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 1

Future Scenarios and Integrated Model of Social-Ecological Systems on National and Regional Scales

The Environment Research and Technology Development Fund,
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Theme 1

Future Scenarios and Integrated Model of Social-Ecological Systems on National and Regional Scales

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

Scenario building and analysis is a useful tool to help us explore plausible futures under various drivers and associated uncertainties. Two major drivers with relatively high uncertainties could differentiate socioeconomic development pathways affecting the future of nature and ecosystem services in Japan up to 2050. That are 'population distribution patterns' (further concentrations on urban areas or dispersion to countryside) and 'the utilization of natural capital' (utilize more domestic natural capital or rely more on produced capital and material contributions from abroad).

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Policy recommendation 2

To apply national scale future scenarios on a local level, we recommend either of two approaches: (i) applying the same national-scale future scenarios to develop local-scale future scenarios, taking into account the local socioeconomic and environmental conditions (top-down approach); or (ii) building new future scenarios with the participation of various local actors as well as researchers and administrators (bottom-up approach). When developing or reviewing Local Biodiversity Strategies and Action Plans (LBSAPs) at the prefectural or municipal level, it would be useful to construct future scenarios on a long-term basis and to consider a LBSAP to indicate the direction to be followed in the coming 10–15 years, if we are to prepare for contingencies.

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Policy recommendation 3

Depending on the characteristics of future scenarios of national scale, we need to develop a model to project, and illustrate in a spatially explicit way, how the distribution of population, industrial population and land use might change by 2050. This will enable projection and estimation of the effectiveness of policies on natural capital and ecosystem services on land and in the sea for each of the future national scenarios, in light of changes in human capital and land use up to 2050.

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Policy recommendation 4

On both national and local scales, projection of ecosystem services needs to consider the ecosystem services on the demand side primarily determined by the size of population (e.g. demand for rice, forestry products and marine products), as well as the ecosystem services on the supply side primarily determined by land use (e.g. rice production, timber production and fish catches). Such assessment will allow consideration of policies on ecosystem services (flow) in light of the supply-and-demand balance required for the sustainable use of natural capital (stock).

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Policy recommendation 5

Future scenarios at a local scale, either prefectural and municipal levels, require assessment guided by local challenges and visions including the compactification of the city center in response to the dwindling population and the utilisation of abandoned farmland in rural areas. It should be supported by the development of population and land use data with finer spatial resolution. In particular, the demographic aspect of the scenarios needs to consider the trends in wider areas, including changes in the local population as well as movement between different areas.

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Policy recommendation 6

The involvement of multiple sectors, including agriculture, forestry, fisheries and education in the development and implementation of LBSAPs can widen the range of ecosystem services incorporated in the document and thereby can effectively promote mainstreaming biodiversity into multiple sectors.

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Policy recommendation 7

The trade-offs between climate change mitigation and ecosystem preservation are a concern in promoting the use of renewable energy. It will be necessary to meet most of the demand for energy with renewable sources in order to achieve an 80% reduction in greenhouse gas emissions by 2050, and net-zero emissions by the end of the century, but ecosystems might be lost depending on where renewable energy is sourced.

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Policy Recommendation 1

1. Future scenarios and predictive assessment on a national scale

In order to construct future scenarios to explore plausible 'futures' of Japan up-to 2050, we built four scenarios for future socioeconomic changes around major uncertainties about Japanese society (Saito et al., 2019). The two conceptual axes to shape the scenarios were identified through: (1) a questionnaire survey (Delphi method) of experts on the direct and indirect factors that might impact natural capital and ecosystem services at the national level; (2) a statistical analysis of the findings; and (3) an interview with officials of the Ministry of the Environment, Japan.

The first axis (horizontal axis) identified from this process represents the alternative population distribution patterns: whether the population continues to concentrate on existing inner urban areas and city centres or will disperse to the suburbs and semi-rural areas. The second axis (vertical axis) of uncertainties focuses on the capital to be prioritised in society going forward: which domestic natural capital (e.g. forests) or natural capital overseas and produced capital (e.g. concrete) should be utilised more proactively.

