PREDICTING & ASSESSING NATURAL CAPITAL & ECOSYSTEM SERVICES

PANCES

Predicting and Assessing Natural Capital and Ecosystem Services through an Integrated Social-Ecological Systems Approach

PolicyBrief

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Theme 2

Predicting and Assessing of Natural Values from Natural Capital and Ecosystem Services of Terrestrial Ecosystems

The Environment Research and Technology Development Fund,
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Introduction

The establishment of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) reflected the need to enhance the interface between science and policy, including through the construction of a conceptual framework for assessment in this field and an approach to make the framework operational. In parallel with this, the group of nearly 100 experts across Japan has started the national scale scenario analysis of nature and ecosystem services to help the government to revise the existing National Biodiversity Strategy and Action Plan. The IPBES Global Assessment Report published in May 2019 indicated that the ongoing loss of biodiversity on a global scale might jeopardise the achievement of the Aichi Biodiversity Targets, as well as the Sustainable Development Goals (SDGs), the 2050 Vision for Biodiversity and the Paris Agreement adopted under the UN Framework Convention on Climate Change (UNFCCC), among others. However, many of the insights presented in the IPBES Global Assessment do not directly apply to Japan due to its declining birth rate, and dwindling and ageing population, where declining utilisation (underuse) of nature is considered to be one of the drivers causing biodiversity loss. In line with the global efforts of assessing nature and ecosystem services, it is of vital importance to conduct assessments and gain a future perspective in light of the unique social and economic conditions of Japan. Based on the findings so far of the Predicting and Assessing Natural Capital and Ecosystem Services through an Integrated Social-Ecological Systems Approach (PANCES) project, which is funded by the Environment Research and Technology Development Fund (S-15) from the Ministry of the Environment, Japan, this Policy Brief sets out comprehensive policy recommendations with a view to building future scenarios and integrated model of social-ecological systems on national and regional scales, in particular.

Policy recommendation 1

The possible influence of ecosystem components, such as the area and degree of natural vegetation, on citizens' recreational activities and outdoor education should be sufficiently considered in decision-making regarding land use and forest management. Moreover, the fact that specific ecological components (e.g., the percentage of primary vegetation) can influence citizens' activities to various degrees depending on context, such as distance from a major city, must be considered. For example, it is highly likely that the amount of vegetation is an important factor for hiking activities on the outskirts of a metropolis; while it is highly likely that the proportion of primary vegetation is important in locations such as the Japan Alps.

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Policy recommendation 2

Attention must be paid to how management policies that dismiss the striking differences in the relationships between different ecosystem services among municipalities can damage multifunctionality in ecosystem services at the local government level. For example, in southern Japan, policies that maximize timber production have the potential to simultaneously promote recreational activities, but in Hokkaido, maximizing timber production can potentially inhibit such activities. As the relationships between ecosystem services change depending on various natural and social conditions, the number of policies that can be applied uniformly to all local governments is limited.

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Policy recommendation 3

Crop supply prediction models estimated that differences in paddy rice supply services among the future scenarios are caused by decreased production due to disappearing paddy fields rather than changes in productivity due to climate change and population/land-use changes. However, predicted differences in vegetable (spinach) supply services among the future scenarios were caused by changes in productivity due to interactions between climate change and population/land-use change, whereas increase or decrease of croplands predicted to have a smaller effect. These results indicate that the relative importance of population change, land-use change, and climate change on future crop supply services may vary according to crop type.

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Policy recommendation 4

The participation of diverse stakeholders and the use of traditional and local knowledge that they possess have significant roles and various functions in the management of social–ecological systems. Nevertheless, the traditional and local knowledge has not been adequately used in the Local Biodiversity Strategy and Action Plan (LBSAP) in many towns and cities, and those knowledges are being lost over the generations. LBSAPs should clearly focus on the comprehension and succession of traditional and local knowledge, and concrete strategies for its use should be implemented in LBSAPs.

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Policy recommendation 5

Watershed management should be conducted at the watershed scale and from the viewpoint of connecting forests, the countryside, rivers, and the sea. Ecosystem services in watersheds should also be maintained and improved under the context of climate change and land-use change. Specifically, suitable nutrient supply can be effectively planned for downstream by sustainably preserving carbon storage and nutrient cycling in forests within watersheds, and maintaining both food production and fertilizer management in croplands.

