A Simulation Study of Rainwater Infiltration Function of Urban Green Spaces for Pluvial Flood Risk Reduction in Tokyo Metropolitan Area

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1. Introduction

Tokyo metropolitan area is vulnerable to urban flood. The city has experienced frequent pluvial floods for the last few decades. The main reasons are decrease in rainwater infiltration amount from highly urbanized areas and increase in short-time heavy rains. Since the flood risk might increase by global climate change, immediate mitigation measures are needed.

Recently the multiple functions of the urban open spaces, which improve the global and regional environmental problems, are paid attention. The rainwater infiltration function, which can reduce pluvial flood risk and improve water quality, is the one of those functions. There are several researches, which evaluate the rainwater infiltration capacity in urban parks, street open spaces, and green roofs; however, there are few quantitative researches in regional scale.

This paper clarifies rainwater infiltration function of urban green spaces and determines vulnerable areas for urban pluvial floods risk by stormwater simulation model with the database of the detail open spaces made from high-resolution aerial photographs. In addition, it discusses mitigation measures from the perspective of green and open space planning.

The study site is the upper stream of the Kanda River watershed, where two branches flow on the Musashino Uplands: Zenpukuji River and Kanda River. The area was developed as residential districts from the early to middle twenty century along the two railroads: JR Line and the Keio Line. Now, low-rise housing occupies 54% among all land use types (Fig. 1). Historically, urban green belt policy was applied to the region in order to conserve the green and open spaces and prevent the urban sprawl; however it ended up abrogation of the policy because of high development pressure[2)].

2. Rainwater infiltration function of green and open spaces

The total green and open space area in the study site is 484 ha, which means 21.2% of the region (Fig. 2). Particularly, home garden is 192 ha, deciduous tree (no shrubs) is 143, and ground (covered by soil of vegetation) is 42 ha in total. Final infiltration capacity (FIC) for each open space types, which are calculated in the previous researches [3-5)], are 102 mm/h, 314 mm/h, and 7 mm/h. The deciduous tree has high capacity; on the other the ground's capacity is very low (Table 1). The open space ratio (OS ratio) and FIC per sub watersheds, which are defined based on sewerage system, are calculated and described on the map (Fig. 3 & Fig. 4). The OS ratios of the sub watersheds are very low where commercial land uses are intensively located along the railroads and main roads (less than 10%). On the other hand, the OS ratios of the sub watersheds located along the rivers are relatively high (more than 20%). FIC of the Zenpukuji River are higher than that of the Kanda River because the green and open spaces along the Zenpukuji River are mostly deciduous trees, but there are lots of ground along the Kanda River.

The relation between OS ratio, FIC and previous green and open space planning are investigated. The sub watersheds that the government set the Scenic District and Open Space Conservation District have high OS ratio and FIC compared with others. For example the

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Scenic District have 33.1% OS ratio and 45.6 mm/h FIC, Open Space Conservation District have 24.6% and 31.2 mm/h, even though the average OS ratio remains 18.1% and average FIC is 23.0 mm/h (Table 2). The result shows the efficiency of previous planning measures.

3. Stormwater simulation: a case of 10-year probable precipitation

In order to determine the vulnerable area to short-time heavy rains, stormwater simulation is conducted. Rainfall data input to the model is 10 years probable precipitation. Fig. 5 shows the result of infiltration amount per the sub watersheds and Fig. 6 shows overflow points and flooded area. Fig.7 and Fig.8 show the zoom up pictures of typical flood sites. Generally, the overflows and the floods happen along the Zenpukuji River. This is because the commercial land use and small detached houses occupied along the railroad and the main roads in the Zenpukuji region, where the land had developed in the early twenty century and no green and open space planning measure had taken, and the infiltration amount are extremely low. Besides, there are some parts on the uplands away from the rivers where overflows and floods also happen since there are sub watersheds of low infiltration amount on the upper stream of the sewerage system.