In PANCES project, the four scenarios plotted along those two axes were named 'natural capital-based compact society', 'natural capital-based dispersed society', 'produced capital-based compact society' and 'produced capital-based dispersed society', respectively (Fig. 1). The future we want may be considered by assessing of natural capital and ecosystem services under the four future scenarios thus developed and analysing differences among them. In a compact society with produced capital, for example, policies will be enhanced to promote increased imports of agricultural products and timber, centralised use of energy and heat, and horticulture under a structure driven by information and communication technology (ICT). In a dispersed society with natural capital, on the other hand, it is important to enhance policies to promote self-sufficiency in food and timber, ecosystem-driven disaster risk reduction and management on abandoned arable land, among others.

We also identified some fundamental trends underlying all future scenarios: there will be no significant increase in the growth of Japan's gross domestic product (GDP); the concentration of population on large- and medium-sized cities will accelerate to the detriment of rural areas; there will be no significant improvement in the fertility rate; and there will be no substantial enhancement of public transport systems.

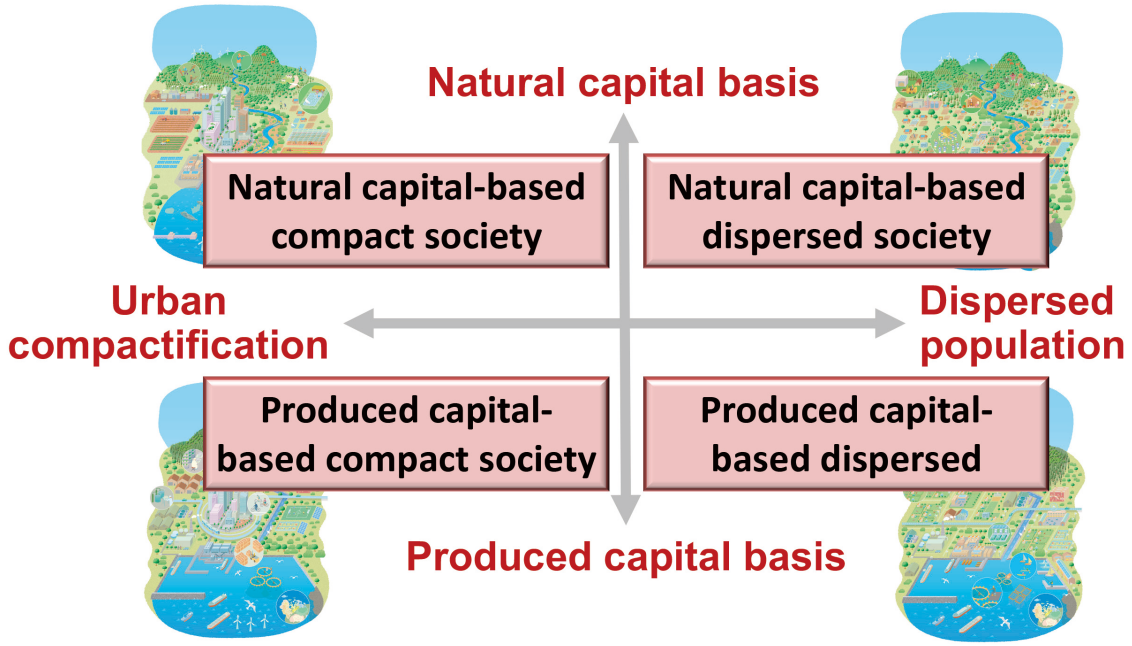

Fig. 1 Four national future scenarios

Policy Recommendation 2

2. Future scenarios and predictive assessment at a local scale

We conducted scenario analysis in Noto (Ishikawa Prefecture) and Sado (Niigata Prefecture).