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Policy recommendation 6

Monitoring biotic indices that connect the land and the sea, analyzing their controlling factors, and continuously observing their associated environmental factors are effective methods for evaluating the connectivity of forests, the countryside, rivers, and the sea. Additionally, river environments (including riparian zones) exhibit the connectivity of forests, the countryside, rivers, and the sea, as well as serve the environmental functions of watersheds. As such, in addition to the biological monitoring of the above-mentioned indices, preservation strategies of river environments such as the establishment of 20–30 m wide riparian vegetation zones and the maintenance of riffle/pool structures within river flow channels are effective methods for watershed management.

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Policy Recommendation 1

1. Important contributions of ecosystem components on recreational and educational activities

We conducted a large-scale and spatially clarified analysis on cultural ecosystem services, which have rarely been the subject of quantitative investigation at a national scale. We also analyzed the influence of a variety of natural and social environments on ecosystem services. In particular, we conducted detailed analyses on recreational activities (hiking and camping) and educational activities (nature education).

In addition to physical environments (e.g., elevation and climate) and social environments (e.g., local population and traffic accessibility), ecological factors (e.g., amount and quality of vegetation) were important explanatory variables for the activities. Fluctuations of over 5% in the amount of hiking activities were predicted at many locations when the three vegetation characteristics (vegetation cover, proportion of natural vegetation, and proportion of primary vegetation) were each decreased by 10% (Fig. 1).

Ecosystem factors showed variable positive or negative relationships with hiking activities depending on the location and season. The variable associations with ecological variables was dependent on regional conditions such as elevation and local population. For example, the vegetation cover showed a strong positive correlation with hiking activities in suburban areas, but no such trends were observed in rural areas. In addition, correlations between the proportion of primary vegetation and hiking activities were positive in the mountainous areas such as the Japan Alps but negative near metropolitan areas.

Similar trends were observed in analyses of camping and nature education, indicating that ecosystem factors play an important role in citizens' recreational activities and education. These results should be sufficiently considered during land-use and vegetation management. It should be also noted that the influence of ecological factors can be entirely different depending on the local conditions.

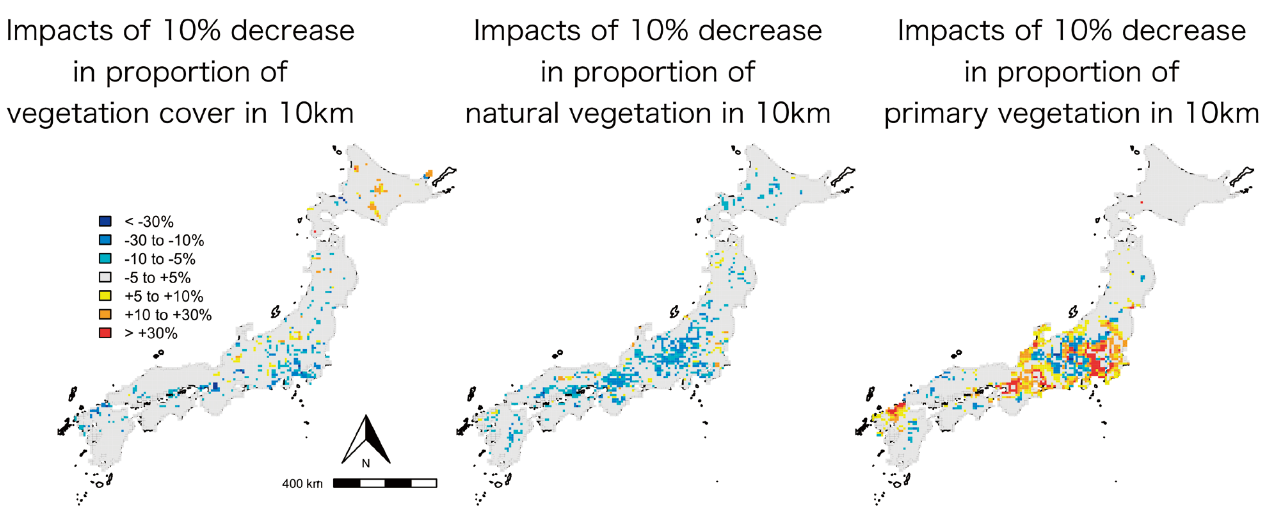


Fig. 1 Impact of changes in vegetation amount/quality on hiking activities

Policy Recommendation 2

2. Importance of ecosystem service management strategies optimized for each location

Understanding the relationships between different ecosystem services is important in the management of those services. In cases where a trade-off exists among services, strategies that do not consider the balance between the two will result in loss of multifunctionality in ecosystem services. However, virtually no analyses have been conducted on the relationships between ecosystem services in Japan.

