Evaluation of “Yato” as a green infrastructure for urban environment

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Japan

Contents

Background

Climate Change

Problems

Influences

Global Warming

Urban Heat Island

Urban Warming

Localized Heavy Rain

Flood

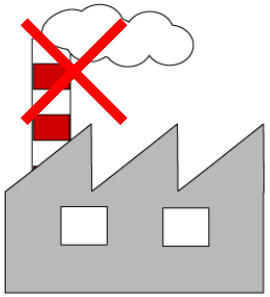
Flood damage

The need of countermeasures to urban warming and flood damage

Background

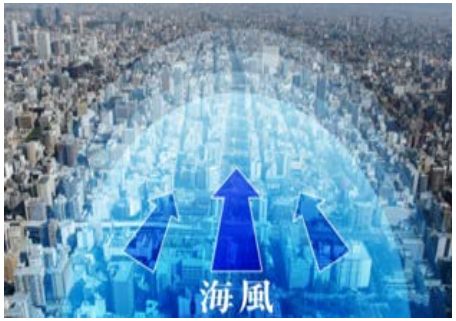
Countermeasure to urban warming

Reduction of anthropogenic heat



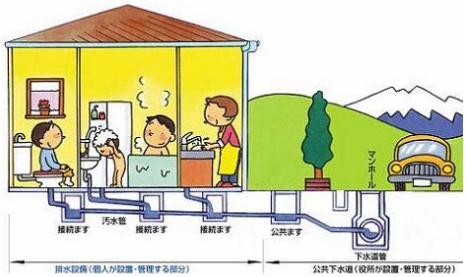
Greening

Improving urban form



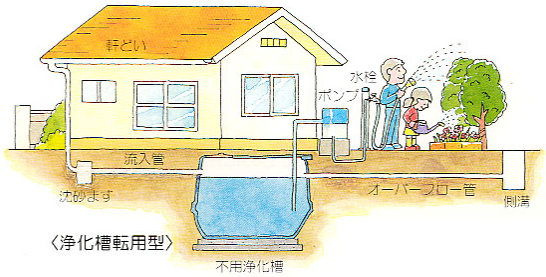
Countermeasure to flood damage

Improvement of the sewage system



Natural penetration

Rainwater storage permeating facility



Green Infrastructure utilizing natural function is proposed as effective measure

Background

Green infrastructure in urban area is classified into two types.

Green infrastructure in urban area

Artificial Green

Park, Street tree

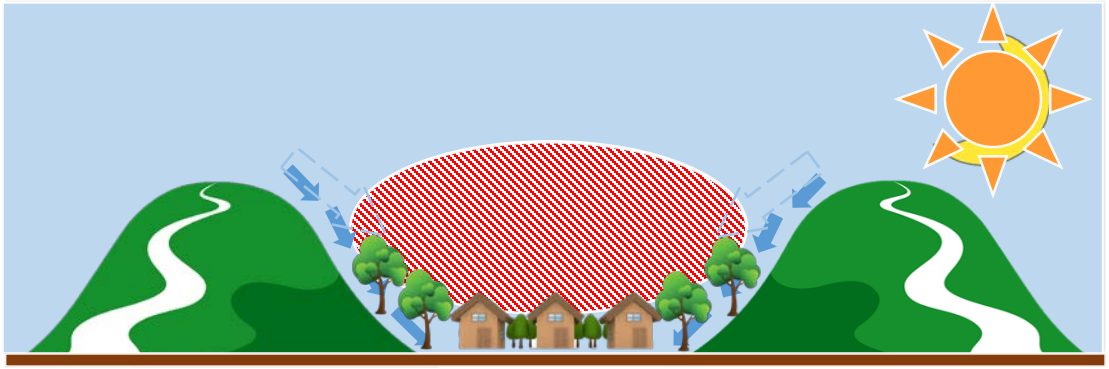
Natural Green

"Yato"

Background

What is “Yato”?

Small horseshoe-shaped flatland and surrounding slope in hilly area



Urban planning considering topographical characteristics is necessary

Depopulation ▷ Considering future land use is necessary

Objectives

Classifying Yato and suggesting future measure policy for each type of Yato to utilize Yato as a green infrastructure in the future

Analysis & Classification

Thermal environment (Air temperature) + Hydrological environment (Flow amount)

Classification　　Classification

Classification of "Yato" as Green Infrastructure

Suggestion

	Type A	Type B	・・・
Thermal environment	○	×	・・・
Hydrological environment	○	×	・・・
	Maintain	Shrink	

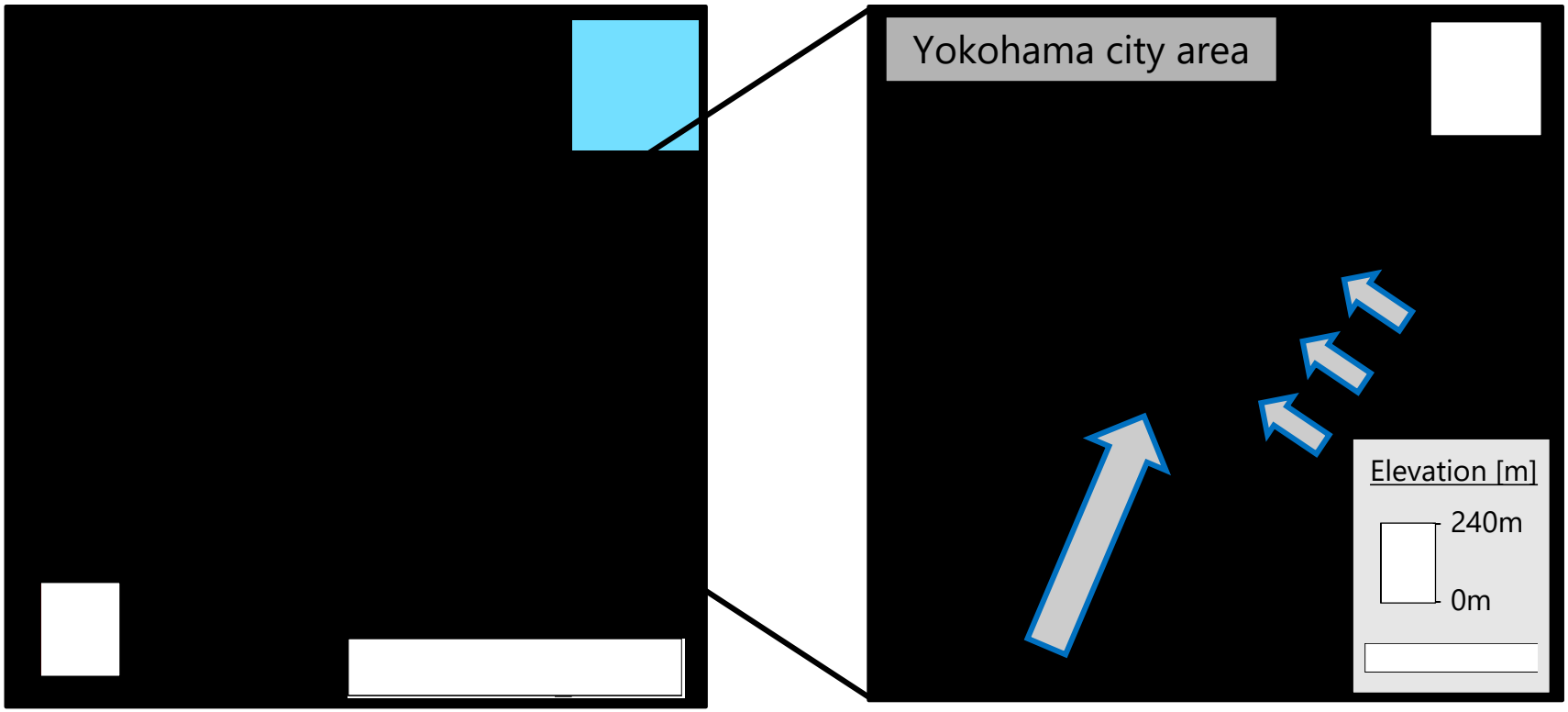
Type B（example）

Air temperature: High　　Flow amount: High

Contents

Target Area

Yokohama city, Japan



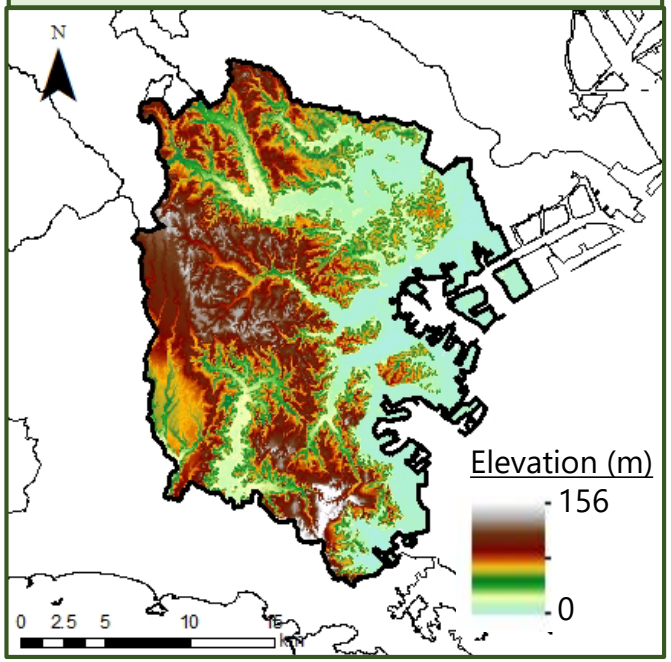
Area: 437.4 [km^2]
Population: 3.7million [persons]