In Noto, we conducted a scenario analysis by localising national future scenarios considering local conditions (Hashimoto et al., 2019). The results of scenario analysis indicate that future conditions of land use, ecosystem services and biodiversity may vary significantly depending on whether domestic natural capital is proactively utilised or not while the concentration or dispersion of population distribution will bring only limited changes by 2050. The declining use of natural capital will result in increased abandonment of farmland, substantial decline in ecosystem services closely related to agriculture such as food supply and nitrogen retention, and the loss of the mosaic landscape that nurtures biodiversity. For the purpose of sustaining the use and management of farmland amid the declining population, relevant measures include effective utilisation of the payment for multifunctionality of agriculture and the direct payment system in hilly mountainous areas, the farmland redistribution, and the efficiency and automation of agricultural production driven by ICT, AI, etc. to enlarge the cultivated area per management entity. In addition, the reduction of agrochemicals inputs through increased production of eco-friendly agriculture and agricultural produce grown with reduced agricultural chemicals will help curtail the environmental burden resulting from agriculture. Where it is difficult to sustain farming due to less favoured geographical conditions, lack of successors or underdeveloped production infrastructure, and hence increased abandonment of farmland is inevitable, it would be possible to maintain the mosaic landscape by proactively encouraging spontaneous regeneration including through tree planting or utilisation as wetlands, rather than allowing the proliferation of abandoned farmlands.

In Sado, we organised a participatory workshop inviting various local stakeholders and developed six scenarios (Kabaya et al., 2019). These scenarios may be largely characterised by two factors: the speed of population decrease and the key industry. Figure 2 shows the results of our scenario analysis of land use and ecosystem services (food production, carbon fixation, clean water and habitats) based on the six scenarios. For Sado island as a whole, ecosystem services reach the highest level in the agriculture-focused scenario but tend to decline with the size of population. It was found, however, that the scenario with the best ecosystem service performance for the whole island might not be the optimal solution for some specific areas. Thus, any initiative that aims at realising a specific scenario will require the identification of areas that may suffer negative impacts, to be followed by proactive countermeasures. It is preferable to promote eco-friendly agriculture and forestry management as our analysis confirmed the positive impact of those practices on agricultural output and forest growth. Since little progress has been made in Sado in addressing the issue of abandoned forests in particular, a proactive approach will be required to that end, including through the upcoming introduction of a forest environment tax.

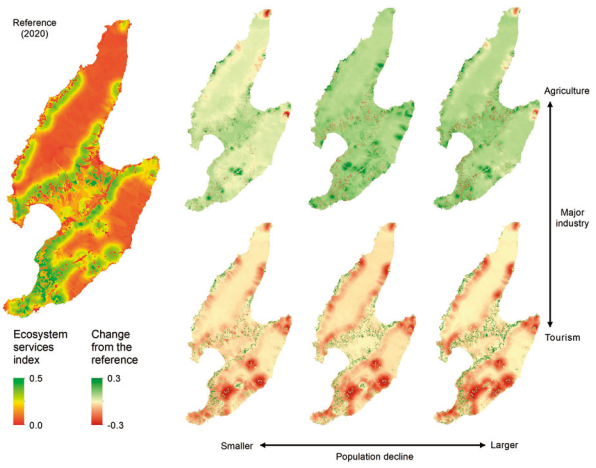

Fig. 2
Ecosystem service index based on the six future scenarios in Sado City (Kabaya et al., 2019)

Policy Recommendation 3

3. Development of population and land use models for each of the future scenarios

As a basic framework to proceed with the predictive assessment of natural capital and ecosystem services effectively, we built population redistribution models corresponding to the storylines of the four future scenarios at the national level to estimate the residential and industrial populations, and the resulting changes in land use for each of the scenarios, in a spatially explicit manner. In accordance with this basic framework, we developed and analysed population (Fig. 3) and land use (Fig. 4) data for 2050 at a resolution of 500 m (Matsui et al., 2019; Shoyama et al., 2019; Hori et al., 2020), and prepared a dataset capable of assessing the impact of climate change for each scenario. The common data foundation thus developed effectively enabled the predictive assessment of various natural capital and ecosystem services on land and in the sea up to 2050.