Here, we estimated eight ecosystem services, namely paddy rice production, lettuce production, timber stock, carbon absorption, water quality, hiking activity, camping, and education, in 1-km grids, and we studied the relationships between these ecosystem services in each municipality of Japan (excluding the remote islands).

The relationships between the ecosystem services varied considerably depending on the municipality, and both positive (synergy) and negative (trade-off) correlations were detected in nearly all service combinations. Differences in the relationships were detected not only at the larger regional scale (e.g., differences between the northern and the south ern parts of Japan), but also between neighboring municipalities. For example, the relationship between timber stocks and number of camping grounds was positive for many municipalities in southern Japan, whereas many negative relationships were noted in Hokkaido (Fig. 2). This suggests that management targeted for timber production can simultaneously promote camp use in south Japan, whereas the same management would result in hindering camp use in Hokkaido.

Such associations among different services should be carefully considered in ecosystem management so as not to lose multifunctionality of ecosystem services.

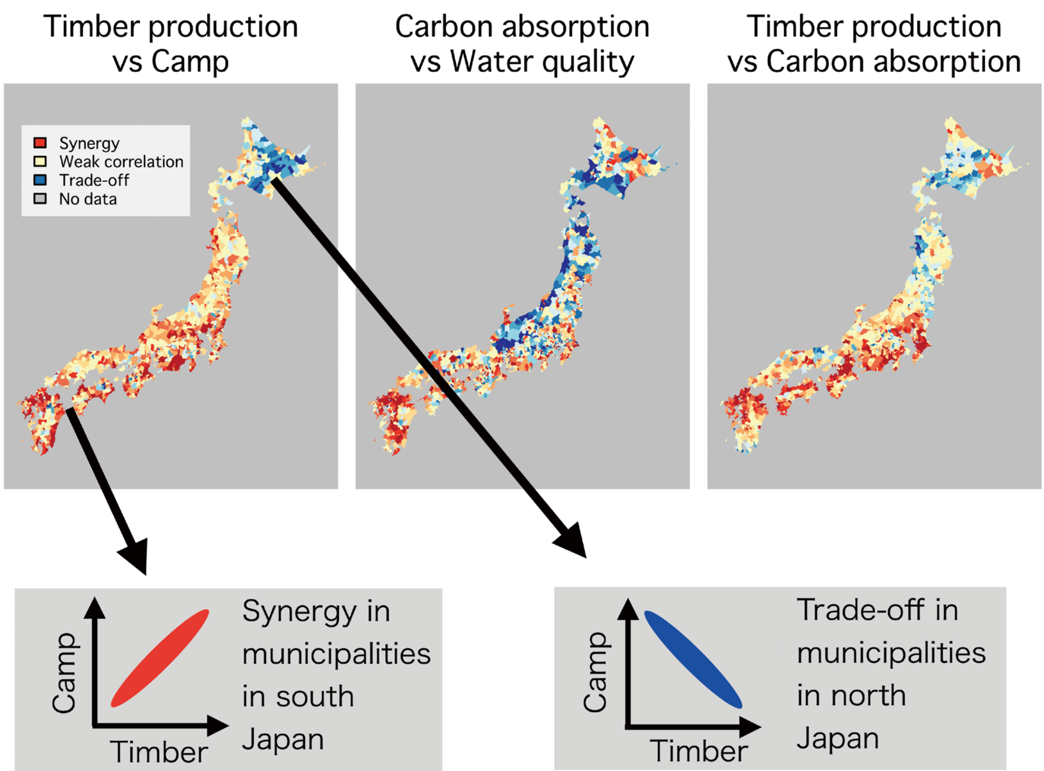


Fig. 2 Comparison of ecosystem service relationships by municipality

Policy Recommendation 3

3. Future predictions of crop supply services based on scenario analysis

We used data on paddy rice and spinach production as well as climate conditions† from 1993–2015, land-use in 1998, and population distribution in 2010 in order to create models that predict paddy rice and spinach supply services based on climate, land-use, and population distribution. Conditions in 2010 and each of the PANCES and BAU scenarios were applied to the models to predict changes in crop supply amount and its causes for each PANCES scenario from 2010–2050.

In all scenarios, rice supply services decreased throughout Japan, with the primary cause predicted to be the loss of paddy fields. These decreases were particularly large in the produced capital use scenarios (Fig. 3, top row); thus, countermeasures for cultivated land that has been abandoned are necessary for maintaining rice supply amounts. On the other hand, the natural capital use scenarios predicted an increase in spinach supply services at the national level (Fig. 3, bottom row). However, the BAU and produced capital dispersed scenarios indicated a decrease in the supply amount, and the primary cause in these cases was the decrease in productivity due to climate change and changes in population and land-use rather than the decrease in cropland (Fig. 3, bottom row). In other words, the countermeasures necessary for preventing decreased crop supply may vary according to crop type.

