Mapping of Green Infrastructure in Sakura City, Central Japan Focusing on Local Climate Mitigation

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Abstract: In recent years, there has been a need for sustainable regional development that combines ecosystem conservation with an improved resilience to disasters and other disturbances. Interconnected networks of green spaces can conserves natural ecosystems' values and functions, while providing various benefits, including improved resilience, to human populations. Green Infrastructure is thus a basic ecological framework needed for environmental, social and economic sustainability. Green infrastructures, however, vary widely from region to region, and detailed maps are thus critical data for regional planning, including risk reduction strategies and habitat assessments. This study is designed to create a green infrastructure map at the municipal scale, which is the basic level of regional planning and management. The study is implemented in Sakura City, population 170,000, located south of Lake Inbanuma in the northwestern part of Chiba Prefecture. The city contains many suburban residential districts. Other parts of the city, however, remain agricultural, with dry vegetable fields and orchards on the plateau-like uplands, and irrigated rice paddies on the alluvial plain and along the bottom of the narrow, highly branched river valleys. These valleys are fringed by heavily forested slopes, and form vital wildlife habitat. The research adopted the classification of green area functions, such as watershed protection, flood risk reduction and localized climate mitigation, proposed by the Green Infrastructure Research Group (2017). Localized climate mitigation was selected for detailed analysis. Landsat8/TIRS data, acquired on May 23, 2017, was used to generate a land surface temperature map using equations based on Irie (2017). These results were then compared with a Land Use/Land Cover map derived from the Ministry of Environment Vegetation Map for Sakura City, and the effects of localized climate mitigation were evaluated in five stages from 1 (low) to 5 (high). The results showed that climate mitigation benefits were high in the area adjacent to Lake Inbanuma, and also in the forested areas. In residential districts the benefits were enhanced by neighborhood parks and street trees. Paddy fields were also found to be highly effective in mitigating local climate, and are especially important where the agricultural lands border closely on residential districts.

1. INTRODUCTION

In recent years there has been a growing demand for regional planning that combines ecological sustainability with increased resilience against natural disasters as earthquakes, torrential rains and localized heat islands. More and more, green infrastructure has been identified as an effective way of meeting this demand. Green infrastructure protects natural ecosystems and their functions, while at the same time providing a range of services and benefits to the regional population. Green infrastructure provides the ecological base for environmental, social and economic sustainability (Benedict and McMahon, 2002).

The function and benefits of green infrastructure, however, differ between urban and rural areas. (Nishida, 2017).In order to effectively integrate green infrastructures into regional management, a 'Green Infrastructure Map', detailing the spatial characteristics of the target region, is required (Firehock and Walker, 2015). Such a map facilitates evaluation of areas as habitat for wildlife and other functions; and can be expected to improve efficiency in utilizing green infrastructures in regional planning. The map, however, must be generated at the most suitable scale, and must be able to show multiple functions for different types of green infrastructure within the target area.

With these requirements in mind, this research presents a case study for developing a green infrastructure map. The scale adopted is a single municipality, which serves as the natural unit for regional planning and management. Sakura City, located in northwestern Chiba Prefecture, was chosen as the target region. Based on Ministry of Environment Vegetation Maps and field work, seven typical land use patterns in the municipality were identified and evaluated as to their effectiveness in providing services and benefits. The services and benefits were classified based on categories established by the Green Infrastructure Research Group (2017). Mitigation of localized climate effects was then chosen as an example to illustrate the process of evaluating green infrastructure benefits and services based on local land cover and land use patterns.

2. RESEARCH AREA

The entire municipal area of Sakura City was chosen as the target region (Figure-1). Sakura City has a population of about 170,000. The city borders on Lake Inbanuma, and contains several rivers that drain into the lake. In their middle and upper reaches these rivers comprise a complicated network of narrow, forking valleys, known locally as *yatsu*, that cut deep into a broad plateau-like upland. The *yatsu* valley bottoms are traditionally planted in irrigated rice paddies, and the steep slopes rising from the valleys to the uplands are covered with several different types of forest. The population of the city is concentrated in suburban style housing developments on top of the uplands, but the *yatsu* valleys with their slope forests play a vital role in supporting regional biodiversity and ecosystems. This close mix of agricultural lands and urban landscapes is a characteristic of Sakura City and other suburban areas that must be identified and analyzed in the green infrastructure map.

Figure-1 Map of Sakura City

3. DATA AND METHODS

3.1 LAND USE/LAND COVER MAP

Vegetation maps for the research area, produced by the Japanese Ministry of Environment, were used to generate a land use/land cover (LU/LC) map for Sakura City (Figure-2). Seven categories of land use, Bare land, Water, Urban, Paddy, Farmland (non-irrigated fields on the uplands), Grassland and Forest, were extracted from the vegetation map and confirmed by fieldwork conducted in August of 2018 (Figure-3). Basic descriptions and preliminary qualitative evaluations for six of the LU/LC categories are presented below.