The formation of medium-sized population centers and rural city block was assumed for the compact scenario, and the formulation of a large number of small-sized population centers and rural city blocks was assumed for the dispersed scenario. In each of the municipalities, the compact scenario assumed migration to densely populated areas, and the dispursed scenario assumed migration to the scarcely populated areas, projection of the population distribution under each of the scenarios was conducted. The results (Fig. 3) indicate the expected population distribution and age structure in 2050 under each scenario. Under the compact scenario, assuming further concentration of population, the areas with no resident (zero population areas) will increase by around 30% compared with the business as usual (BAU) scenario. We also found that there would be over 50% less zero population areas under the distribution scenario than under BAU. Given the result, decision-makers should develop plans on the formation and distribution of population centers and rural city blocks in line with their vision on transport, industry, and natural environment, while considering the promotion of migration and how to address the issue of zero population areas.

For land use, assumptions were developed for each of the four scenarios about the amount of future land use demand and possible land use transitions, and the change of land use distribution under different geographic and social conditions in each region was spatially predicted. As the overall result (Fig. 4), the natural capital-based scenarios (NC/ND) resulted in a few percent more agricultural land cover than BAU. In contrast, the produced capital-based compact scenario (PC) resulted in a decrease of 0.8%. Similarly, the percentage of cover of grassland and abandoned land was projected to increase by about 3% under the PC scenario and decrease by about 3% under the ND scenario. For forests, there was an increase in secondary forests and a decrease in plantation forests in all four scenarios relative to BAU, but the range of change was larger in the produced capital-based scenarios (PC/PD), where the percentage of secondary forest was projected to increase by about 4%, and plantation forests were projected to decrease by 4-6%. Utilizing these results, which spatially show the land that may no longer be used as agricultural land or plantation forests, the strategic land use conversion policies must be considered to avoid degradation but improve biodiversity and ecosystem functions.

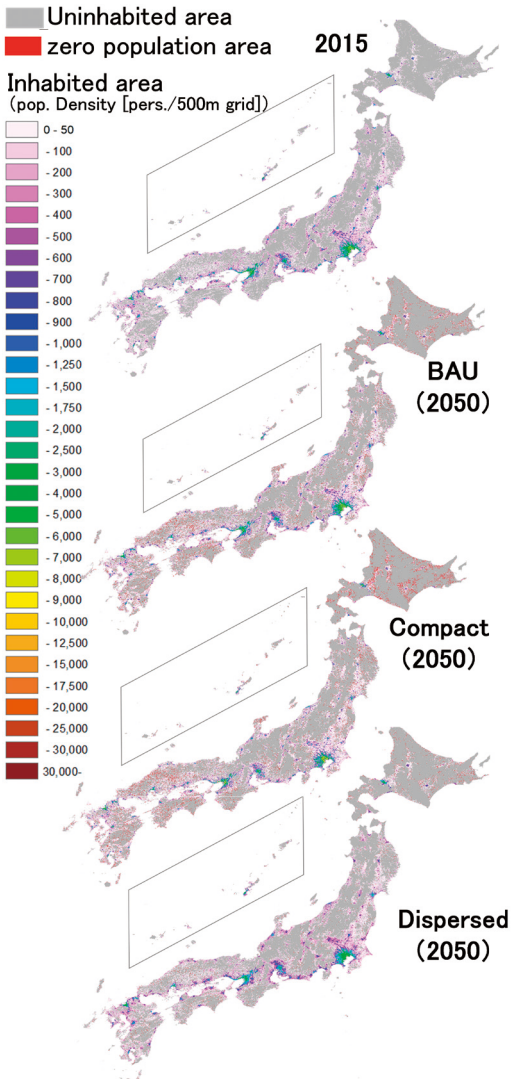

Fig. 3
Population distribution projected by scenario (resolution of 500 m, Hori et al., 2020)