When investigating the changes in the supply/demand balance in each PANCES scenario, decreases in demand exceed decreases in supply in almost all future scenarios in which the rice and spinach supply decreases (Fig. 4). These results indicate the possibility of converting cultivated land that has been abandoned to other land-use purposes (e.g., forests), and using such land to improve other ecosystem services.

† The climate data used for the analyses was produced using [AMeDAS climate mesh production program Ver. 5.2] by The National Agriculture and Food Research Organization (NARO).

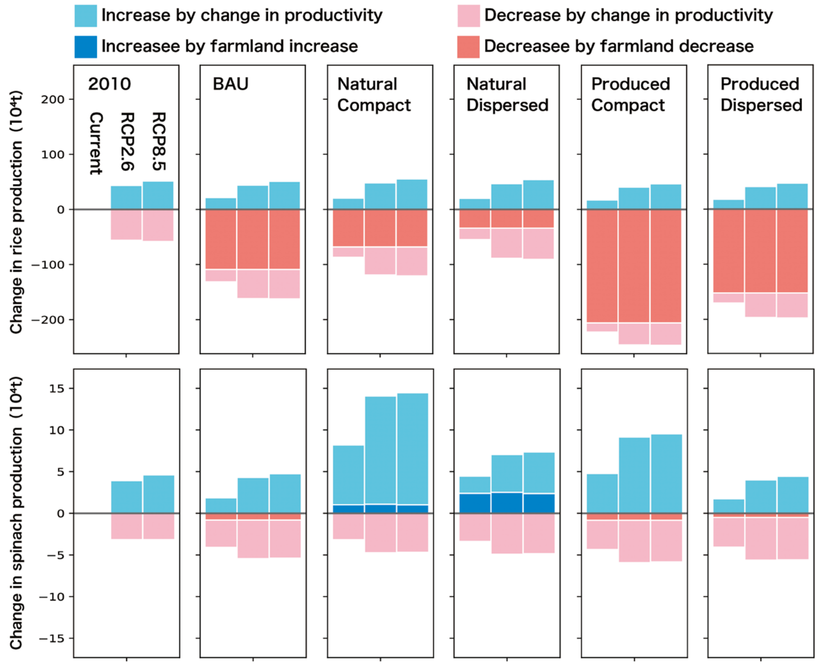


Fig. 3

Predicted changes in rice (top row) and spinach (bottom row) supply services throughout Japan for variations in land-use, population distribution, and climate

(Panel differences indicate differences in land-use and population scenarios, and the differences in the bars within each panel denote differences in climate scenarios (current climate, MIROC5 RCP 2.6, and MIROC5 RCP 8.5). The dark colors in the bars indicate changes due to cropland fluctuation, and the light colors refer to changes in productivity due to changes in land-use, climate, and population distribution near croplands. Minimal differences between representative concentration pathways (RCPs) are thought to be a characteristic of the model used here, and therefore, care should be taken when interpreting the results).

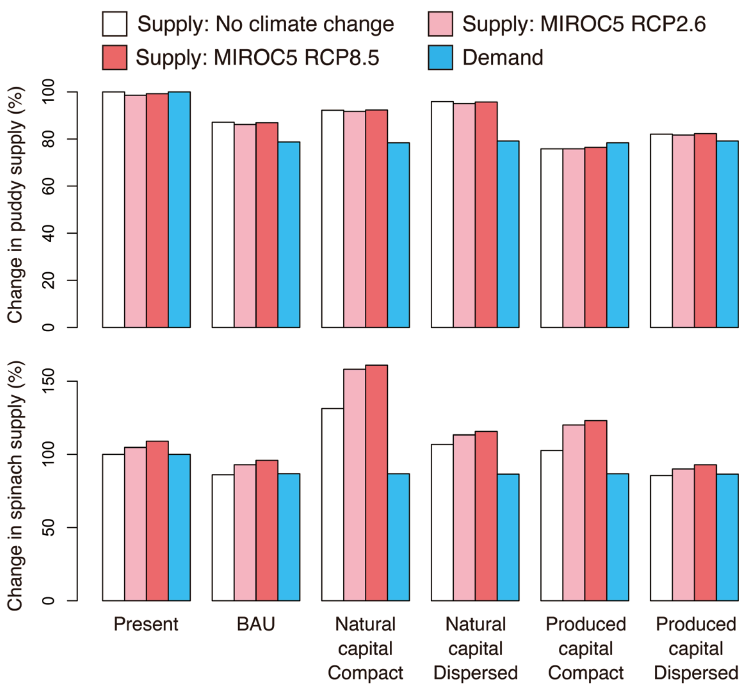


Fig. 4

Predicted relative changes in supply and demand of rice (top row) and spinach (bottom row) under each PANCES scenario

