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

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Background

Problems
- Global Warming
- Urban Heat Island

Influences
- Urban Warming
- Flood damage

Localized Heavy Rain
- Flood

Climate Change

The need of countermeasures to urban warming and flood damage
Green Infrastructure utilizing natural function is proposed as effective measure

**Background**

**Countermeasure to urban warming**
- Reduction of anthropogenic heat

**Countermeasure to flood damage**
- Improvement of the sewage system
- Natural penetration

**Greening**

**Improving urban form**
- Rainwater storage permeating facility

Green Infrastructure utilizing natural function is proposed as effective measure.
Green infrastructure in urban area is classified into two types.

- **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**

<table>
<thead>
<tr>
<th>Thermal environment (Air temperature)</th>
<th>Hydrological environment (Flow amount)</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

Classification

<table>
<thead>
<tr>
<th>Suggestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A</td>
</tr>
<tr>
<td>Thermal environment</td>
</tr>
<tr>
<td>Hydrological environment</td>
</tr>
</tbody>
</table>

Maintain Shrink

Type B (example)

- Air temperature: High
- Flow amount: High

Classification of "Yato" as Green Infrastructure
Contents

- Background
- Target Area
- Thermal environment of “Yato”
- Hydrological environment of “Yato”
- Evaluation and Suggestion for every types of “Yato”
- Summary
Yokohama city, Japan

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

Target Area

Area: 437.4 [km²]
Population: 3.7million [persons]
Yato map is made from elevation map

Extracting all Yato in Yokohama
Contents

✓ Background
✓ Target Area
✓ Thermal environment of “Yato”
✓ Hydrological environment of “Yato”
✓ Evaluation and Suggestion for every types of “Yato”
✓ Summary
Field measurement of air temperature

Observation points: 34 Stevenson screens located at elementary schools in Yokohama (Inside Yato: 17 points, Outside Yato: 17 points)
Period: July 25th 2016 – September 5th 2016
Interval: 10 minutes

Outline of Field measurement of air temperature
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 isn’t remarkable
(Almost observation points locate outside Yato)

Sea breeze effect is remarkable

Factors on air temperature inside Yato is differ to general urbanized area
Horizontal hourly average air temperature distribution of sunny days

Result in 2015 (14:00)

Sea breeze effect isn’t remarkable
(Almost observation points locate outside Yato)

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

Result in 2016 (14:00)

Air temperature [°C] (14:00)

-30.9
31.0-31.4
31.5-31.9
32.0-32.4
32.5-32.9
33.0-

Correlation coefficient

Hourly correlation coefficient between air temperature and distance from coastline

Distance from coastline

Sea breeze effect is remarkable

Result and factorial analysis of thermal environment
Result and factorial analysis of thermal environment

Item of the classification according to the type

<table>
<thead>
<tr>
<th>Location (Coast or inland)</th>
<th>Catchment area</th>
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<tbody>
<tr>
<td>Urbanization rate</td>
<td>Direction</td>
</tr>
</tbody>
</table>
Result and factorial analysis of thermal environment

Catchment area

Daytime (14:00)

Nighttime (2:00)

Scatterplot of air temperature and catchment area

- Inside Yato
- Outside Yato

Catchment area is effective factor in nighttime
Result and factorial analysis of thermal environment

Urbanization rate is effective factor in daytime and nighttime

Scatterplot of air temperature and urbanization rate

Inside Yato
Outside Yato
Result and factorial analysis of thermal environment

Catchment area

Urbanization rate

Cold air drainage effect?