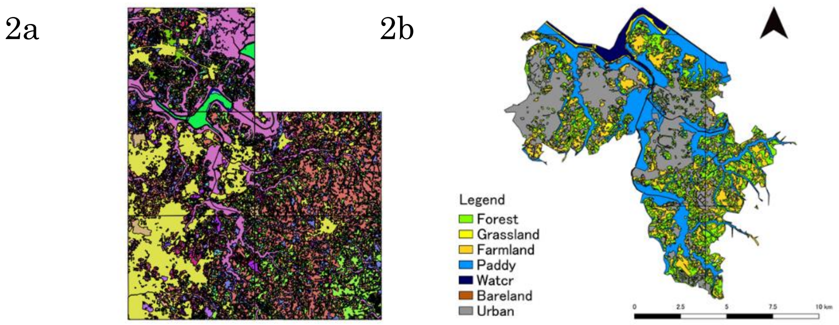


Figure-2 Ministry of Environment Vegetation Map (2a) and LU/LC Map (2b) for Sakura City

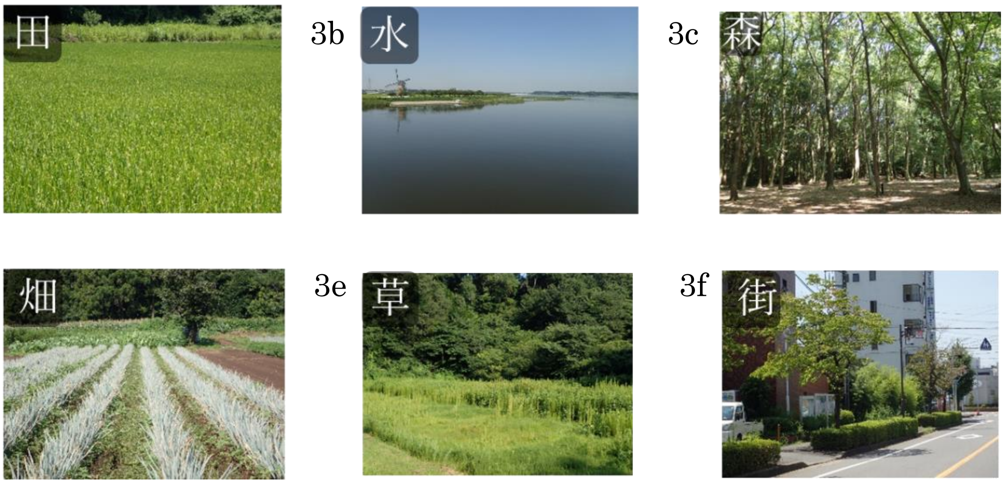


Figure-3 Major Land Use Categories 3a Paddy 3b Water; 3c Forests; 3d Farmland; 3e Grassland; 3f Urban. All photographs taken 01 Aug 2018.

PADDY Irrigated rice paddies are found on the broad alluvial plain surrounding Lake Inbanuma, and also on the *yatsu* valley bottoms. In addition to their obvious service of supplying the local population with a major food source, the paddies also serve as vital wildlife habitat. Paddies and their associated irrigation canals and ponds also function to stabilize the watershed and help prevent floods (Hayase, 1994; Masumoto et al, 2002).

WATER Lake Inbanuma is a large, shallow body of water rimmed with reed beds and other aquatic vegetation communities. The lake is a major regional source of industrial, agricultural and household water. In the past the lake fisheries also provided a vital supply of protein. The reed beds around the edge of the lake are important breeding and wintering habitat for a variety of waterfowl. Boating and fishing provide recreational activities, and a bike path follows the levees around the lake.

FOREST Sakura City contains a wide variety of forest types, including secondary woodlands, conifer plantations, bamboo groves and groves of native evergreen broad-leaved groves. The forests filter and purify groundwater, fix carbon dioxide, stabilize slopes and help prevent floods during periods of intensive rain (Hayase, 1994). They are the mainstay of local biodiversity, and provide wood, fuel, compost and building materials. People enjoy strolling in the forest provides people with numerous holistic health benefits.

FARMLAND The upland portions of Sakura City are widely planted in non-irrigated fields used to grow a wide variety of vegetables throughout the year. Fresh local produce, supplied daily to supermarkets and roadside stands, is a major service provided by these farmlands. The crops also help prevent wind erosion on the top of the uplands.

GRASSLAND Grasslands are found on abandoned farmland, and in parkland and undeveloped areas. In the past these habitats provided fuel, thatch, feed and compost materials. Today they offer recreational services, support biodiversity and in areas close to residential sectors serve as emergency evacuation spots.

URBAN The residential areas of Sakura City provide vital urban functions such as shopping and entertainment. Many sections contain abundant street trees and neighborhood parks that provide shade and mitigate temperatures, and as local and exercise grounds provide welfare and holistic health benefits.

3.2 GREEN INFRASTRUCTURE BENEFITS AND SERVICES

The Green Infrastructure Research Group (2007) lists numerous benefits and services potentially provided by green infrastructure. For the purpose of this research, these benefits and services were classified into three categories.