Policy Recommendation 4

4. Importance of traditional and local knowledge and its succession

The participation of diverse stakeholders and the importance of traditional and local knowledge in ecosystem management have been stated. Our research provided a concrete result about the participation of diverse stakeholders and the use of traditional and local knowledge in ecosystem management in Japan by comparing various cases of the Local Biodiversity Strategy and Action Plan (LBSAP). The activities and outcomes relating to LBSAPs were analyzed using a social–ecological system analysis framework, which showed that socioeconomic factors were generally more correlated to the activities and outcomes of LBSAPs than were natural and ecological factors (Fig. 5). The participation of diverse stakeholders had positive relationships with the amount of time spent discussing plans for LBSAP and the number of planned actions in LBSAP. The recognition and use of traditional and local knowledge had a positive relationship with information sharing with citizens, amount of time spent on discussions, activeness in evaluating actions, and changes of citizens' awareness due to LBSAPs. These results indicate that the participation of diverse stakeholders and the use of traditional and local knowledge have important effects for ecosystem management, and actively promoting these aspects is effective for ecosystem management.

Additionally, a high degree of awareness existed with regard to the necessity of using traditional and local knowledge in LBSAPs (Fig. 6). A total of 89% of respondents (those who responded with "very necessary" as well as those who responded with "somewhat necessary") recognized the necessity of incorporating traditional knowledge for promoting LBSAPs. Similarly, a total of 86% of respondents recognized the necessity of incorporating local knowledge for promoting LBSAPs (those who

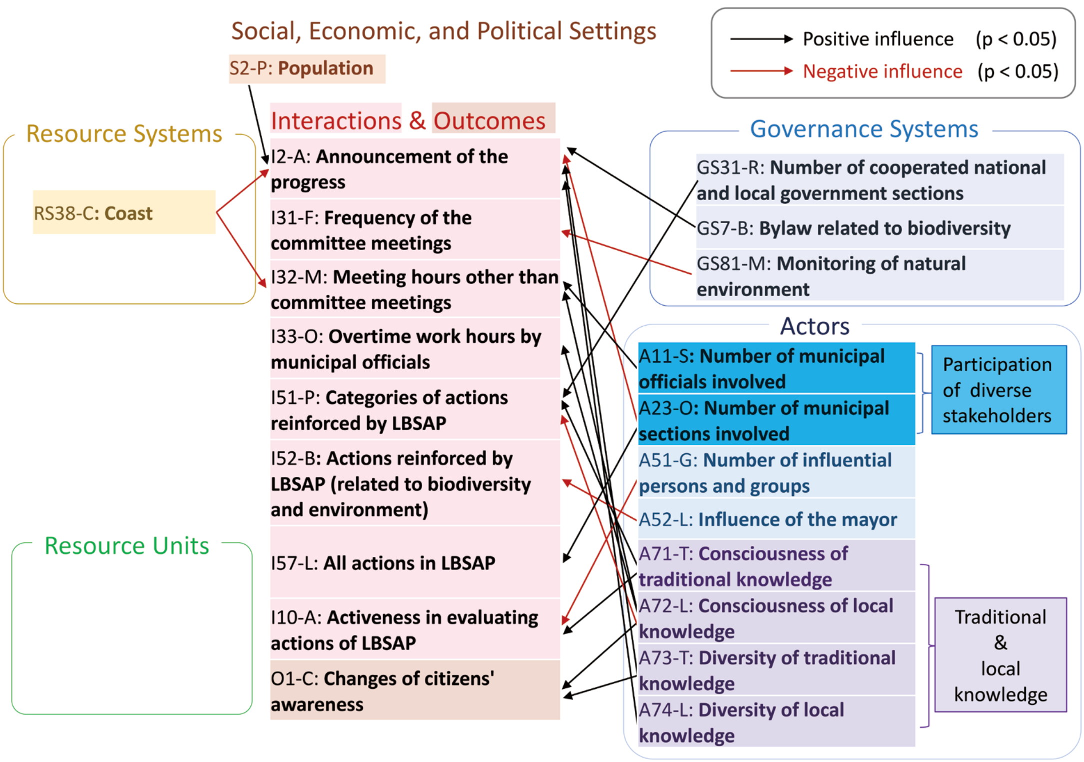


Fig. 5
Effects of the participation of diverse stakeholders and the use of traditional and local knowledge in ecosystem management based on LBSAPs. Results of analyses using the social–ecological system analysis framework by McGinnis & Ostrom (2014) showed that the participation of diverse stakeholders and the use of traditional and local knowledge had positive relationships with a variety of activities and effects relating to LBSAPs.