Daytime (14:00)

Nighttime (2:00)

Air temperature [°C]

Catchment area [ha]

Air temperature [°C]

Urbanization rate [%]

Air temperature [°C]

Urbanization rate [%]

Daytime
Nighttime

Daytime
Nighttime
Analysis by using shallow water equation

Cold air amount calculated by shallow water equation

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

Hourly correlation coefficient between nighttime air temperature and cold air amount
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)
- Average minimum air temperature = 25°C
- Classified based on 150ha

**Urbanization rate (Daytime)**
- Scatterplot of air temperature and urbanization rate (14:00)
- Average maximum air temperature = 32°C
- Classified based on 70%

**Urbanization rate (Nighttime)**
- Scatterplot of air temperature and urbanization rate (2:00)
- Average minimum air temperature = 25°C
- Classified based on 85%
Classification based on thermal environment analysis

Classification results and measures policy for thermal environment

- Under 70%
  - Maintain the present condition
  - Good Thermal environment
  - Adaptation (weak)
  - Poor space for greening

- 70%~85%
  - Mitigation (weak)
  - Enough space for greening
  - Adaptation (strong)
  - Poor space for greening

- Over 85%
  - Mitigation (strong)
  - Enough space for greening
  - Shrink urban area
  - Bad thermal environment

Catchment area [ha]

0 70 85

Urbanization rate [%]

Over 150 ha

Under 150 ha

Good Thermal environment

Mitigation

Adaptation

Shrink urban area

Bad thermal environment

Good Thermal environment

Mitigation

Adaptation

Shrink urban area
Classification based on thermal environment analysis

Classification results and measures policy for thermal environment

- **Under 70%**
  - Good Thermal environment
  - Maintain the present condition

- **70%~85%**
  - Mitigation (weak)
  - Example

- **Over 85%**
  - Mitigation (strong)
  - Enough space for greening
  - Shrink urban area
  - Bad thermal environment

- **Catchment area [ha]**
  - Under 150ha
  - Over 150ha

- **Urbanization rate [%]**
  - Under 70%
  - 70%~85%
  - Over 85%

- **Examples**
  - Poor space for greening
  - Enough space for greening
✓ Background
✓ Target Area
✓ Thermal environment of “Yato”
✓ Hydrological environment of “Yato”
✓ Evaluation and Suggestion for every types of “Yato”
✓ Summary
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
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

<table>
<thead>
<tr>
<th>No.</th>
<th>1</th>
<th>5</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>15</th>
<th>20</th>
<th>22</th>
<th>23</th>
<th>27</th>
<th>29</th>
<th>31</th>
<th>33</th>
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</thead>
<tbody>
<tr>
<td>max. flow amount [m³/s]</td>
<td>4.9</td>
<td>8.3</td>
<td>1.5</td>
<td>3.1</td>
<td>2.0</td>
<td>4.6</td>
<td>3.7</td>
<td>5.5</td>
<td>2.8</td>
<td>3.2</td>
<td>4.7</td>
<td>7.9</td>
<td>6.8</td>
<td>0.8</td>
<td>7.6</td>
</tr>
</tbody>
</table>
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

Some tendency

Catchment area + Urbanization rate

Scatterplot between catchment area, urbanization rate and maximum flow amount
Classification based on hydrological environment analysis

Scatterplot between catchment area and maximum flow amount

- **150ha**

Average maximum flow amount: 4.5 m$^3$/s

Classified based on 150ha

Scatterplot between catchment area, urbanization rate, and maximum flow amount

- **Necessary level of measures**
  - High
  - Middle
  - Low

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

- **Under 70%**
  - Adaptation (weak)
  - Maintenance of the osmotic road

- **70%~85%**
  - Adaptation (Middle)
  - Maintenance of the rainwater Storage and Infiltration facilities

- **Over 85%**
  - Adaptation (Middle)
  - Levee, evacuation facilities, and movement of houses

- **Good Hydrological environment**
  - Maintain the present condition

- **Catchment area [ha]**
  - Under 150ha
  - Over 150ha

- **Urbanization rate [%]**
  - Under 70%
  - 70%~85%
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Classification based on hydrological environment analysis

Classification results and measures policy for hydrological environment

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**Catchment area [ha]**
- Under 150ha
- Over 150ha

**Urbanization rate [%]**
- Under 70%
- 70%~85%
- Over 85%

- **Good**
- **Bad**
Evaluation and Suggestion for every types of “Yato”

