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Measuring and spatial mapping of multiple functions provided by green infrastructure and their contribution to well-being of residents in Sakura City, Japan

Mesure et cartographie spatiale des fonctions multiples assurées par l'infrastructure verte et leur contribution au bien-être des habitants de Sakura, au Japon

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RÉSUMÉ

Les écosystèmes naturels et semi-naturels d'un bassin versant remplissent diverses fonctions pour la société humaine locale, de sorte qu'ils constituent une infrastructure verte fondamentale. Il est donc essentiel, pour une gestion durable des bassins hydrographiques, de déterminer quelles fonctions sont situées à quel endroit et dans quelle mesure ces fonctions répondent aux besoins de la société humaine locale. Cependant, des défis techniques subsistent dans la mesure et la cartographie spatiale des multiples fonctions de l'infrastructure verte, y compris son potentiel (offre) que les écosystèmes naturels et semi-naturels fournissent, les besoins (demande) et l'utilisation réelle (flux) par la société humaine, ainsi que leurs interrelations (pénurie ou excès). Notre recherche vise à développer une nouvelle méthodologie de mesure et de cartographie spatiale des fonctions multiples à travers l'étude de cas menée dans la ville de Sakura, dans la préfecture de Chiba, au Japon. En collaboration avec les parties prenantes locales et les fonctionnaires municipaux, nous avons identifié plusieurs types de fonctions importantes pour les habitants et la ville, notamment le contrôle des inondations, la purification de l'eau, la recharge des nappes phréatiques, la séquestration du carbone, l'éducation à l'environnement, la qualité du paysage et la conservation de la biodiversité. En combinant les méthodologies existantes et nouvelles, nous sommes sur le point d'examiner où se situent ces fonctions multiples et dans quelle mesure elles répondent aux besoins des habitants et de la ville de Sakura. Nous mesurerons également le bien-être des résidents locaux et la contribution de ces multiples fonctions de l'infrastructure verte. Lors de cette présentation, nous exposerons nos derniers résultats de recherche et nous nous pencherons sur les défis à venir.

ABSTRACT

Natural and semi-natural ecosystems in a watershed provide various sorts of functions to the local human society, so that they are recognized as green infrastructure that is the fundamental asset for the society. Thus, considering what functions are located in where and how much these functions meet the needs of the local human society is a key for sustainable watershed management. However, there remain technical challenges in measuring and spatial mapping of multiple functions of green infrastructure, including its potential (supply) that natural and semi-natural ecosystems provide, needs (demand) of and actual usage (flow) by the human society, and their interrelations (shortage or excess). Our research aims at developing a new methodology of measuring and spatial mapping of multiple functions through the case study conducted in Sakura City, Chiba Prefecture, Japan. In collaboration with local stakeholders and city officials, we identified several sorts of functions that are important for the residents and city, including flood control, water purification, groundwater recharge, carbon sequestration, environmental education, scenic quality of landscape, and biodiversity conservation. By combining existing and new methodologies, we are about to examine where these multiple functions are located and how much these functions meet the needs of the residents and Sakura City. Also, well-being of local residents and the contribution of these multiple functions of green infrastructure are about to be measured. In this talk, we will present our latest research results and discuss future challenges.

KEYWORDS

ecosystem services, green infrastructure, new methodology, spatial mapping, subjective well-being

cartographie spatiale, infrastructure verte, nouvelle méthodologie, services écosystémiques, bien-être subjectif

1 GREEN INFRASTRUCTURE IN SAKURA CITY

Sakura City is a part of the Lake Imba watershed, located on the pacific ocean side of central Japan. The topography of the watershed is characterized by the upland, which was formed by the uplift of the seafloor about 120 thousand years ago, and the lowland, which used to be the seafloor during the sea level rise peaked about 6 thousand years ago. The combination of the upland and the lowland forms plenty of small valleys, called *yatsu*. Rainfall on the upland infiltrates into the ground and becomes groundwater, which re-appears on the ground as spring water from the edges of *yatsu* valley floor. This spring water collects to form streams, and eventually flows into the Lake Imba. This topography and water cycle produce the variation of landscape, including wetlands, grasslands, and forests (Figure 1).