Namely, the infiltration function of green and open space takes an important role to prevent the floods. Therefore, it could be effective to make green and open spaces with high infiltration vegetation type on the lands, which are now vacant spaces such as street side, pavement in yards, or the rooftops *etc.* The lands, which don’t have enough spaces, the compound approach of setting stormwater shortage facilities would be an effective measure.

4. Conclusion

This research investigates the rainwater infiltration function of urban green and open spaces for the pluvial flood risk reduction in short-time heavy rain by stormwater simulation model. The infiltration amount and restraint effects depend on the green and open space ratios of the region and those ratios differ from not only land use types but also the past green and open space planning measures such as the Scenic District and the Open Space Conservation District. It is clarify that these green and open space policies have an important role in the restraint of flood risk. Since the results of the infiltration and the flooded events are described on the maps per the sub watersheds, the typical key areas are identified that have high vulnerability to the flood risk and improvement measures should be taken at.

Keywords*: Urban Green, Rainwater Infiltration, Flood Risk Reduction, Simulation*

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Table 1 Open space type, area and final infiltration capacity

(Abbreviation - OS: Open space, FIC: Final Infiltration Capacity)

Type		Area (ha)	A OS Ration / Total Research Area (%)	A OS Ration / Total OS Area (%)	FIC (mm/h)	FIC Total (㎥/h)
Forest	Deciduous trees (no shrubs)	143	6.3	29.4	215	306,389
	Deciduous trees (copse with shrubs)	2	0.1	0.4	222	3,772
	Evergreen trees and Coniferous trees	1	0.0	0.1	144	955
	Mixed-trees	9	0.4	1.9	230	21,339
Others	Home garden	192	8.4	39.7	102	196,077
	Home garden with large trees	25	1.1	5.1	230	57,054
	Lawn and Grassland	13	0.6	2.7	22	2,832
	Bare land	15	0.7	3.1	7	1,050
	Ground (covered by soil or vegetation)	42	1.8	8.7	7	2,941
	Ground (covered by artificial material)	12	0.5	2.4	0	0
	Farmland	22	1.0	4.5	215	46,593
	Graveyard	10	0.4	2.0	13	1,254
Total		484	21.2	100.0	-	640,257