Characteristics

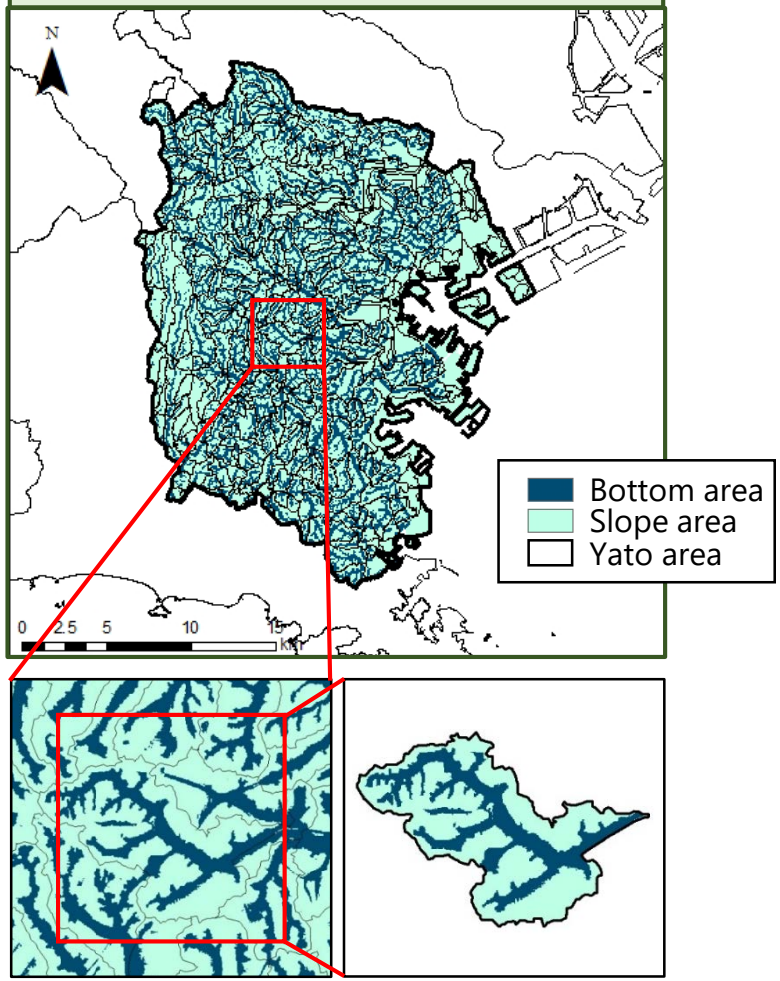
- Hilly city & many Yato
- Almost city area is urbanized
- Sea breeze blows from two bays

Target Area

Elevation data



Yato map
(distribution of Yato)



Yato map is made from elevation map

Extracting all Yato in Yokohama

Contents

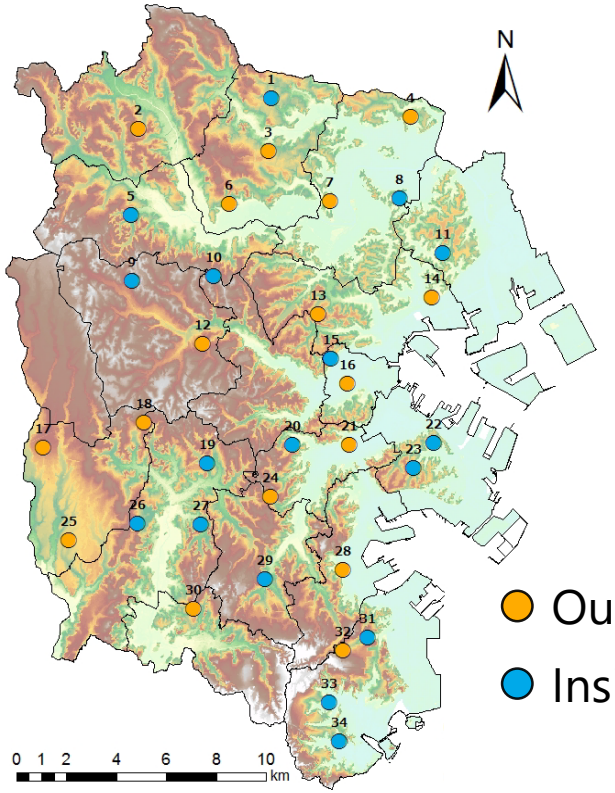
Outline of Field measurement of air temperature

Field measurement of air temperature

Observation points: 34 Stevenson screens located at elementary schools in Yokohama (Inside Yato: 17points, Outside Yato: 17points)

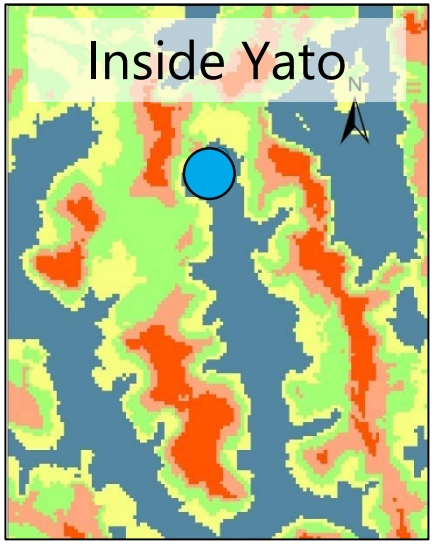
Period: July 25th 2016 – September 5th 2016

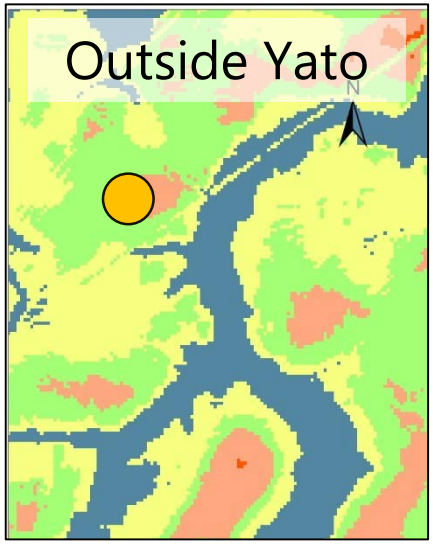
Interval: 10 mistunes



Outside Yato

Inside Yato



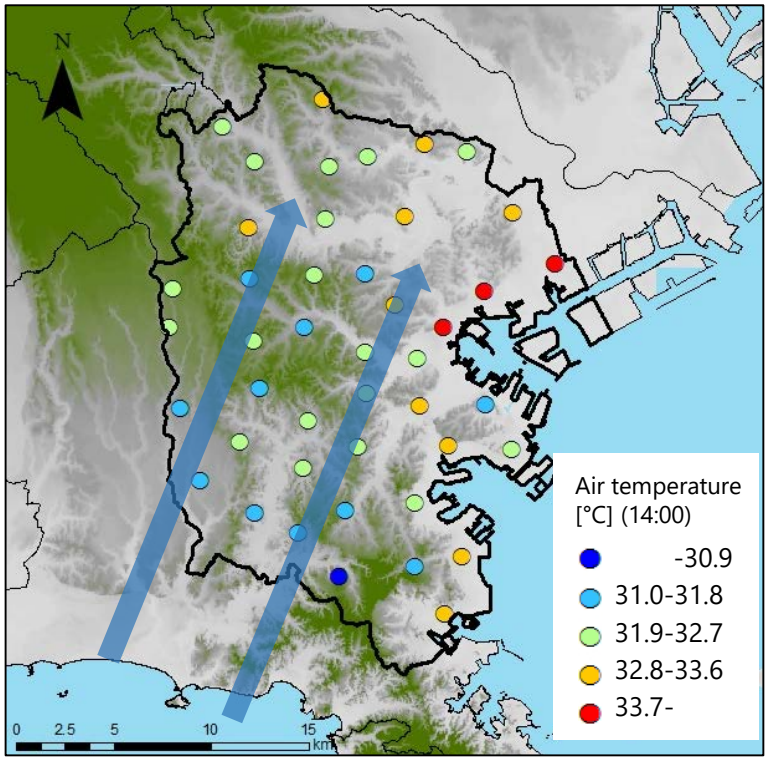


Bottom area of Yato

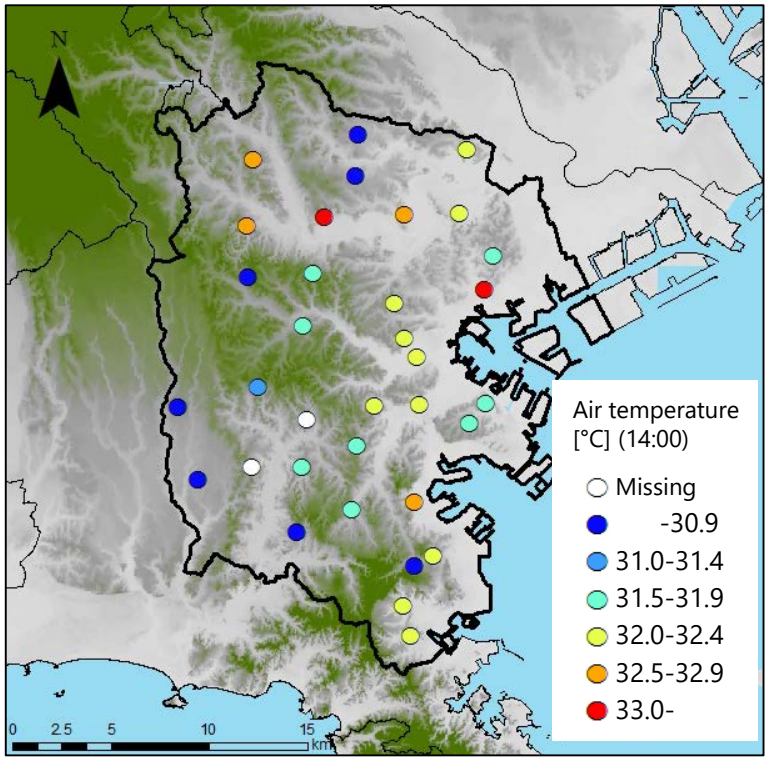
Result and factorial analysis of thermal environment

Horizontal hourly average air temperature distribution of sunny days

Result in 2015 (14:00)



Result in 2016 (14:00)



Sea breeze effect is remarkable
(Almost observation points locate outside Yato)