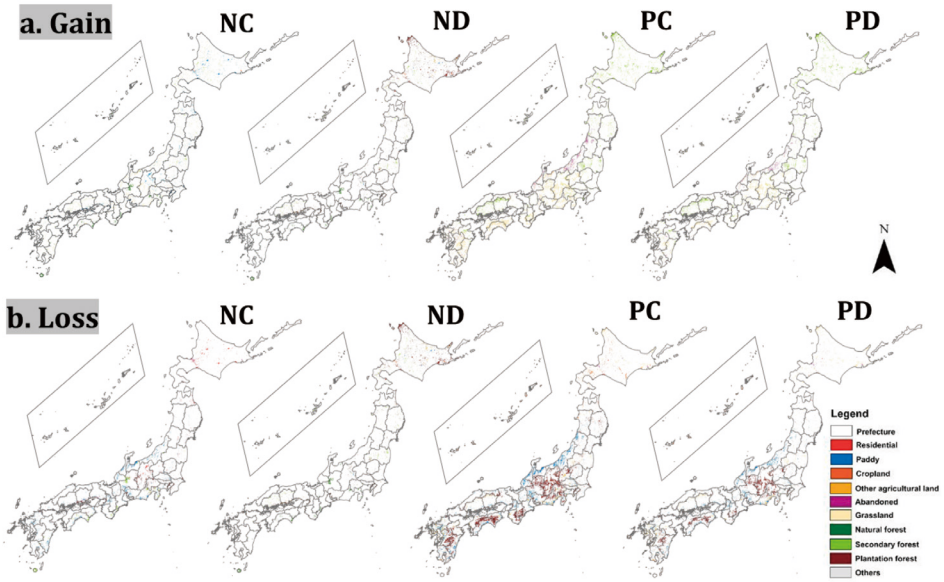

Fig. 4
Change in land use by scenario (indicating a) increase or b) decrease in each land use category)
NC: 'compactification with natural capital' scenario;
ND: 'distribution with natural capital' scenario;
PC: 'compactification with produced capital' scenario;
PD: 'distribution with produced capital' scenario
(resolution improved on Shoyama et al., 2019)

Policy Recommendation 4

4. Supply-demand balance assessment on ecosystem services

So far, ecosystem service assessment has often defined ecosystem services as the potential amount of services that may be obtained from a specific land use. Although this approach is useful for assessing the potential of ecosystem services, it has a problem of not being able to assess scientifically the underuse of natural capital, which is one of the crises for biodiversity in Japan.

Thus, in addition to the traditional ecosystem service assessment on the supply side based on land use, this project adopted a demand-based approach to ecosystem service assessment integrating the declining population and individual consumption behaviour (e.g. per capita consumption of rice and fish). Figure 5 visualizes the gap between rice production and consumption at the municipal scale, and red, blue, and purple colors are oversupply, over-demand, and balanced, respectively. The Natural capital-based dispersed society has a potential to mitigate the demand-supply gap and to enhance the balance compared with the produced capital-based compact society. These results enable to evaluate spatially explicit quantification of the demand-supply gap, so this type of supply-demand gap analysis, and integrated assessment of ecosystem services linked with the future scenarios on a national scale enables scientific evidence-based decision-making on underuse or overuse that has generally been discussed only quantitatively. For example, whether abandoned farmland, which will inevitably increase in the future, should be directed towards spontaneous regeneration (into broadleaf forests, etc.) or maintained and preserved as farmland, may be considered in a qualitative, spatially distinct manner in accordance with the future demand for food estimated from the expected population change. It should also be noted that policies on ecosystem services have been largely considered from the supply side, mostly in terms of payment systems and protected areas for farms and forests. In conducting predictive assessment of ecosystem services from the demand side, however, it would be important for policies to address the factors affecting demand for ecosystem services, including through the conservation of traditional local vegetables and dishes, and the promotion of dietary education.

This project also conducted a questionnaire survey to explore whether people prefer services derived from natural capital or those derived from produced capital (Hori et al., 2019). Despite some variation depending on the age, sex, place of residence, type of service, etc., we found that people tend to have a strong preference for ecosystem services derived from natural capital in general. This result points to the contribution of natural capital-based services to human well-being. In particular, we should consider retaining the carbon storage service by forests, and cultural service providing sacredness by authentic nature, for which a preference for natural capital-based services tends to be clearly expressed, even if produced capital scenario is adopted. Thus, assessment of the demand for ecosystem services based on future demographics and public preference are likely to be key criteria in policy discussions going forward.