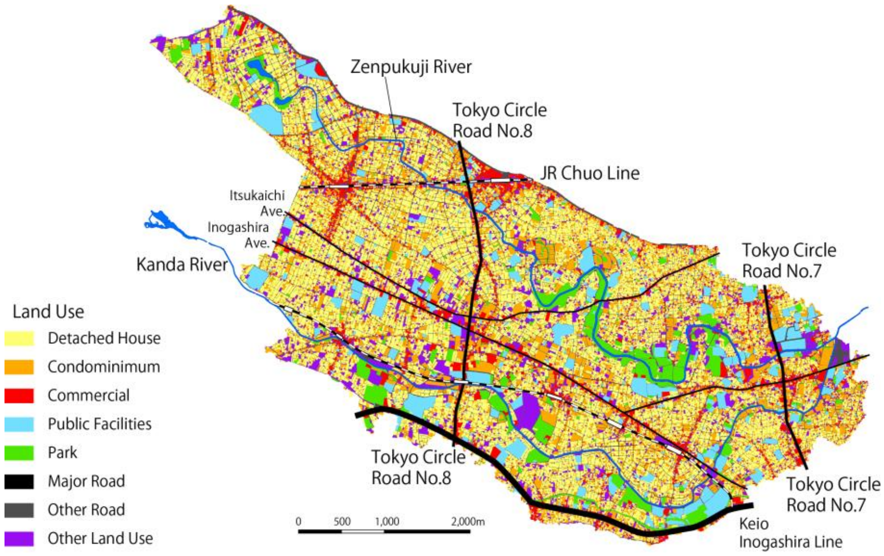

Fig. 1 Study area: upper steam of Kanda River watershed

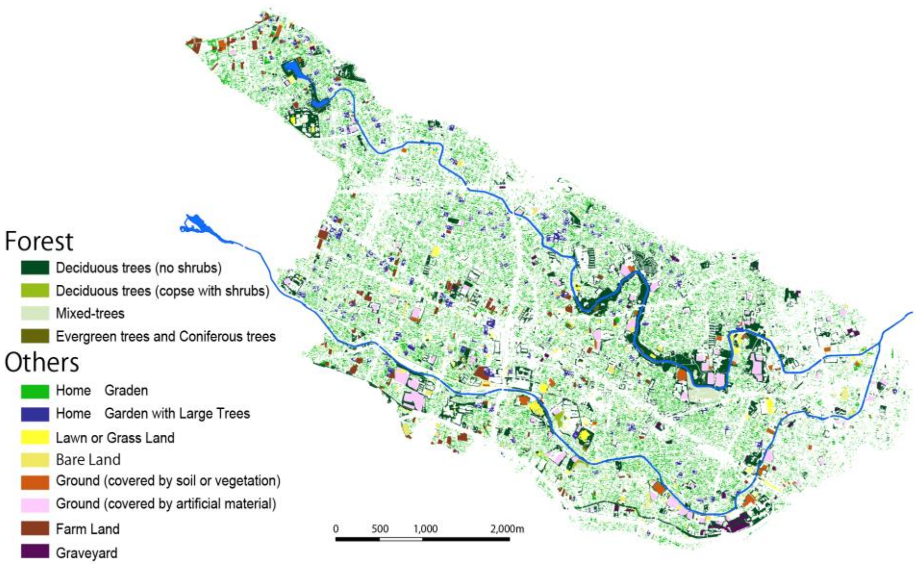

Fig. 2 Distribution and types of green and open spaces

Table 2 Average run off and infiltration amount in sub watersheds: case of 10-year probable precipitation

(Abbreviation - OS: Open space, FIC: Final Infiltration Capacity, RO: Run Off, IF: Infiltration)

Planning Measures	OS Ratio (%)	Land UseRatio (%)							FIC (mm/h)	RO (mm)	IF (mm)
		Education	Commercial	Residential Detached House	Residential Condominium	Road	Park	Others			
Scenic district	33.1	10.4	4.8	32.5	13.9	15.3	15.6	7.5	45.6	46.7	48.9
Not - Scenic district	17.1	5.1	5.6	40.2	20.5	18.3	3.8	6.6	21.6	51.9	40.4
Old open space conservation district	24.6	7.0	4.1	38.9	16.7	16.9	9.4	7.1	31.2	48.4	45.8
Not - Old open space conservation district	15.1	4.7	6.2	40.2	21.6	18.7	2.3	6.4	19.4	53.0	38.8
District plan	17.5	3.5	6.4	39.7	20.8	17.1	2.6	9.8	24.3	51.5	40.7
Not - Disrict plan	18.1	5.5	5.5	39.8	20.1	18.1	4.6	6.5	23.0	51.6	40.9
Land consolidation district	17.0	4.9	7.6	43.9	21.2	17.1	1.4	3.9	21.0	55.4	35.7
Not - Land consolidation district	18.1	5.4	5.5	39.7	20.1	18.1	4.6	6.6	23.1	51.5	41.0
Land readjustment district	14.9	4.3	6.3	41.8	20.4	20.0	1.2	6.0	18.9	53.3	38.0
Not - Land readjustment district	18.7	5.7	5.3	39.3	20.0	17.7	5.2	6.7	23.9	51.2	41.5
No planning measure	15.1	5.0	6.0	39.4	22.0	18.2	2.8	6.6	19.5	52.8	39.1
Average	18.1	5.4	5.5	39.8	20.1	18.1	4.5	6.6	23.0	51.6	40.9