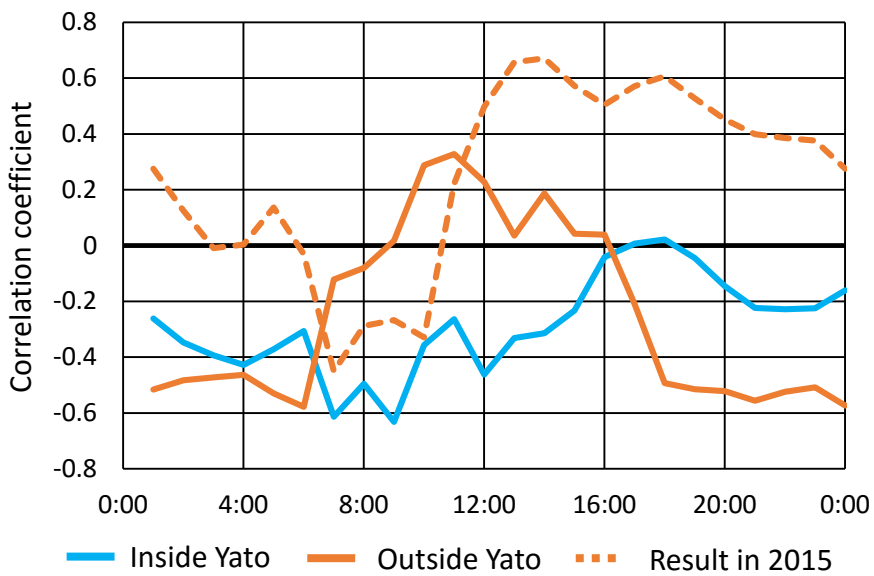
Sea breeze effect isn't remarkable

Factors on air temperature inside Yato is differ to general urbanized area

Result and factorial analysis of thermal environment

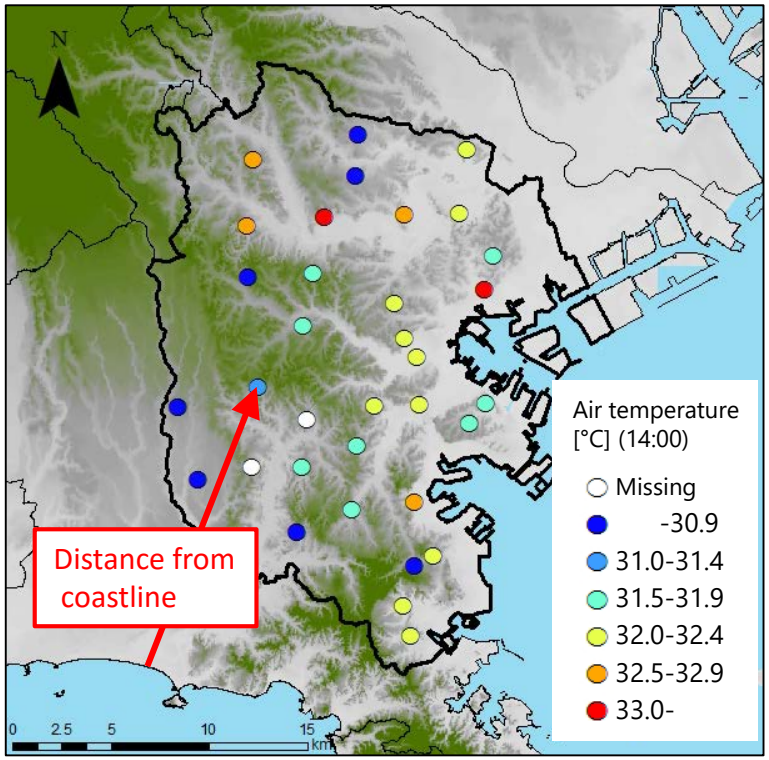
Horizontal hourly average air temperature distribution of sunny days

Result in 2015 (14:00)



Hourly correlation coefficient between air temperature and distance from coastline

Result in 2016 (14:00)



Sea breeze effect is remarkable
(Almost observation points locate outside Yato)

Sea breeze effect isn't remarkable

Factors on air temperature inside Yato is differ to general urbanized area

Result and factorial analysis of thermal environment

Item of the classification according to the type

Location (Coast or inland)

Catchment area

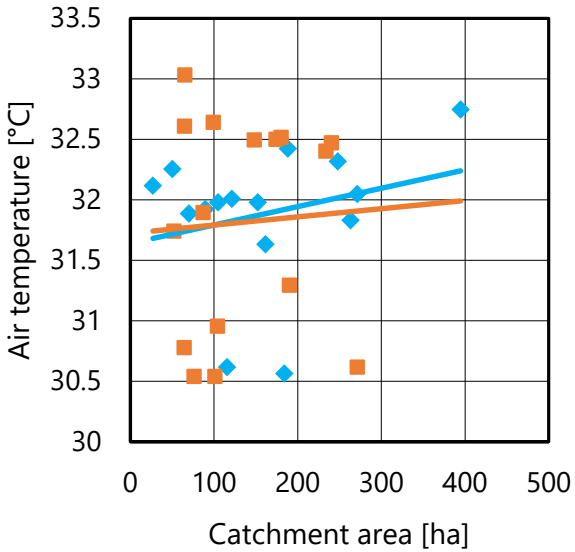
Urbanization rate

Direction

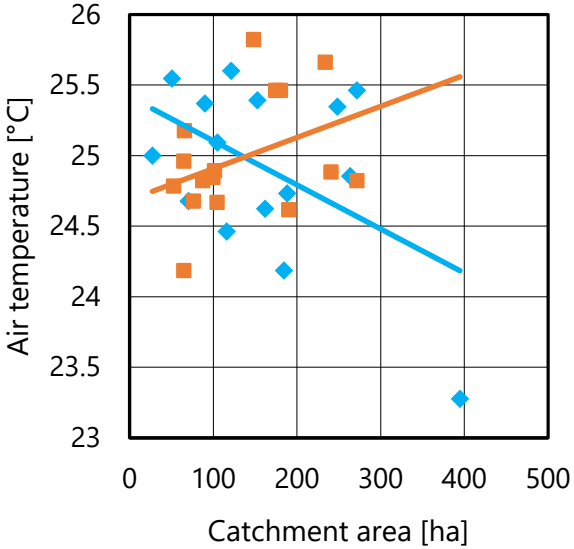
Result and factorial analysis of thermal environment

Catchment area

Daytime (14:00)



Nighttime (2:00)



◆ Inside Yato ■ Outside Yato

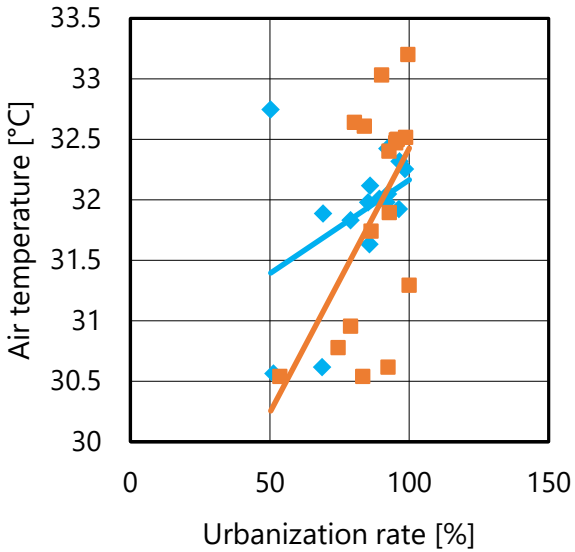
Scatterplot of air temperature and catchment area

Catchment area is effective factor in nighttime

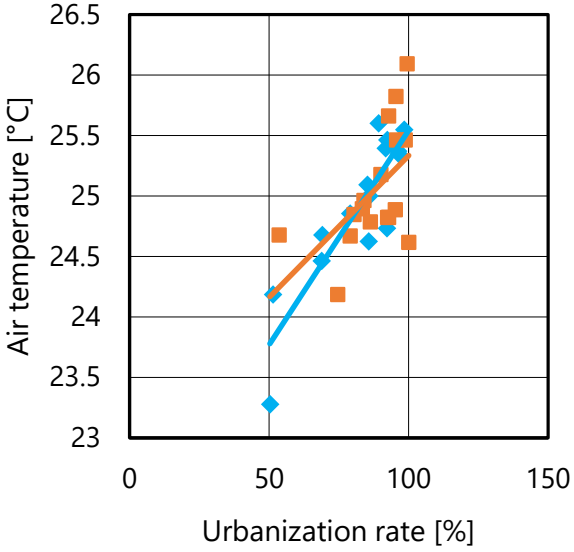
Result and factorial analysis of thermal environment

Urbanization rate

Daytime (14:00)



Nighttime (2:00)



◆ Inside Yato ■ Outside Yato

Scatterplot of air temperature and urbanization rate

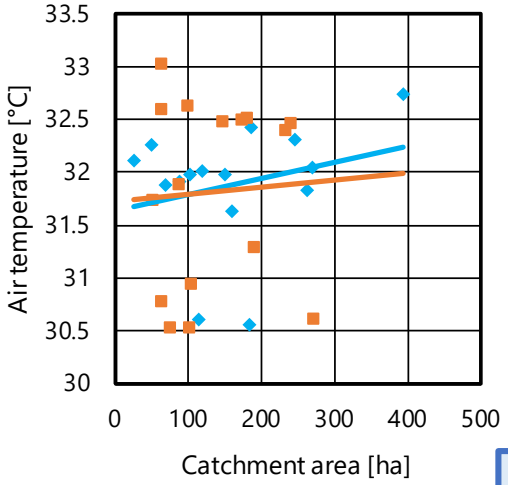
Urbanization rate is effective factor in daytime and nighttime

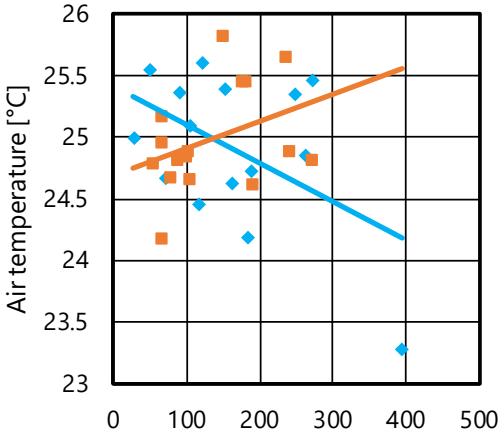
Result and factorial analysis of thermal environment

Daytime (14:00)

Nighttime (2:00)

Catchment area

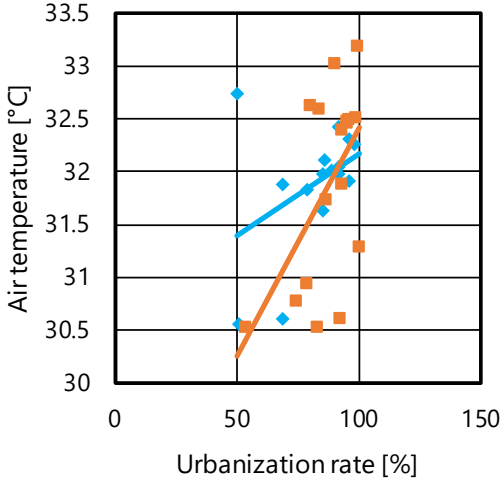


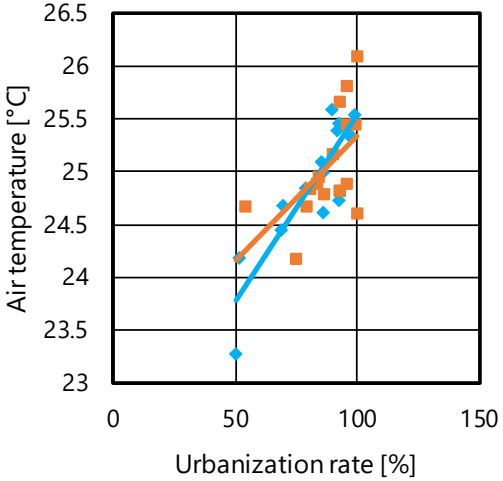


× Daytime
○ Nighttime

Cold air drainage effect?