responded with "very necessary" as well as those who responded with "somewhat necessary"). Moreover, a total of 27% of respondents indicated that traditional knowledge is not well used in LBSAPs, and 34% indicated that local knowledge is not done so. The responses were attributed to lack of information regarding traditional and local knowledge, and lack of understanding about how to incorporate such information into LBSAP (Fig. 6). Thus, it is necessary to advance our understanding of traditional and local knowledge in the context of ecosystem management and specifically analyze how such knowledge may be used.

Additionally, it was clear that traditional and local knowledge was being progressively lost with each generation. Various seaweed species are used in a wide range of cooking in the Sado Island of Niigata Prefecture, but the survey results in all areas of the island revealed that the number of seaweed species that individuals chanced upon in dishes decreased with age (Fig. 7). There is a concern that traditional and local knowledge of seaweed use would not be inherited by future generations if this decrease in experiences were to continue. The generation born in the 2050s may eat only two seaweed species as part of a cooked dish if this trend were to continue in a linear fashion. Similarly, it is predicted that the generation born in the 2050s will be aware of only three species and will never experience cooking or eating them (Fig. 7). These results were about the culture of seaweed use in the Sado Island, but similar trends have been confirmed in other regions of Japan. Initiatives that allow for the succession of traditional and local knowledge accumulated by ancestors and avoid their loss are thus necessary.

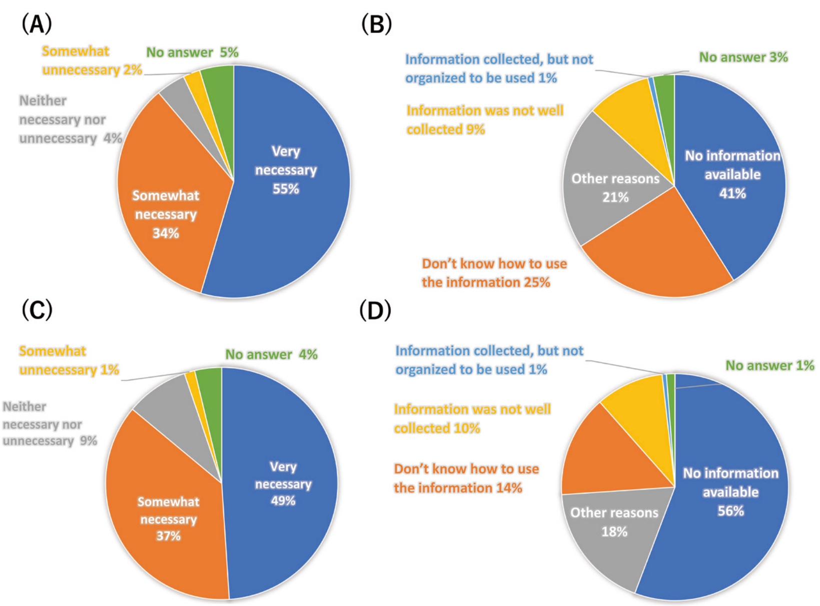


Fig. 6
Awareness of the importance of traditional and local knowledge in LBSAPs, and reasons for their not being used. A high degree of awareness exists regarding the importance of incorporating traditional knowledge (A) or local knowledge (C) for promoting LBSAPs. Moreover, the lack of information or understanding were often expressed as reasons for not using traditional knowledge (B) or local knowledge (D).

