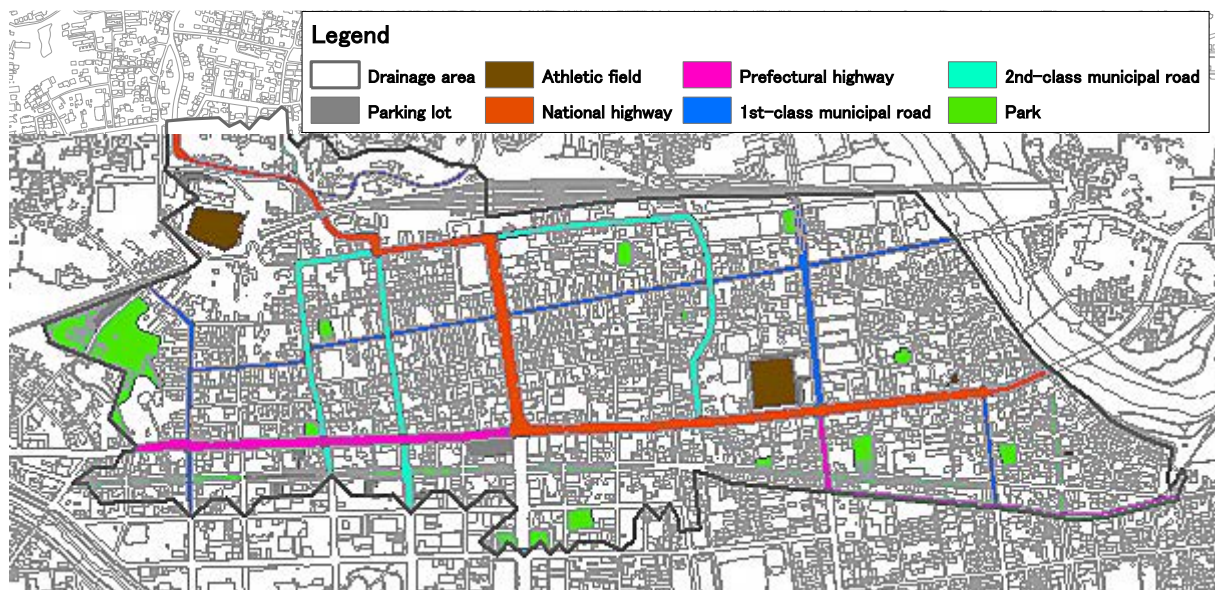


Fig.1. SUDS Potential Map

3 STUDY METHOD

3.1 Procedures of the Study

First, a potential map was created by identifying locations where sustainable urban drainage systems (SUDS) for storage, permeation, and evapotranspiration could be installed. Next, SUDS were modeled for the identified locations. Then, inundation simulations for before and after installation were performed to look at the design rainfall—taking climate change into consideration—and the observed maximum rainfall. We then quantitatively evaluated the stormwater runoff control effect.

3.2 Modelling Green Infrastructure

3.2.1 Potential Map

Parks and green spaces, roads, athletic fields, and parking lots shown in Fig. 1 were identified as facilities with potential for SUDS within the target area.

3.2.2 Sustainable Urban Drainage Systems (SUDS)

The EPA Storm Water Management Model (SWMM) published by the United States Environmental Protection Agency (EPA) incorporates eight controls for SUDS. In this study, using InfoWorks ICM, which can express these functions, a total of about 10 ha of parks, athletic fields, and roadside plant areas were modeled with bioretention cells. A total of 3.3 ha of roadside sidewalks and parking lots were also modeled with permeable pavements. For example, an athletic field was modeled with bioretention cells as in Table 1. Conductivity of the Soil Layer and the seepage rate of the Storage Layer considered the effects of clogging and groundwater.

Table 1. Bioretention cell parameters (athletic fields)

Schematic Diagram	Layer	Field	Value	
	Surface	Berm height (mm)	10	
			Vegetation volume fraction	0
			Surface slope (m/m)	0
	Soil	Soil class	Sand	
			Soil thickness (mm)	150
			Soil porosity	0.437
			Field capacity	0.062
			Wilting point	0.024
			Conductivity (mm/h)	120.396×0.9
			Conductivity slope	48
	Storage	Storage thickness (mm)	1,350	
			Storage void ratio	0.429
			Seepage rate (mm/h)	120.396×0.81

3.3 Inundation Simulations

Inundation simulations were performed for before and after the installation of SUDS. The target rainfall was the design rainfall ($I_1=52$ mm/h) considering climate change and the observed maximum rainfall ($I_2=91$ mm/h) shown in Fig. 2. The drainage area A is 148.06 ha. SUDS cover 13.3 ha (approximately 9% of the drainage area). Also, the runoff coefficient C was set to 70% for the entire area.