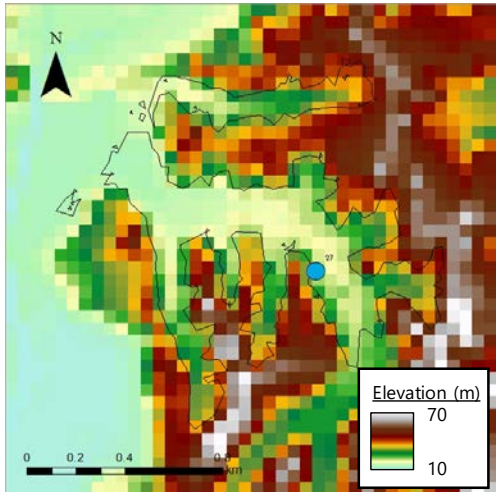
Urbanization rate

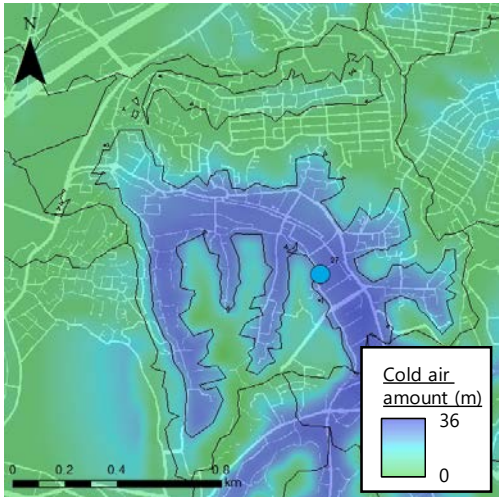




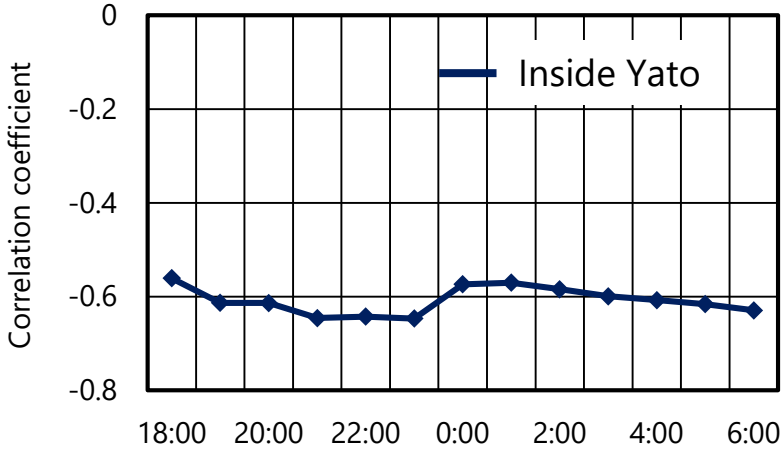
○ Daytime
○ Nighttime

Analysis by using shallow water equation





Cold air amount calculated by shallow water equation

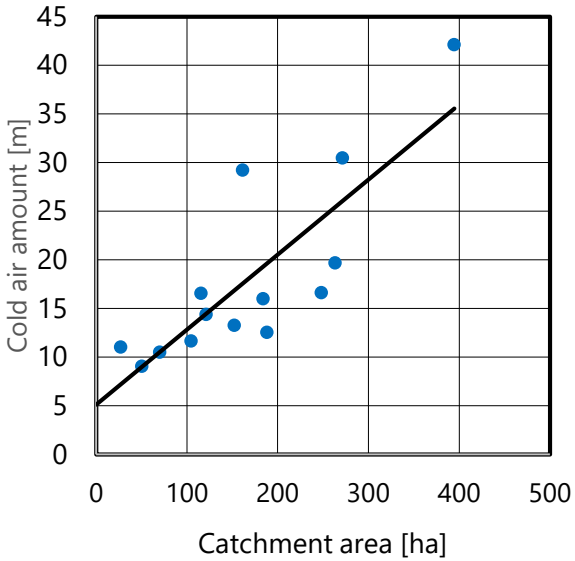


Hourly correlation coefficient between nighttime air temperature and cold air amount

Negative correlation can be seen between nighttime air temperature and cold air amount

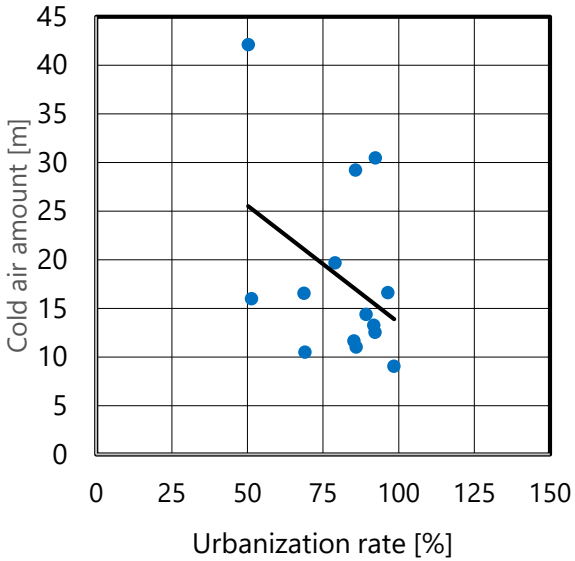
Analysis by using shallow water equation

Catchment area



Scatterplot between cold air amount and catchment area

Urbanization rate

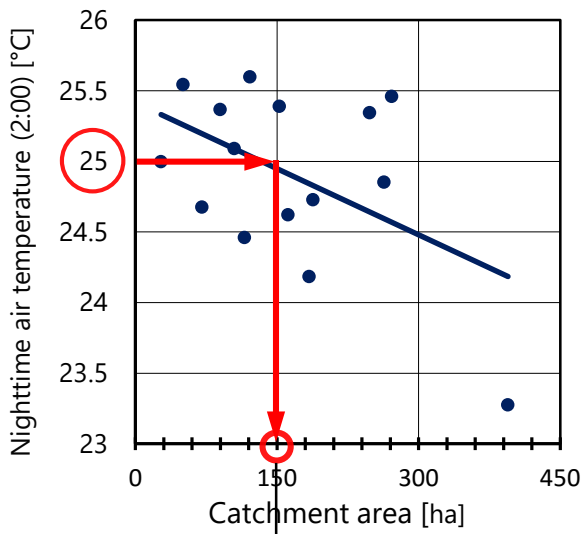


Scatterplot between cold air amount and urbanization rate

Correlation between air temperature and catchment area/urbanization rate during nighttime is caused by cold air drainage from slope green in Yato

Classification based on thermal environment analysis

Catchment area



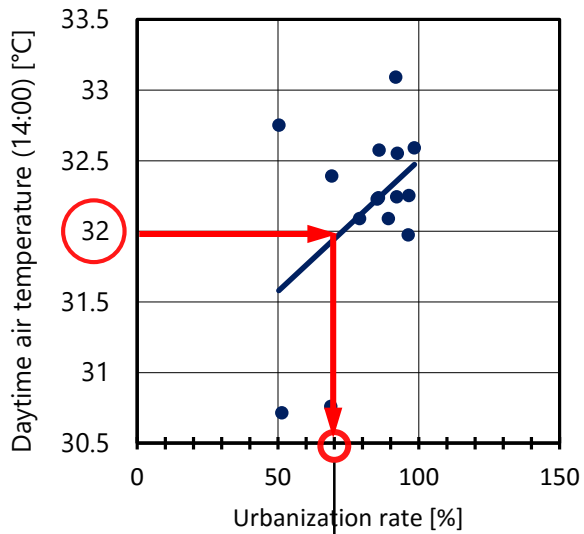
Scatterplot of air temperature and catchment area (2:00)

→ 150ha

Average minimum air temperature =25°C

Classified based on 150ha

Urbanization rate (Daytime)



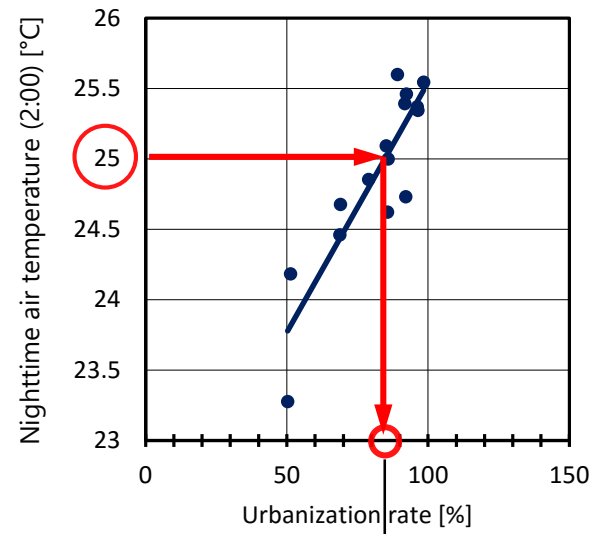
Scatterplot of air temperature and urbanization rate (14:00)

→ 70%

Average maximum air temperature =32°C

Classified based on 70%

Urbanization rate (Nighttime)



Scatterplot of air temperature and urbanization rate (2:00)

