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Estimating the beneficiaries of ecosystem services with consideration of spatial information

KUNII Daisuke

1. Introduction

As awareness of climate change and environmental issues has increased, so too has the use of the term "ecosystem services (ES)," meaning the benefits people receive from ecosystems. According to Kunii (2016), the number of studies on ES began to increase in the late 1990s, and has increased dramatically since around 2010 when the report from "The Economics of Ecosystems and Biodiversity (TEEB)" was published. As introduced in this journal in FY2018 (Hayashi, 2018), "visualization," enabling people to recognize the value of ES and "mainstreaming," enabling people to recognize the value and take real action, are regarded as important trends in the valuation of ES in recent years. With regards to value assessments of ES, research into economic indexing and mapping at the national level and policy implementation is advancing internationally. In particular, when using ES for policy, it is important to understand the specific service providers and beneficiaries. Taking flood prevention service of forest as an example, this is because residents living in downstream areas of the forest may be able to benefit from the service, while those living upstream are not.

Taking a case of the Kasshigawa River, which flows through Kamaishi City, Iwate Prefecture, this study estimates the beneficiaries of ES with consideration of spatial information. Among ES, this study is particularly focused on flood prevention service and water resource protection service of forest.

2. Method of analysis

The number of households living downstream from each of the tributaries of the Kasshigawa River was calculated by specifying the river basin from elevation data and overlaying the basin on mesh data of the number of households using GIS. Analysis was performed based on the assumption that ES from the target forest are available only to households living in the same basin area as that forest. First, the river basin was determined including not only the entire basin spanning the mouth of the Kasshigawa River to the watershed, but also the basins of the tributaries that branch off from the main stream of the river (termed "sub-basins"). Next, the forest area for each sub-basin was calculated by overlaying the sub-basins data with forest registers data. Finally, we specified the beneficiaries of ES provided by the forests within the sub-basins and estimated their number, adding together the total number of households distributed downstream of each sub-basin. A 10m mesh numerical elevation model [(1)] obtained from the website of the Geospatial Information Authority of Japan was used for elevation data, the 250m mesh population data of the FY2015 regional mesh statistics obtained from the Government Statistics Office [(2)] was used for the number of households, while data on forests in the surveyed area was obtained from forestry registers from the Forestry Agency Japan and Iwate Prefecture.

3. Results of analysis of ecosystem service beneficiaries

First, the distribution of forests and households within the basins is shown in Figure 1, while the results of calculating the forested areas within the basins are shown in Table 1. In the Kasshigawa River Basin, broad-leaves trees are shown in yellow-green in the upper reaches of the river and conifers are shown in green along the river and on mountainsides, in other words, areas that are comparatively easily accessed by people are considered to be used as coniferous planted forest. The forest area within the river basin is 11,787 ha and the total forest area within Kamaishi City is 39,459 ha (calculated by the author using the forestry registry); 29.9% of the city's forests are distributed within the river basin. Moreover, the coverage area of coniferous and broadleaf trees in the total forest area of the basin is 50% and 47%, and the area occupied by national and private forests is 37% and 63%, respectively. These show similar trends in the proportion of forest areas to Iwate Prefecture as a whole. On the

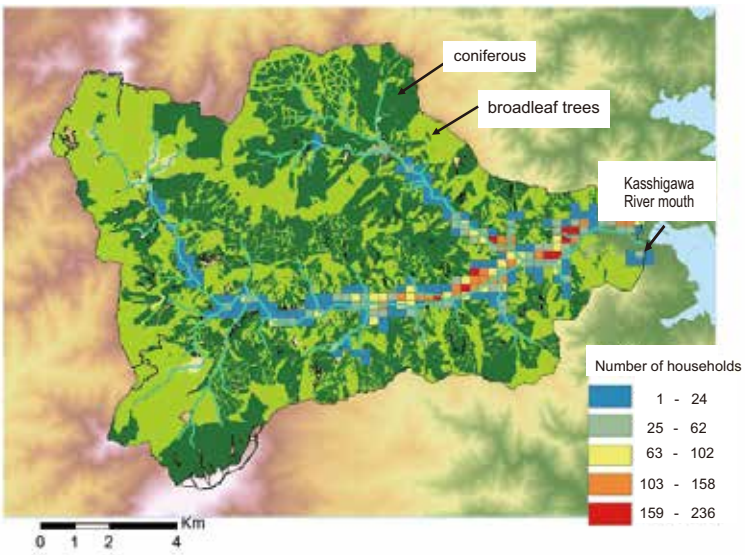

Figure 1. Distribution of forests and households in the Kasshigawa River Basin

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other hand, forest rate in the basin was found to be 90%, which is much higher than that of Iwate Prefecture as a whole, which is 77% (Iwate Prefecture, 2019). In other words, even for Iwate Prefecture, which has one of the highest forest rates in the country, the Kasshigawa River Basin has a particularly high rate, suggesting that the people living in the basin receive many ES from the forests.