Human activities have also influenced the landscape of the watershed. Until around the 1950s, most of the *yatsu* valley floor was used for rice paddy fields, taking advantage of the abundant spring water. In addition, lots of grasses were needed as fertilizer and food for horses and cattle used for farming, and these grasses were obtained from grasslands on the upland and other places. Grasslands and forests on the upland contributed to the recharge of groundwater and the maintenance of spring water. Thus, the water cycle and land use were closely related. However, since the 1960s, paddy fields in the *yatsu* valleys, which are small and difficult to drain, have been abandoned. Since the 1970s, urbanization has progressed on the upland, and land reclamation has also occurred in many *yatsu* valleys. As a result, the number of valleys has decreased to about half of previous numbers, a trend that continues even now. Due to urbanization on the upland, the ground has been covered with concrete and other materials that make the surface impenetrable to rainwater. As a result, the amount of spring water in *yatsu* has also decreased.

The natural and semi-natural ecosystems in the watershed provide various sorts of functions to the local human society or Sakura City (Hirano et al. 2023, Kato et al. in press), so that they are recognized as green infrastructure that is the fundamental asset for the society. For sustainable watershed management, understanding what functions the green infrastructure in the watershed provide and how much the functions meet the needs of the society is necessary.

Figure 1. Green infrastructure located in the Lake Imba watershed and Sakura City therein. Examples include (a) Lake Imba, (b) wetland at the bottom of *yatsu* valley, (c, d) grassland and forest on the upland.

2 MEASURING AND SPATIAL MAPPING OF MULTIPLE FUNCTIONS

There remain technical challenges in measuring and spatial mapping of multiple functions of green infrastructure, including its potential (supply) that natural and semi-natural ecosystems provide, needs (demand) of and actual usage (flow) by the human society (Figure 2). The actual usage of functions depends on the potential or supply of those functions, as well as the needs or demand of those functions by the local residents and the city. Also, whether the functions provided by green infrastructure meet the needs depends on the relationship between the potential and the needs.

Our research aims at developing a new methodology of measuring and spatial mapping of multiple functions, including the potential, needs and actual usage of the functions, through the case study conducted in Sakura City, Chiba Prefecture, Japan. We collaborate with local stakeholders and city officials through regularly scheduled meetings. First, we identified several sorts of functions of green infrastructure that are important for the residents and the city (Figure 2). They include flood control, water purification, groundwater recharge, carbon sequestration, environmental education, scenic quality of landscape, and biodiversity conservation. We then started to examine where these multiple functions are located and how much these functions meet the needs of the residents and Sakura City, by using the existing and newly developed methodologies.

Figure 2. Multiple functions of green infrastructure to be measured in Sakura City (a), including the interrelations among potential, needs and flow and the contributions to well-being of the residents (b).

3 LINKAGE TO THE WELL-BEING OF RESIDENTS

Various functions by green infrastructure support the well-being of residents in Sakura City, although the detailed relationship between the functions and the well-being needs to be explored (Figure 2). We started to measure the well-being of local residents with regard to different components that consist of the well-being. The subjective well-being judged by the local residents is assumed to be the collection of components (Figure 3), including positive emotion, engagement, relationship, meaning of life, achievement, place attachment, spirituality, etc. (Seligman 2011, Krys et al. 2024)

We then construct a statistical model to explain the linkage between multiple functions of green infrastructure and different components of well-being of the residents of Sakura City. In this talk, we will present our latest research results and discuss future challenges.

Figure 3. Linkage between multiple functions of green infrastructure and components of well-being of the residents of Sakura City, to be examined by statistical modelling and spatially illustrated in a map of Sakura City.

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