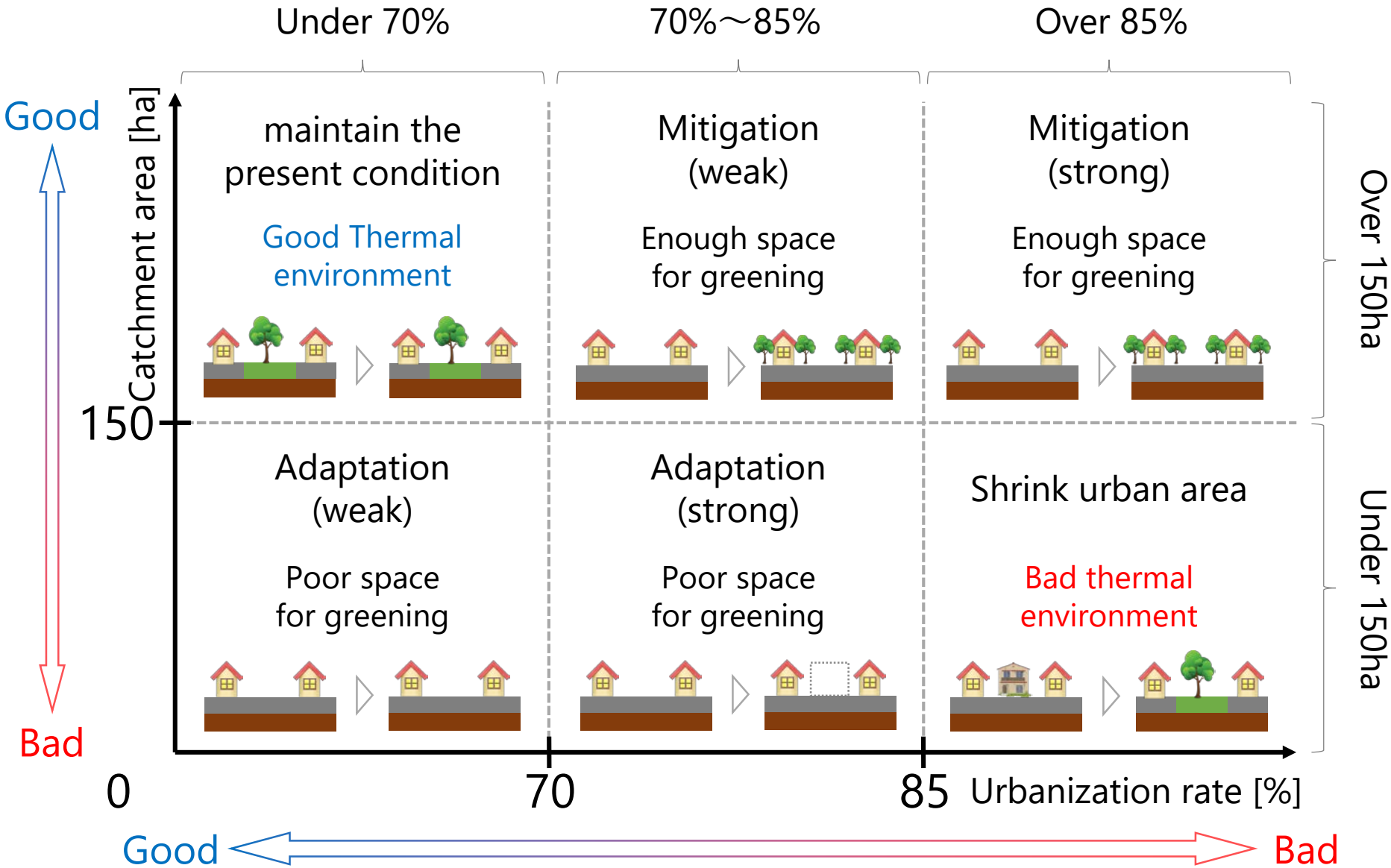
→ 85%

Average minimum air temperature =25°C

Classified based on 85%

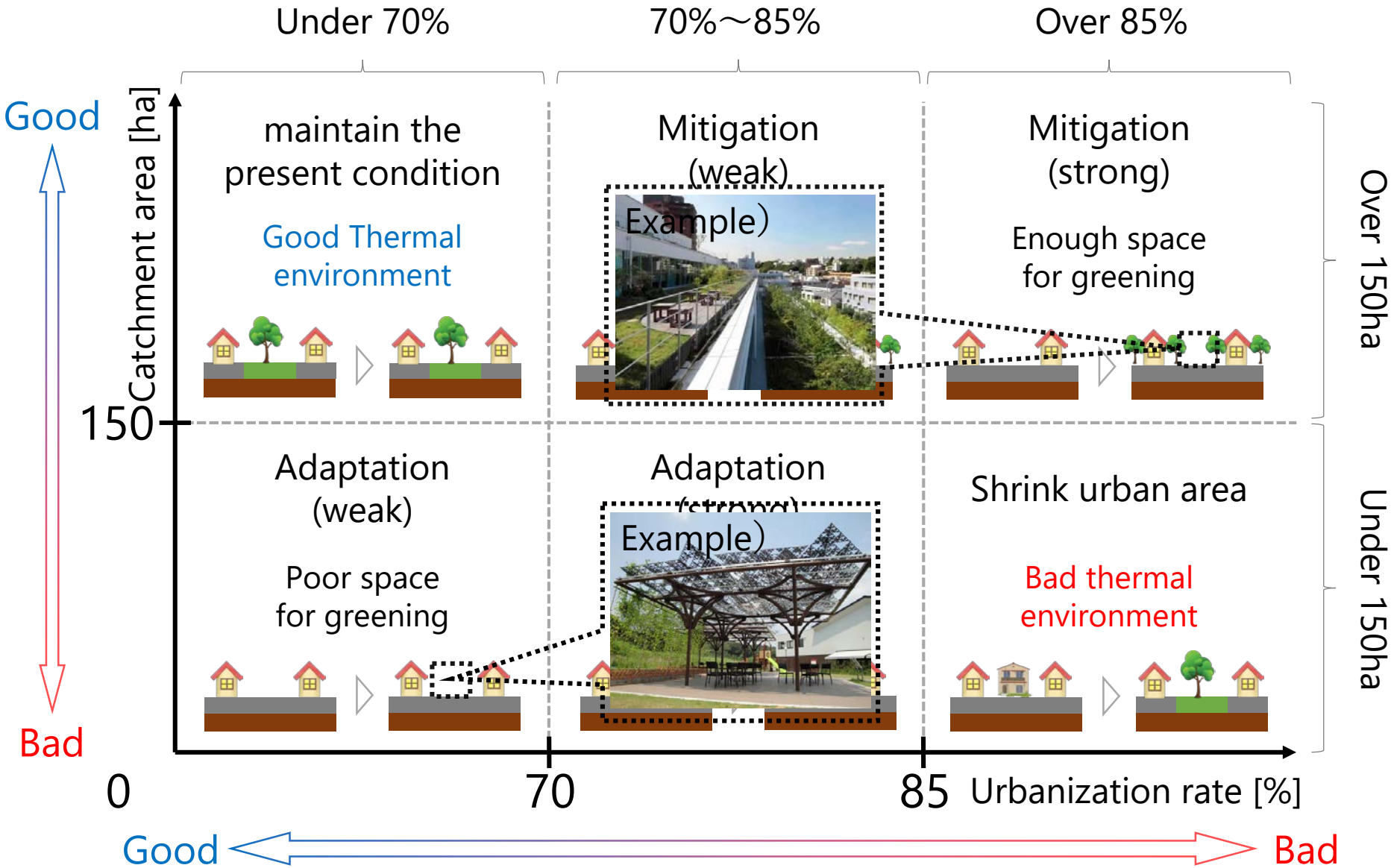
Classification based on thermal environment analysis

Classification results and measures policy for thermal environment



Classification based on thermal environment analysis

Classification results and measures policy for thermal environment



Contents

Outline of hydrological simulation

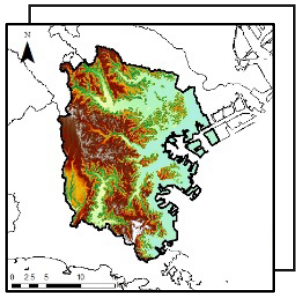
Maximum flow amount of each Yato analyzed in previous section is calculated by ArcHydro and HEC-GeoHMS

Input（on ArcGIS）

Arc Hydro

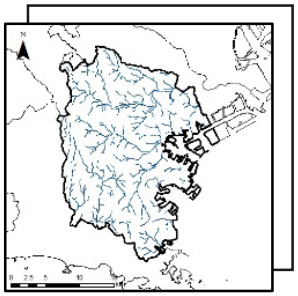
Making input dataset

Elevation



Catchment

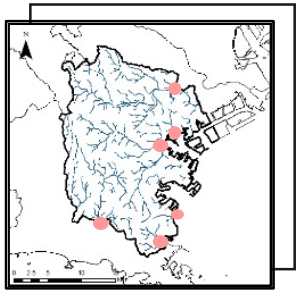
River



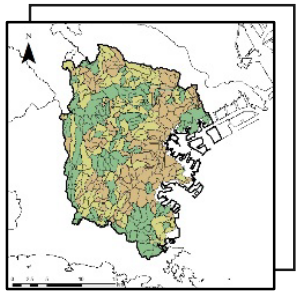
HEC-GeoHMS

Setting parameter and method

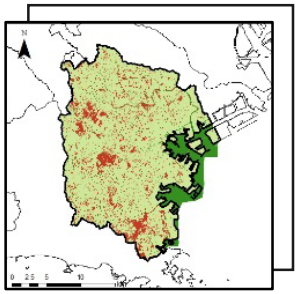
Runoff and rainfall points



Landuse



Soil



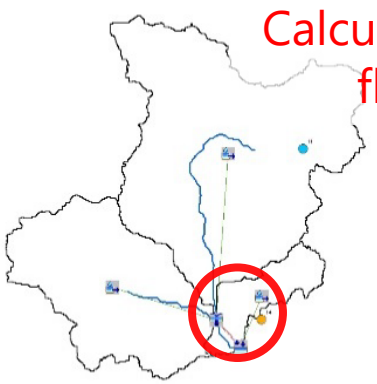
Outline of hydrological simulation

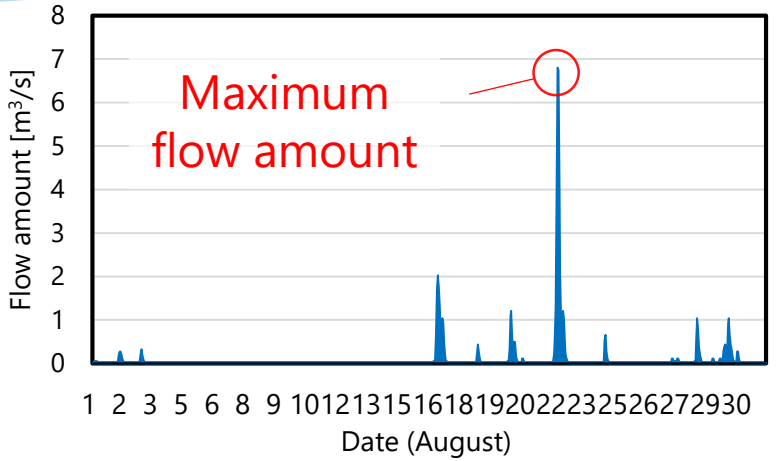
Maximum flow amount of each Yato analyzed in previous section is calculated by ArcHydro and HEC-GeoHMS