RESILIENCE Services that prevent or mitigate damage due to natural disasters such as earthquakes, landslides, tsunami and floods.

SUSTAINABILITY Services that protect the water supply and circulation of water within the watershed, maintain water and air quality, enhance local supply of food and other materials, mitigate localized climate effects (Hayase, 1994; Masumoto et al., 2002), conserve biodiversity and maintain a natural balance that prevents sudden increases in invasive insects and plants.

LIFESTYLE AND CULTURAL Services that promote a holistically healthy lifestyle, strengthen community ties, protect landscape and scenery, encourage tourism and environmental education and connect local residents with regional history.

From these services and benefits this research chose mitigation of localized climate effects (Sustainability) for in-depth evaluation of the various LU/LC categories as green infrastructure.

3.3 MITIGATION OF LOCALIZED CLIMATE EFFECTS

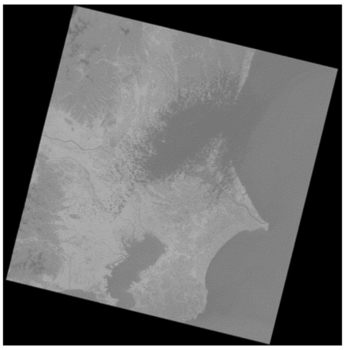
In recent years, as global warming progresses, high temperatures and localized heat islands have become a major cause of concern. In this research, Landsat8/TIRS data covering the entire area was acquired for 23 May 2017, and used to create a Surface Temperature Map for Sakura City (Figure-4). Data from Thermal Infrared Bands 10 and 11 were utilized, and the following equations, based on Irie (2017) were employed.

Equation 1 Thermal Infrared Images (DN values) converted to Top of Atmosphere (TOA) values by: $TAO = ML \times DN \times AL$

Equation 2 TOA converted to Absolute Temperate (K) by: $K = K2 / in(K1 / TAO + 1)$

Equation 3 K converted to Celsius (T) by: $T = K - 273.15$

4a



4b

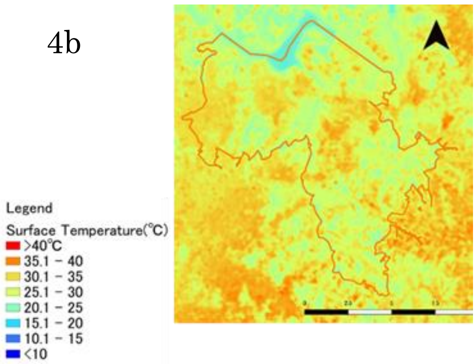


Figure-4 Landsat/TIRS data(4a) and Surface Temperature Map (4b) for Sakura City

4. RESULTS AND DISCUSSION

The Surface Temperature Map generated from the Landsat data was collated with the LU/LC map created from the Ministry of Environment Vegetation Map. Areas with lower temperatures were considered to score high in the ability of mitigate localized climate effects. The mitigation function for each LU/LC class was ranked from 1 (lowest) to 5 (highest). The results are shown in Figure-6 below.

As can be seen, the Water LU/LC class scored highest (5) in this service, followed by Forest and Paddy (4). These results show that these three types of LU/LC play a vital role in mitigating localized climate effects. In addition, urban areas close to rice paddies showed lower temperatures than other urban areas, indicating that the mitigation services provided by the paddies extend into neighboring residential areas as well.

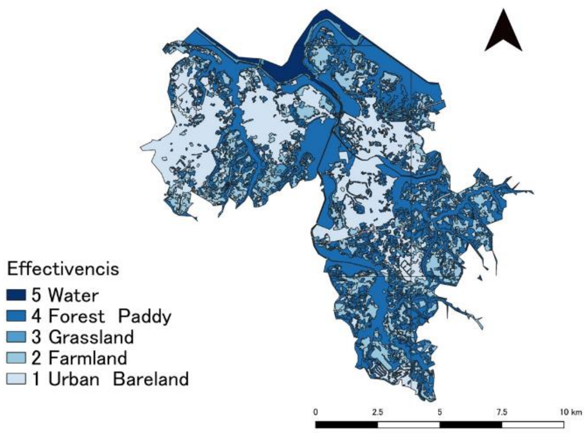


Figure-6 Map of Localized Climate Mitigation for Sakura City

5. CONCLUSIONS

Green infrastructures are vital for maintaining ecological sustainability while enhancing lifestyle services and improving resilience against disasters such as earthquakes, floods, tsunami and landslides. This research takes the first steps towards developing a Green Infrastructure Map, which can serve as a blueprint for effectively integrating green infrastructures into regional planning and management. The map was created at the municipal scale, and evaluated services and benefits provided by different land use/ land cover categories. The results showed that forests, rice paddies and bodies of water are effective for mitigating localized climate effects such as heat islands. Hopefully the results of this study will be of use in green infrastructure-based municipal planning and management.

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