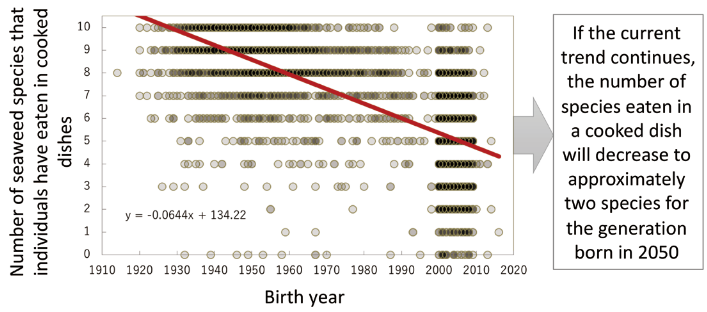


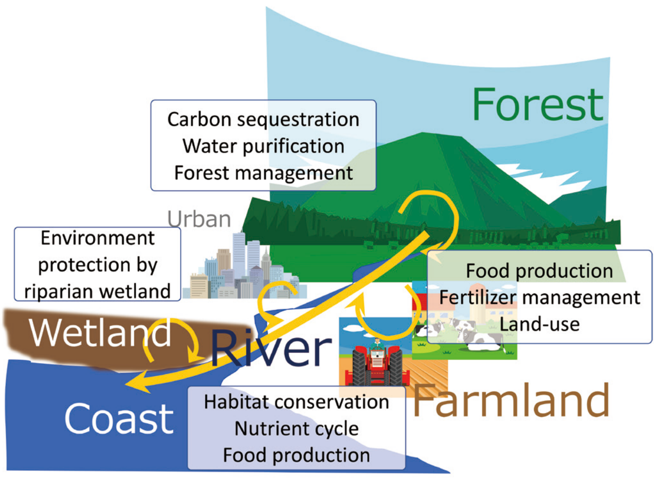
Fig. 7
Relationship between knowledge of seaweed use and birth year in the Sado Island. The number of seaweed species that individuals have eaten in cooked dishes decreases with age, and the inheritance of this knowledge is at risk. The red line indicates the result of a linear regression.

Policy Recommendation 5

5. Preservation of and ecosystem services provided by forests, the countryside, rivers, and the sea in watersheds

Connections between forests, the countryside, rivers, and the sea in watersheds are closely related to the natural capital and ecosystem services of a region. Forests located in upstream watersheds function as sites for carbon fixation and global warming mitigation. Suitable forest management relates to the maintenance of carbon accumulation amounts as well as clean water supply in ecosystems due to nutrient cycling (Fig. 8 (left)). An appropriate balance between crop production and fertilizer management in downstream and midstream countryside is important for stable regional food supply and environmental preservation. For these reasons, it is essential to quantitatively evaluate the relationships between resource use, food production, and material cycling as well as variable land-use in the overall watershed ecosystem. The preservation of riparian marshes, which are distributed over the boundaries between countryside and rivers, must also be given particular attention due to their water purification function. Nutrients supplied from forests, rivers, and the countryside to oceans are important for biological production and biodiversity in coastal regions, while land-use changes and climate change in watersheds are connected to changes in this nutrient supply.

Studying the connections between forests, the countryside, rivers, and the sea while sufficiently considering regional characteristics (particularly the dynamics of nutrient through rivers as movement routes) is essential in order to ensure sustainable regional development based on the regional circular and ecological sphere proposed by the Fifth Basic Environmental Plan. As shown in Fig. 8 (right), nutrient supply and water quality connected to forests, the countryside, rivers, and the sea are predicted to change according to future land-use change scenarios. As such, it is important to facilitate quantitative predictions of future changes in natural conditions (e.g., global warming and extreme climate change) and socioeconomic conditions (e.g., land-use change accompanying aging and depopulation), so that regional stakeholders can analyze future scenarios based on these predictions.



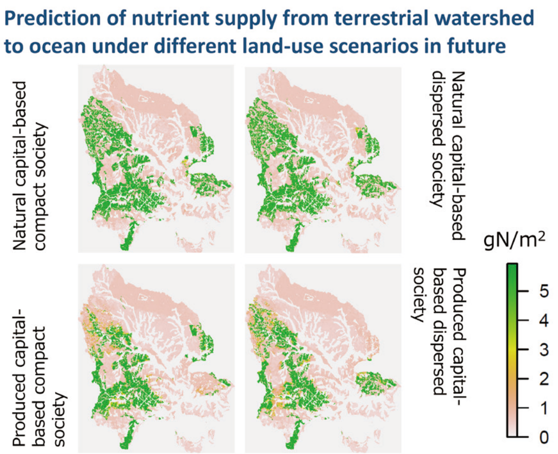
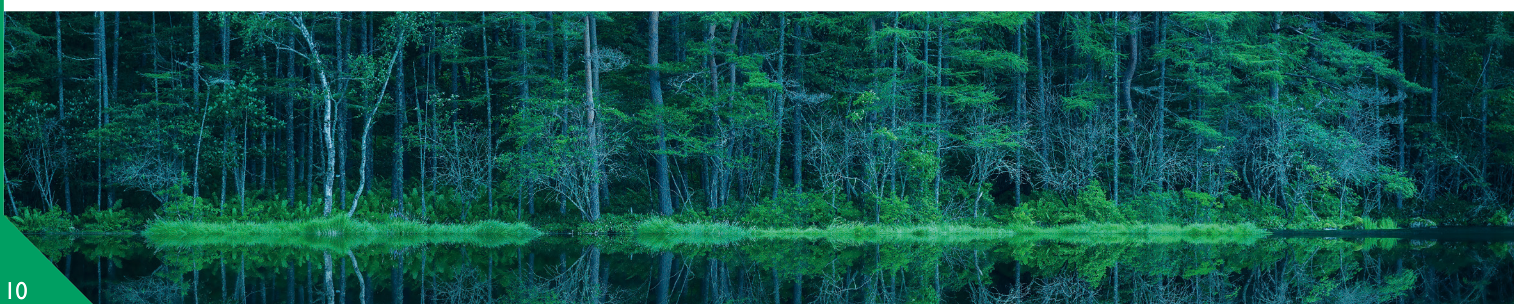