Output（HEC-HMS）

Rainfall–runoff simulation

Period：August 2016
Rainfall data：Precipitation at Yokohama local meteorological observatory
Analysis target：15 Yato analyzed in previous section



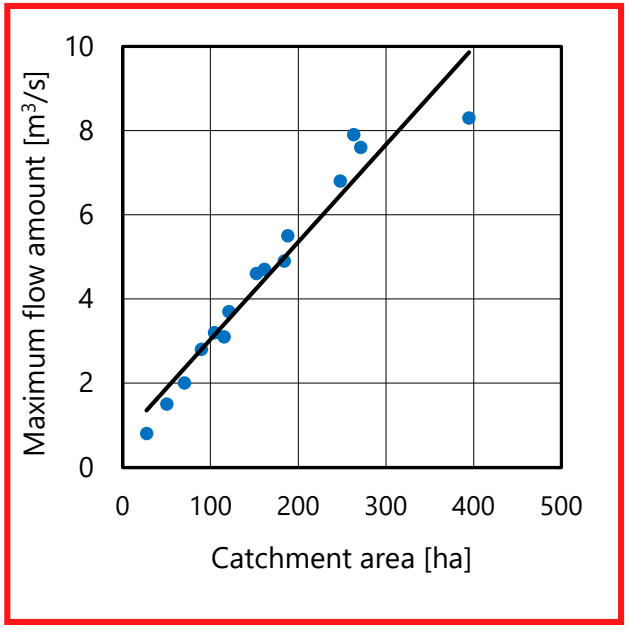


Calculation result of maximum flow amount

No.	1	5	8	9	10	11	15	20	22	23	27	29	31	33	34
maximum flow amount [m³/s]	4.9	8.3	1.5	3.1	2.0	4.6	3.7	5.5	2.8	3.2	4.7	7.9	6.8	0.8	7.6

Results and factorial analysis of hydrological environment

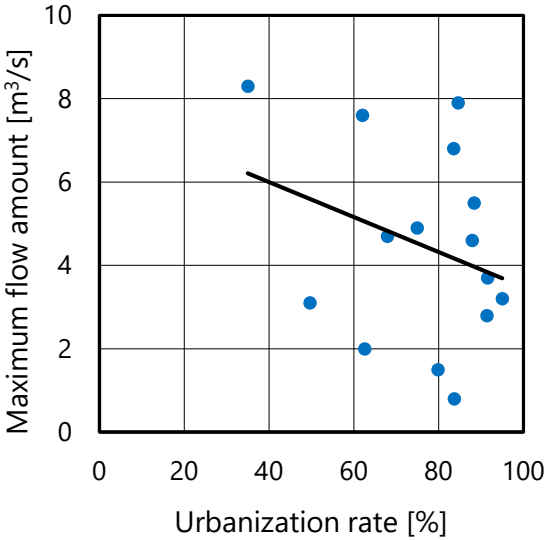
Catchment area



Scatterplot between catchment area and maximum flow amount

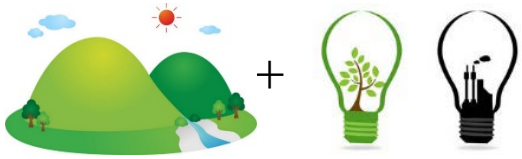
Effective as a factor

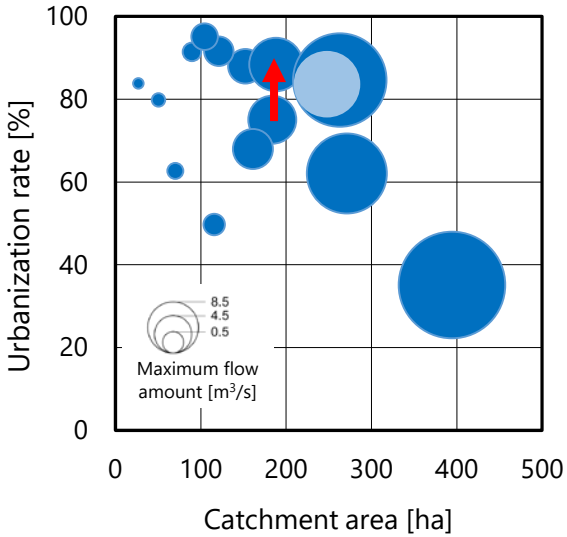
Urbanization rate



Scatterplot between urbanization rate and maximum flow amount

Catchment area + Urbanization rate



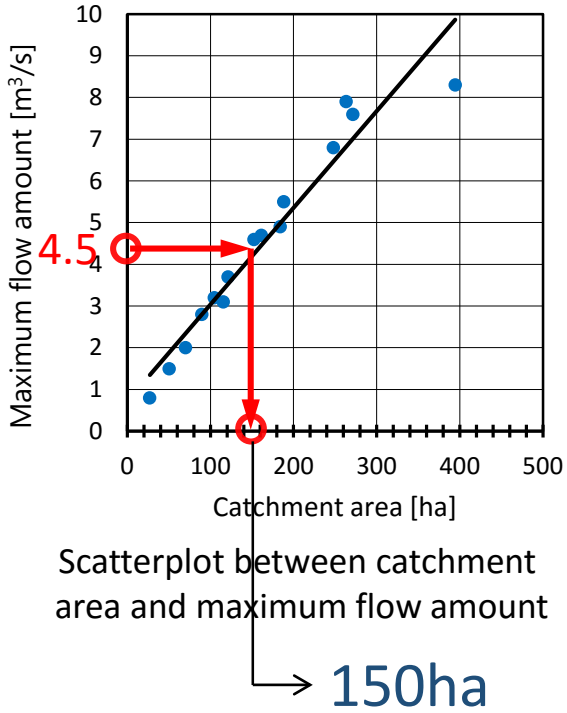


Scatterplot between catchment area, urbanization rate and maximum flow amount

Some tendency

Classification based on hydrological environment analysis

Catchment area

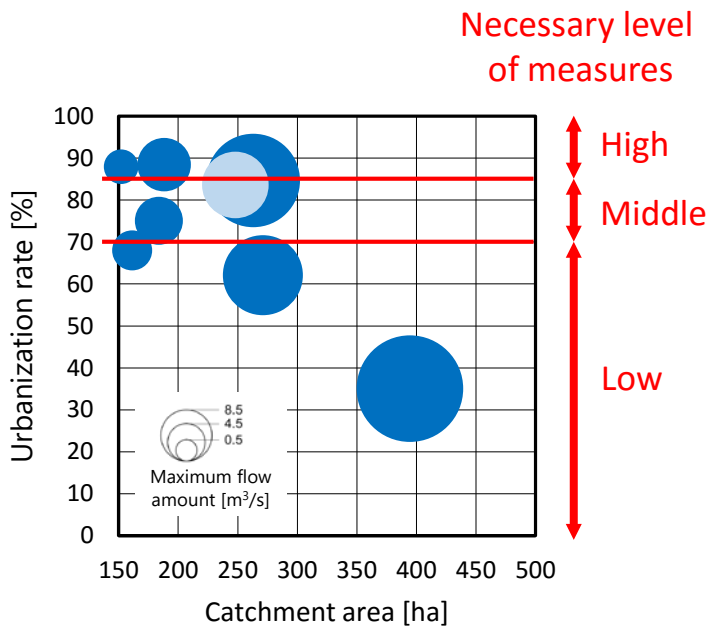


Scatterplot between catchment area and maximum flow amount

Average maximum flow amount: 4.5m³/s

Classified based on 150ha

Catchment area & Urbanization rate

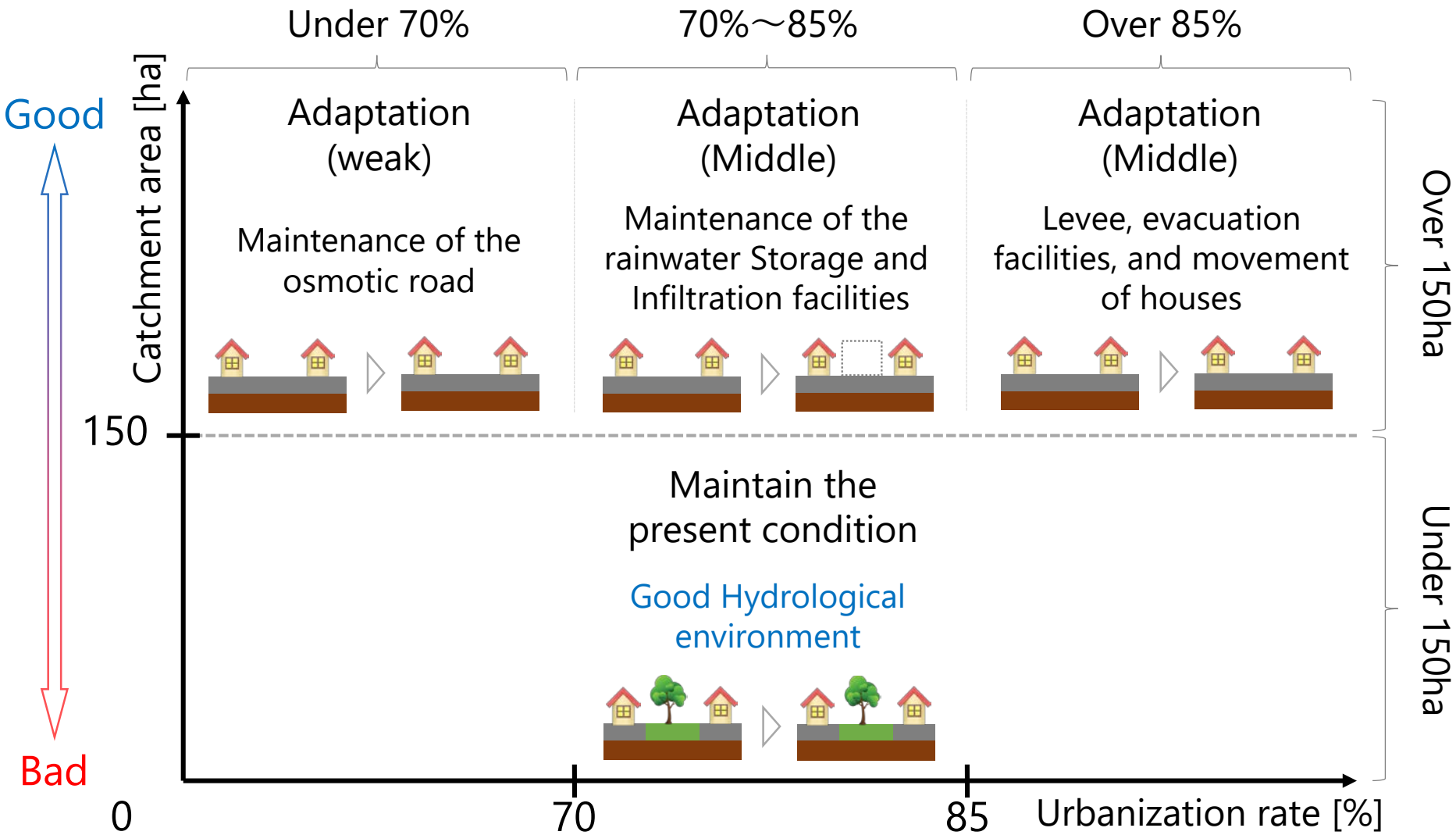


Scatterplot between catchment area, urbanization rate and maximum flow amount

Necessary level of measures is decided based on “urbanization rate” (only over 150ha)