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<th>Urbanization rate</th>
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<tbody>
<tr>
<td></td>
<td>Over 85%</td>
<td>70% ~ 85%</td>
<td>Under 70%</td>
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<tr>
<td>Over 150ha</td>
<td>Type (1)</td>
<td>Type (2)</td>
<td>Type (3)</td>
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<tr>
<td>Under 150ha</td>
<td>Type (4)</td>
<td>Type (5)</td>
<td>Type (6)</td>
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</tbody>
</table>

Catchment area

- ~ 150ha
- 150ha ~

Urbanization rate

- ~ 70%
- 70% ~ 85%
- 85% ~
# Evaluation and Suggestion for every types of “Yato”

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<td>Adaptation</td>
<td>Consideration is need (△)</td>
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<tr>
<td>Mitigation</td>
<td>Consideration is particularly need (▲)</td>
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<tr>
<td></td>
<td>Catchment area Over 150ha</td>
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<td>Under 150ha</td>
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<td>Measures to flood damage</td>
<td>Maintain the present condition (○)</td>
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<td>Adaptation</td>
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### Specific examples

1. Prevention of heat stroke, cool biz, water sprinkling
2. Installation of fractal sunshade, pergola and arcade
3. Installation of permeable pavement and high reflection pavement
4. Improvement of building surface i.e. exterior materials and green roof, creating small forests in public area such as urban parks
5. Greening roadside and parking lot, planting street trees and greening for wide area in type 4 and 6
6. Osmotic street space: green street
   
   **Example**）Rainfall planter type...digging into ground and creating rainfall planter in space between sidewalk and curb stone
7. Installation of infiltration inlet and trench, permeable pavement and underground reservoir
8. Maintenance of levee, river wall and evacuation facilities
9. Hazard area: inundation hazardous areas
# Evaluation and Suggestion for every types of “Yato”

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<td>Consideration is particularly need (▲)</td>
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<tr>
<td>Maintenance of green area</td>
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<tr>
<td>Improvement of lifestyle</td>
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<td>Improvement of artificial pavement</td>
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<td>Microclimate relaxation by greening</td>
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<tr>
<td>Increase of green ratio in bottom area of Yato</td>
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<tr>
<td>Increase of green ratio in slope area of Yato</td>
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<td>Increase of green ratio by shrinking urbanised area</td>
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<tr>
<td>Measures to flood damage</td>
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<tr>
<td>Adaptation</td>
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<tr>
<td>Restraint of flow amount by preparation of osmotic street space</td>
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<tr>
<td>Improvement penetration rate by equiping rainwater storage and infiltration facilities</td>
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<tr>
<td>Prevention of flood by equiping evacuation facilities</td>
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<tr>
<td>Safety management by moving buildings in hazard area</td>
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( 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) Maintainance of levee, river wall and evacuation facilities
(ix) Hazard area: inundation hazardous areas
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<td>Improvement of lifestyle ......( i )</td>
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<td>Shading......( ii )</td>
<td>△</td>
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<td></td>
<td>Improvement of artificial pavement......( iii )</td>
<td>△</td>
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<td>Mitigation</td>
<td>Microclimate relaxation by greening......( iv )</td>
<td>△</td>
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<tr>
<th>Measures to flood damage</th>
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| Mitigation               | — | Type of Yato |
|--------------------------|—— |—— |
|                          | Consideration is need (△) | — |
|                          | Microclimate relaxation by greening......( iv ) | (1) |
|                          | Increase of green ratio in bottom area of Yato......( v ) | (2) |
|                          | Increase of green ratio in slope area of Yato......( v ) | (3) |

Example plan for type (1):

- Restraint of flow amount by preparation of osmotic street space......
- Improvement penetration rate by equiping rainwater storage and infiltration facilities......
- Prevention of flood by equiping evacuation facilities......
- Safety management by moving buildings in hazard area......
Evaluation and Suggestion for every 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

Introduction area
- Urbanized area
- Narrow road width (Infrastructure is underdeveloped)
Contents

✓ Background
✓ Target Area
✓ Thermal environment of “Yato”
✓ Hydrological environment of “Yato”
✓ Evaluation and Suggestion for every types of “Yato”
✓ Summary
Summary

In this study, Yato located in Yokohama city is classified into six types 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”)

Future work
• 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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