Fig. 8 Various factors associated with connections between forests, rivers, the countryside, and the sea in a watershed (left), and an example of a future prediction model for nutrient (nitrate nitrogen) supply from watershed in east Hokkaido (right)



Policy Recommendation 6

6. Connectivity of forests, the countryside, rivers, and the sea, and use/preservation of biotic indices

The connectivity of forests, the countryside, rivers, and the sea is extremely important for organisms that move between the land and the sea. Based on these characteristics, the identification of biotic indices that connect forests and the sea, monitoring of the habitat environments and distribution statuses, and analysis of the controlling factors are essential for the evaluation of the connectivity between forests, the countryside, rivers, and the sea. In eastern Hokkaido, for example, the relationships between masu salmon, which migrates between the land and the sea, and the freshwater pearl mussel, which inhabit symbiotically with them, have been studied as biotic indices to evaluate the forest–countryside–river–sea connectivity in watersheds (Fig. 9). By assessing whether the habitat environments (e.g., particle size of riverbed substrates and extent of water pollution) necessary for species considered as biotic indices are suitably preserved, continuously monitoring for any changes in the number of individuals in each growth stage (including digenesis), and effectively implementing preservation strategies, the loss of forest–countryside–river–sea connectivity can be prevented. Riparian ecosystems in particular exhibit functionalities that mitigate the degradation of habitat environments for biotic index species (e.g., decreased changes in water temperature/quality and prevention of sediment runoff). Thus, it is important to enact suitable preservation strategies. It is also crucial to select biotic indices that correspond with regional characteristics, preserve river habitat environments (e.g., establishment of a 20–30 m riparian vegetation zone and maintenance of riffle/pool structures within river flow channels), and continuously determine the distribution statuses of biotic indices. Doing so will allow the sustainable use of the abundant regional natural capital in regional circular and ecosystem spheres as well as the use of the various natural capital and ecosystem services facilitated by forest–countryside–river–sea connectivity.

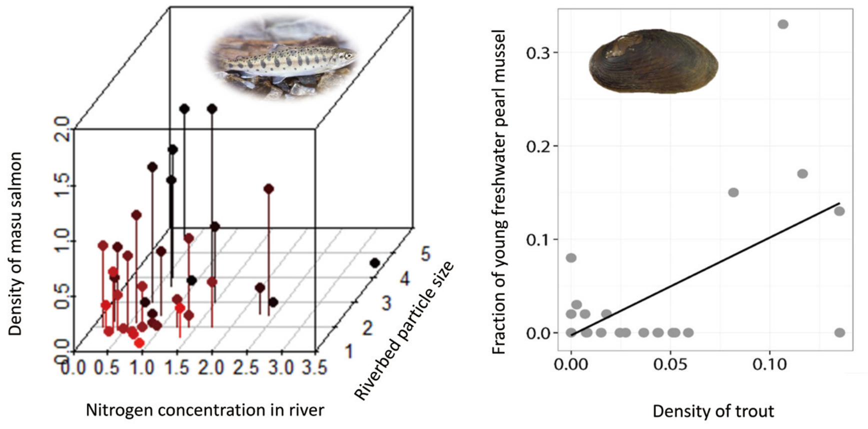


Fig. 9
Example of growth conditions, local environmental factors, and symbiotic relationship between masu salmon and the freshwater pearl mussel in relation to forest–countryside–river–sea connectivity in eastern Hokkaido

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