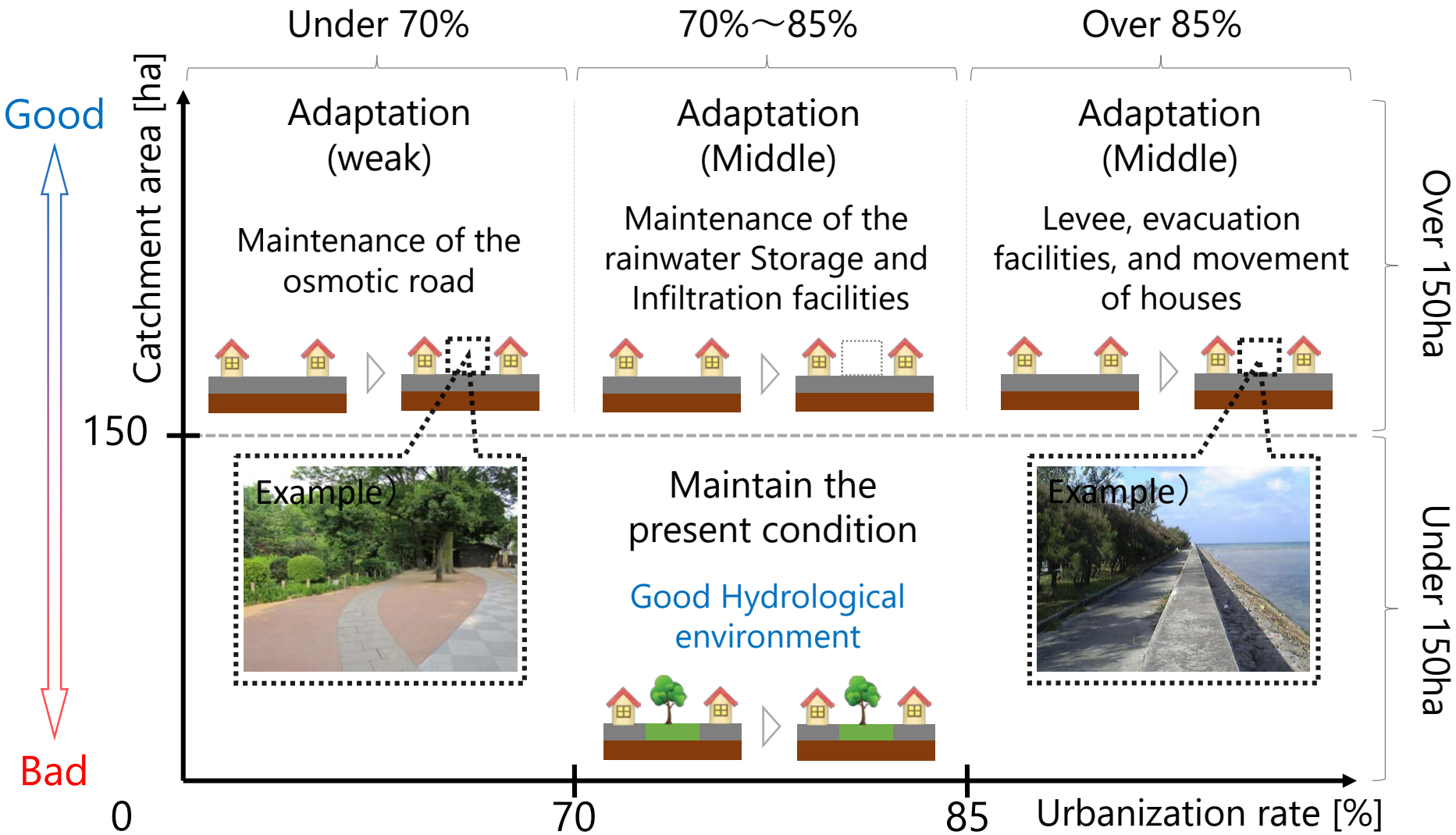
Classification based on hydrological environment analysis

Classification results and measures policy for hydrological environment



Classification based on hydrological environment analysis

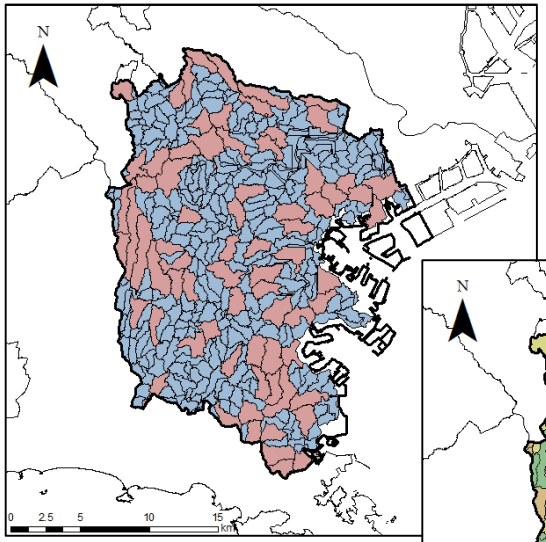
Classification results and measures policy for hydrological environment



Contents

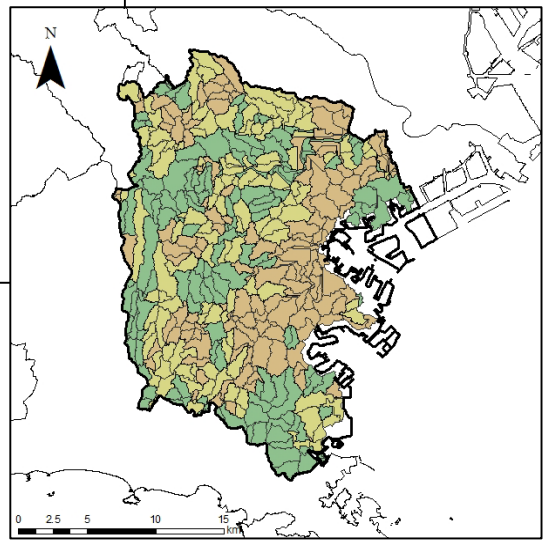
Evaluation and Suggestion for every types of “Yato”

	Urbanization rate Over 85%	Urbanization rate 70%～85%	Urbanization rate Under 70%
Catchment area Over 150ha	Type (1)	Type (2)	Type (3)
Catchment area Under 150ha	Type (4)	Type (5)	Type (6)



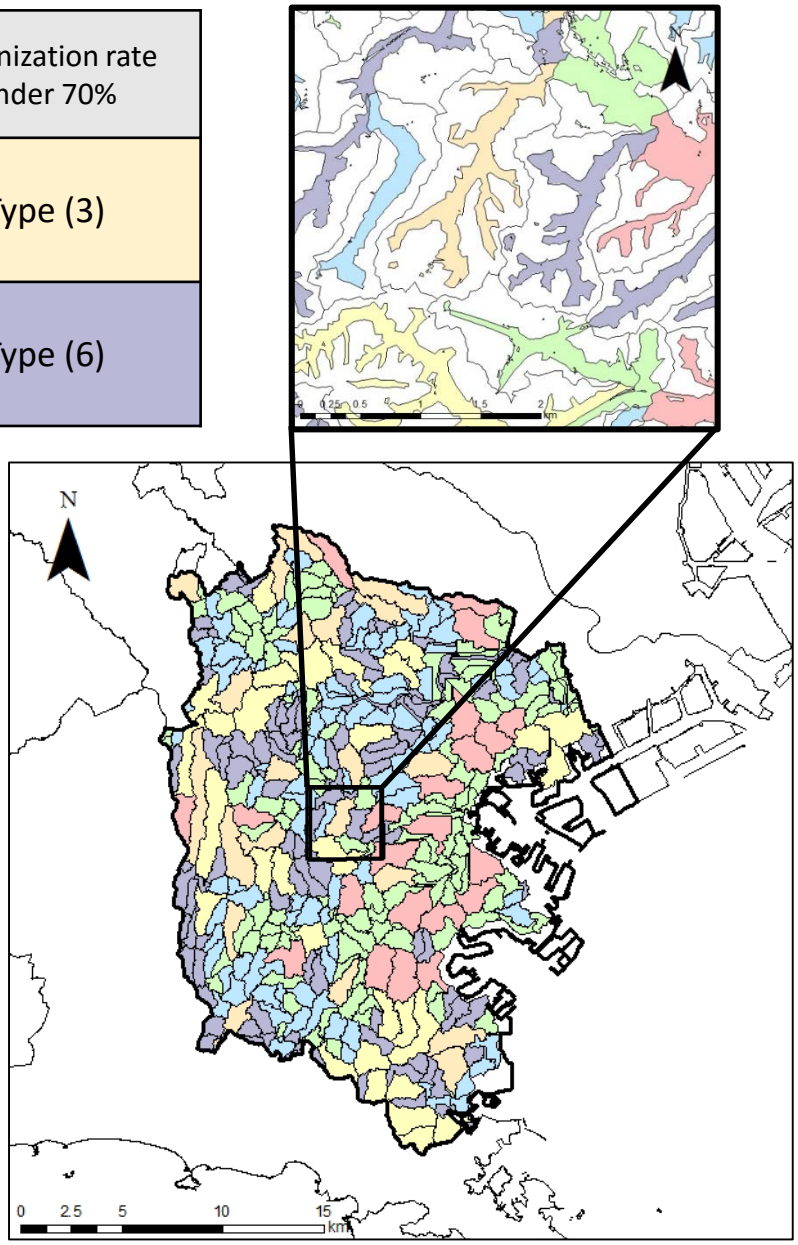
Catchment area

- ~ 150ha
- 150ha~



Urbanization rate

- ~ 70%
- 70% ~ 85%
- 85% ~



Evaluation and Suggestion for every types of “Yato”