Beneficiary households are distributed along the river and are particularly localized within an area approximately 5km from the mouth of the river (Figure 1). The number of households within the basin is calculated to be 10,645, which makes up 63.1% of the 16,860 households in Kamaishi City as a whole (2015 National Census). In other words, 63.1% of the total city's households benefit from flood prevention and water resource protection services provided by 29.9% of Kamaishi City's forests.

Therefore, to analyze which forests are able to provide the services to what number of beneficiaries, we identified the tributaries of the river and calculated the number of households benefiting from ES provided by the forests distributed along the basins (sub-basins) of each tributary. The results indicate that the number of beneficiary households in upper river sub-basins is greater than in lower ones. In contrast to the distribution of sub-basins with a large number of beneficiary households in the upper river basin of the main stream of the Kasshigawa River (sub-basins shown in red in Figure 2), in the upper basin of the Ogawagawa River, which branches off from the downstream of the Kasshigawa River, there are many sub-basins with a middling number of beneficiaries (sub-basins shown in yellow-green in Figure 2). This shows that the number of beneficiaries does not simply increase in upstream areas, the number of it varies greatly even in the same basin depending on differences in the distribution of households in downstream areas.

As described above, by using elevation data to identify river basins and overlaying the distribution of households on the basins, it was possible to clarify the number of beneficiaries of ES provided by forests.

Table 1. Forest area in the Kasshigawa River Basin

(Units : ha)

		National forests	Private forests	Total
Planted forest	Coniferous	1,090	3,787	4,877
	Broadleaf trees	84	14	98
Natural forest	Coniferous	905	129	1,034
	Broadleaf trees	2,184	3,320	5,504
Others		150	123	273
Total	Area	4,413	7,373	11,787

Source : Author's estimate based on the forest registry

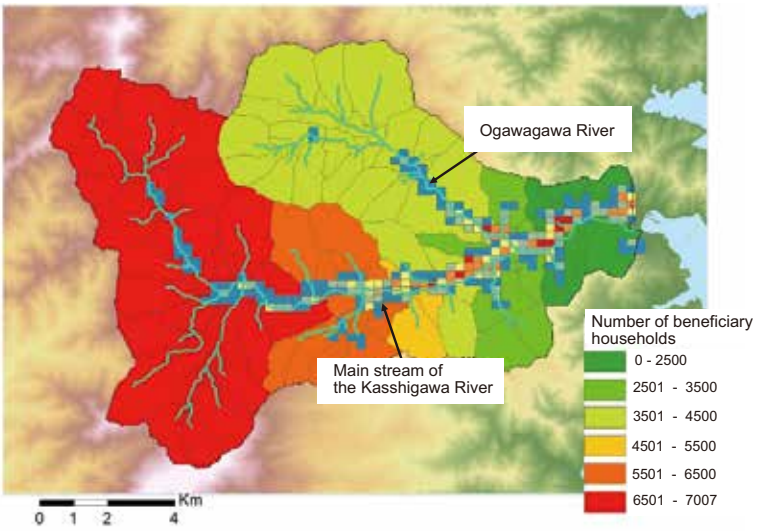

Figure 2. Number of ecosystem service beneficiaries to sub-basins

4. Conclusion

To make policy for preservation and enhancement of ES, it is necessary to understand what kind of relationship exists between the beneficiaries and providers of these services. Since ecosystems spread as a spatial extent and are heavily influenced by their location and surrounding environments, It is thought that analysis with consideration for spatial information such as that introduced here is important to the analysis of ES.

(1) Downloaded from the Geospatial Information Authority of Japan Basic Map Information download service (https://fgd.gsi.go.jp/download/menu.php) (Accessed on November 12th, 2019)
(2) Downloaded from the e-Stat homepage (https://www.e-stat.go.jp/) (Accessed November 12th, 2019)

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