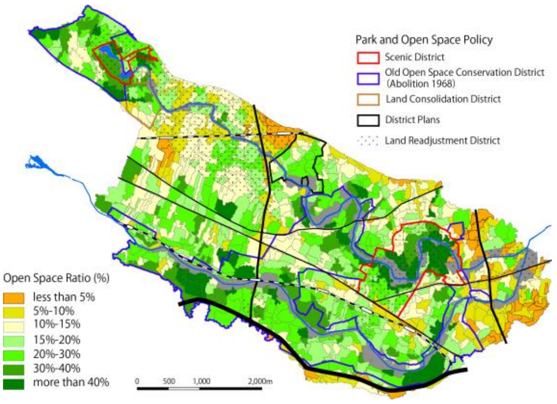

Fig.3 Open space ratio per sub watersheds

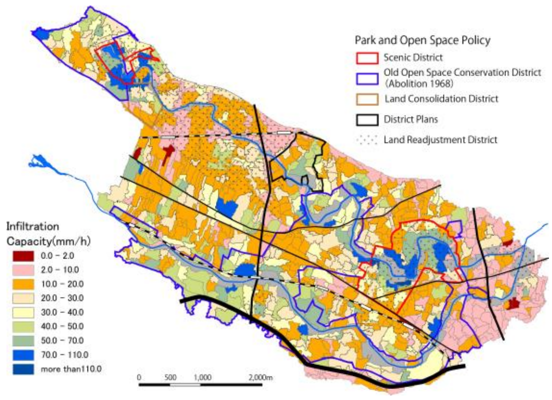

Fig.4 Final infiltration capacity per sub watersheds

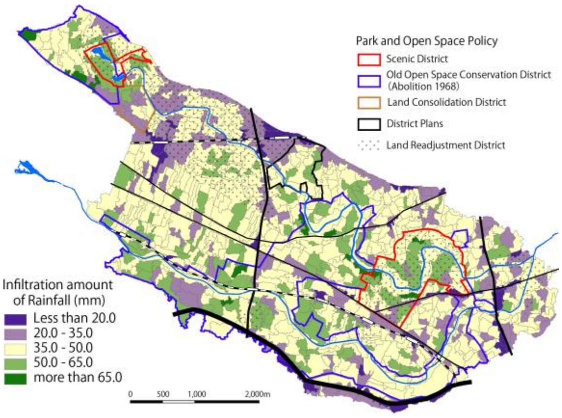

Fig.5 Infiltration amount of rainfall per sub watersheds: case of 10-year probable precipitation

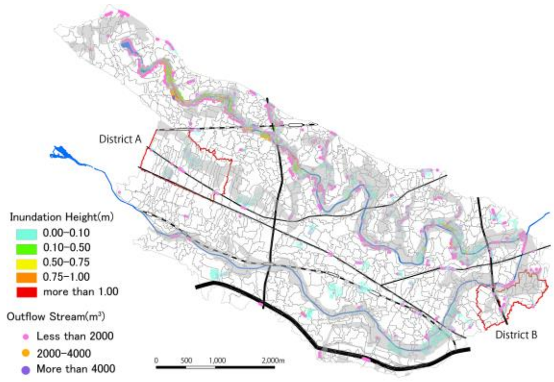

Fig.6 Overflow points and flooded area: case of 10-Year probable precipitation

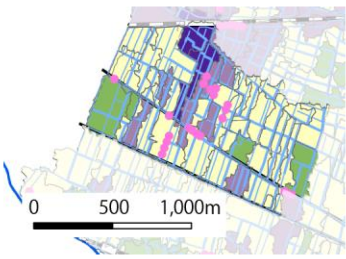

Fig.7 Infiltration amount, overflow points and flooded area of District A

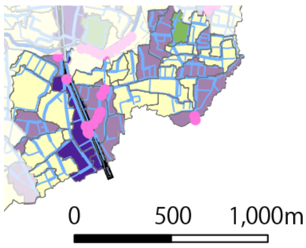

Fig.8 Infiltration amount, overflow points and flooded area of District B