Consideration levels			–	Type of Yato					
			No	(1)	(2)	(3)	(4)	(5)	(6)
Maintain the present condition（○） Consideration is need（△） Consideration is particularly need（▲）			Catchment area	Over 150ha	Over 150ha	Over 150ha	Under 150ha	Under 150ha	Under 150ha
			Urbanization rate	Over 85%	70%～85%	Under 70%	Over 85%	70%～85%	Under 70%
Measures to urban warming	–	Maintaining present green area				○			
	Adaptation	Improvement of lifestyle .....(i)					△	△	△
		Shading.....(ii)					△	△	△
		Improvement of artificial pavement.....(iii)					△	▲	▲
	Mitigation	Microclimate relaxation by greening.....(iv)		△	△		△	▲	
		Increase of green ratio in bottom area of Yato.....(v)		▲	▲		△		
		Increase of green ratio in slope area of Yato.....(v)		▲			△		
		Increase of green ratio by shrinking urbanised area					▲		
Measures to flood damage	–	Maintenance of green area					○	○	○
	Adaptation	Restraint of flow amount by preparation of osmotic street space.....(vi)		△	△	△			
		Improvement penetration rate by equiping rainwater storage and infiltration facilities.....(vii)		△	△	▲			
		Prevention of flood by equiping evacuation facilities.....(viii)		△	▲				
		Safety management by moving buildings in hazard area.....(ix)		▲					

<u>Specific examples</u>

(i) Prevention of heat stroke, cool biz, water sprinkling

(ii) Installation of fractal sunshade, pergola and arcade

(iii) Installation of permeable pavement and high reflection pavement

(iv) Improvement of building surface i.e. exterior materials and green roof, creating small forests in public area such as urban parks

(v) Greening roadside and parking lot, planting street trees and greening for wide area in type 4 and 6

(vi) Osmotic street space: green street

Example） Rainfall planter type…digging into ground and creating rainfall planter in space between sidewalk and curb stone

(vii) Installation of infiltration inlet and trench ,permeable pavement and underground reservoir

(viii) Maintanance of levee, river wall and evacuation facilities

(ix) Hazard area: inundation hazardous areas

Evaluation and Suggestion for every types of “Yato”

	Consideration levels		–	Type of Yato		
			No	(1)	(2)	(3)
	Maintain the present condition（○） Consideration is need（△） Consideration is particularly need（▲）		Catchment area	Over 150ha	Over 150ha	Over 150ha
			Urbanization rate	Over 85%	70%～85%	Under 70%
Measures to urban warming	–	Maintaining present green area				○
	Adaptation	Improvement of lifestyle ……(i)				
		Shading……(ii)				
		Improvement of artificial pavement……(iii)				
	Mitigation	Microclimate relaxation by greening……(iv)		△	△	
		Increase of green ratio in bottom area of Yato……(v)		▲	▲	
		Increase of green ratio in slope area of Yato……(v)		▲		
		Increase of green ratio by shrinking urbanised area				
Measures to flood damage	–	Maintenance of green area				
	Adaptation	Restraint of flow amount by preparation of osmotic street space……(vi)		△	△	△
		Improvement penetration rate by equiping rainwater storage and infiltration facilities……(vii)		△	△	▲
		Prevention of flood by equiping evacuation facilities……(viii)		△	▲	
		Safety management by moving buildings in hazard area……(ix)		▲		

(v) Greening roadside and parking lot, planting street trees and greening for wide area in type 4 and 6

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(ix) Hazard area: inundation hazardous areas

Evaluation and Suggestion for every types of “Yato”

	Consideration levels		–	Type of Yato		
			No	(4)	(5)	(6)
	Maintain the present condition（○） Consideration is need（△） Consideration is particularly need（▲）		Catchment area	Under 150ha	Under 150ha	Under 150ha
			Urbanization rate	Over 85%	70%～85%	Under 70%
Measures to urban warming	–	Maintaining present green area				
	Adaptation	Improvement of lifestyle ……(i)		△	△	△
		Shading……(ii)		△	△	△
		Improvement of artificial pavement……(iii)		△	▲	▲
	Mitigation	Microclimate relaxation by greening……(iv)		△	▲	
		Increase of green ratio in bottom area of Yato……(v)		△		
		Increase of green ratio in slope area of Yato……(v)		△		
		Increase of green ratio by shrinking urbanised area		▲		
Measures to flood damage	–	Maintenance of green area		○	○	○
	Adaptation	Restraint of flow amount by preparation of osmotic street space……(vi)				
		Improvement penetration rate by equiping rainwater storage and infiltration facilities……(vii)				
		Prevention of flood by equiping evacuation facilities……(viii)				
		Safety management by moving buildings in hazard area……(ix)				

(v) Greening roadside and parking lot, planting street trees and greening for wide area in type 4 and 6

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Example）Rainfall planter type…digging into ground and creating rainfall planter in space between sidewalk and curb stone

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(ix) Hazard area: inundation hazardous areas

Evaluation and Suggestion for every types of “Yato”

	Consideration levels		–	Type of Yato					
			No	(1)	(2)	(3)	(4)	(5)	(6)
	Maintain the present condition（○） Consideration is need（△） Consideration is particularly need（▲）		Catchment area	Over 150ha	Over 150ha	Over 150ha	Under 150ha	Under 150ha	Under 150ha
			Urbanization rate	Over 85%	70%～85%	Under 70%	Over 85%	70%～85%	Under 70%
Measures to urban warming	–	Maintaining present green area				○			
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	Mitigation	Microclimate relaxation by greening.....(iv)		△	△		△	▲	
		Increase of green ratio in bottom area of Yato.....(v)		▲	▲		△		
		Increase of green ratio in slope area of Yato.....(v)		▲			△		
		Increase of green ratio by shrinking urbanised area					▲		
Measures to flood damage	–	Maintenance of green area					○	○	○
	Adaptation	Restraint of flow amount by preparation of osmotic street space.....(vi)		△	△	△			
		Improvement penetration rate by equiping rainwater storage and infiltration facilities.....(vii)		△	△	▲			
		Prevention of flood by equiping evacuation facilities.....(viii)		△	▲				
		Safety management by moving buildings in hazard area.....(ix)		▲					

Mitigation	Microclimate relaxation by greening.....(iv)	△
	Increase of green ratio in bottom area of Yato.....(v)	▲
	Increase of green ratio in slope area of Yato.....(v)	▲

Adaptation	Restraint of flow amount by preparation of osmotic street space.....(vi)	△
	Improvement penetration rate by equiping rainwater storage and infiltration facilities.....(vii)	△
	Prevention of flood by equiping evacuation facilities.....(viii)	△
	Safety management by moving buildings in hazard area.....(ix)	▲

Example plan for type (1)

Evaluation and Suggestion for everys type of “Yato”

Type (1)

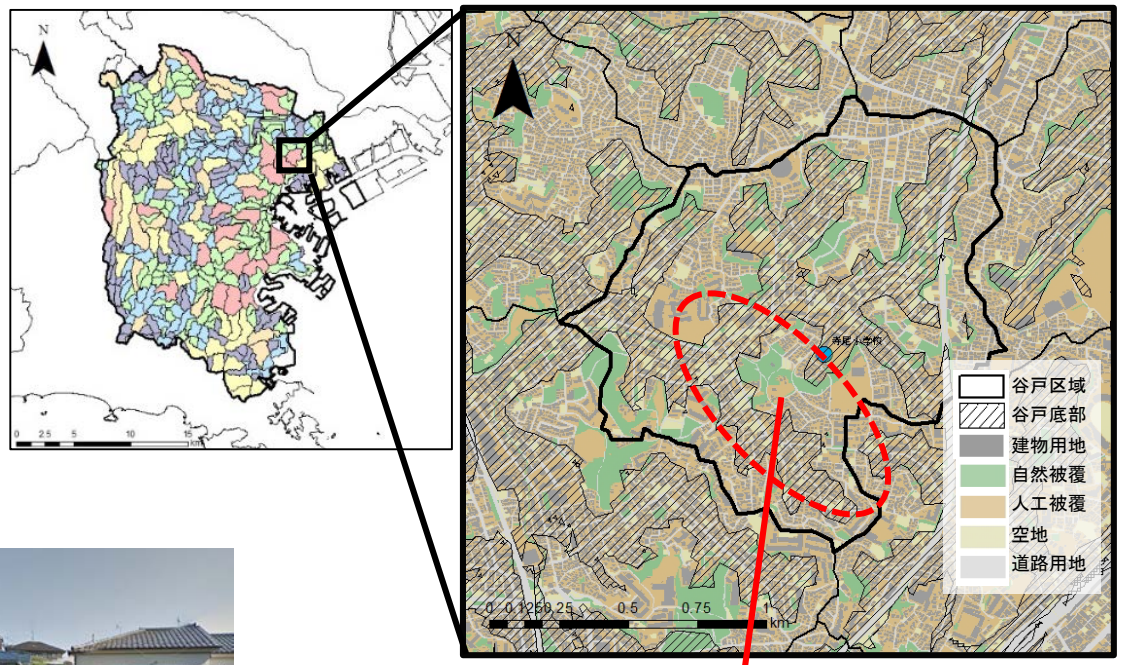
Yato including point 11

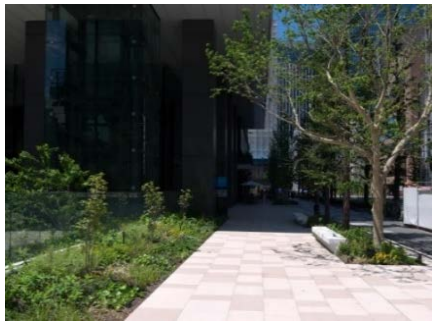
- Catchment area: 152.4ha (over 150ha)
- Urbanization rate: 90.0% (over 85%)

Urbanization rate is reduced to 70%

75 % of underdeveloped infrastructure zone is greened

- Greening roadside
- introducing osmotic street space





Rainfall planter

underdeveloped infrastructure zone

Introduction area

- Urbanized area
- Narrow road width

(Infrastructure is underdeveloped)

Contents

Summary

In this study, Yato located in Yokohama city is classified into six type based on thermal and hydrological environment analysis and future measures policy for each type of Yato is suggested.

Effective factors on thermal environment of Yato
"Catchment area"
"Urbanization rate"

+

Effective factors on thermal environment of Yato
"Catchment area"
(Setting necessary level of measures based on "urbanization rate")

<u>Future work</u>

- Improvement of hydrological simulation
- Evaluating effectiveness of utilizing Yato as GI to outside Yato area

Thank you for your kind attention !

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