3.4 Method for Evaluating the Runoff Control Effect

In this study, the stormwater runoff control effect was quantitatively evaluated by converting the stormwater runoff before and after the introduction of green infrastructure into rainfall intensity and comparing it. The flow rate obtained from the inundation simulation was converted into rainfall intensity using the following calculation.

$$Q = \frac{1}{360} \times C \times I \times A, \quad \Sigma(Q_1 - Q_2) = C \times (I_1 - I_2) \times A, \quad (I_1 - I_2) = \Sigma(Q_1 - Q_2) / (C \times A) \dots\dots\dots(1)$$

Q: flow rate, A: drainage area, I: rainfall intensity

4 RESULTS AND DISCUSSIONS

4.1 Quantitative Evaluation Results of the Effects from the Countermeasures

Fig. 2 shows the comparison results of stormwater runoff before and after the introduction of green infrastructure. In the case of the target rainfall I_1 , the hourly stormwater runoff control effect was maximized during the timeframe from 11:35 to 12:35, indicated by the red frame in the figure. The flow rate reduced after the introduction of green infrastructure was 5,251 m^3/h . As a result of converting the reduced flow rate into rainfall intensity using Formula (1), an effect equivalent to 5.1 mm/h was expected by introducing green infrastructure.

Similarly, with target rainfall I_2 , the flow rate fell to 9,137 m^3/h after the introduction of green infrastructure during the timeframe from 1:25 to 2:25, indicated by the red frame in the figure. As a result of converting the reduced flow rate into rainfall intensity using Formula (1), an effect equivalent to 8.8 mm/h was expected by introducing green infrastructure.

We found that the introduction of green infrastructure in the target area can be expected to reduce stormwater runoff by about 10% compared to the maximum hourly rainfall.

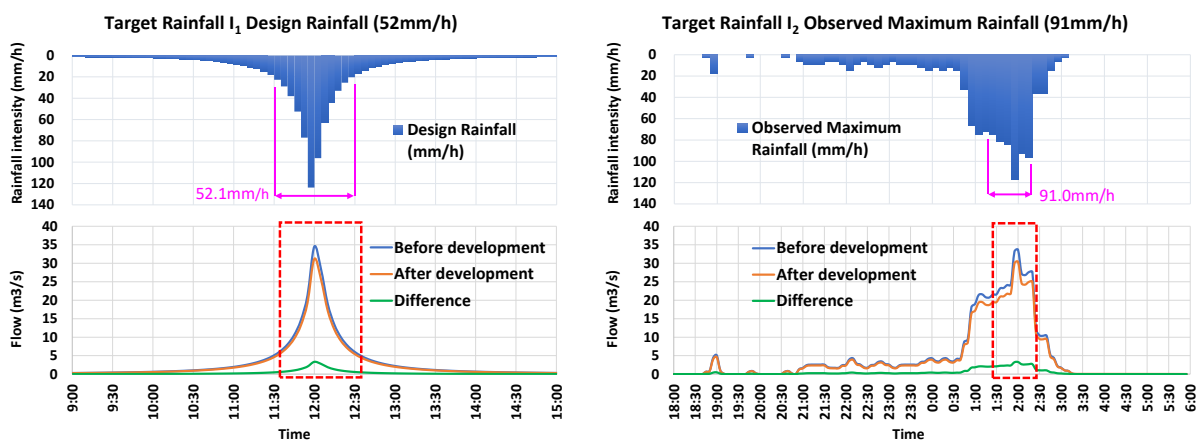


Fig. 2. Target rainfall, stormwater runoff before and after the introduction of green infrastructure

4.2 Discussions

The stormwater runoff control effect through the introduction of green infrastructure was quantified by converting it into rainfall intensity. This made it possible to simply apply the effect of the green infrastructure inundation countermeasures into the sewerage plans. The results are expected to help promote the systematic introduction of green infrastructure in urban areas as well as contribute to the development of communities more resistant to flood-related disasters.

It should be noted that the reproducibility of the models used (calibration accuracy) and the settings for each parameter of the green infrastructure (especially the soil constant for calculating the amount of seepage into the ground) may affect the evaluation results.

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