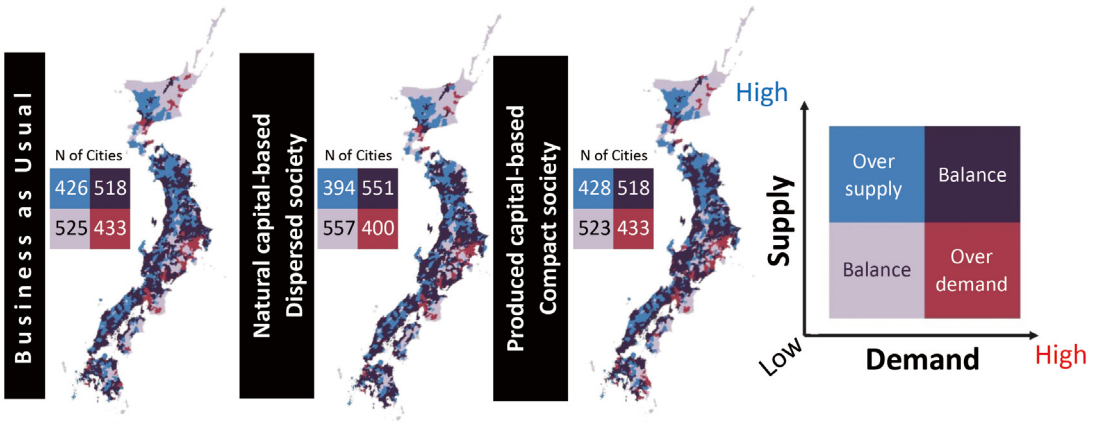

Fig. 5 Gap between rice production and consumption in the municipality resolution (Miyamoto et al., 2020)

Policy Recommendation 5

5. Modelling of population and land use on a local scale

Based on the future scenarios on a national scale, we developed a local version of the future scenarios for the Bekanbeushi river basin integrating the interests and concerns of local stakeholders. Under those local scenarios, we conducted an assessment of natural capital and ecosystem services to serve the development of local biodiversity strategies by calculating the vegetation succession of forests and meadows with the LANDIS-II forest landscape model (Haga et al., 2020).

Experience in this river basin suggests that in localising the characteristics of national future scenarios, decision-makers need to consider thoroughly if they are in line with conditions specific to the area and the future vision of local residents. When providing the result of prediction under the future scenarios to local residents, they need to facilitate communication by linking the outcome of the ecosystem prediction model, such as changes in ecosystem services and the habitat suitability of organisms, with social issues that attract the attention of local residents. The results of estimating future changes in land use and demographics with a high spatial resolution can be utilised for the following purposes: reconciling local policies to introduce renewable energy sources such as photovoltaics and biomass with the promotion of local industries such as pasture production and stock breeding; using sustainable ecosystem services harmonised with iconic local species and local culture; and designing concrete future scenarios such as the zoning of places to be reserved for spontaneous regeneration.

As part of this project, we also conducted a questionnaire survey of 7,556 Japanese citizens on preferred destinations for future migration or multi-habitation and the areas where they frequently visit as part of 'related population' (Hori et al., 2020). The results indicated that metropolitan areas are the most preferred destination for migration or as a secondary place of residence. Although limited as a proportion, however, a certain number of respondents preferred migration from metropolitan to rural areas or multi-habitation. Indeed, rural areas were preferred more as a secondary home than a destination for migration

from urban areas. Thus, a policy aimed at dispersing the population should promote multi-habitation rather than migration to create a movement of people from metropolitans to rural areas. Since those preferring to migrate to a rural area tend to prioritise accessibility to nature, community development to maintain accessibility to natural resources that may provide cultural services, for example, would be effective for rural areas to attract a certain number of immigrants from metropolitan areas.

Metropolitan areas were most popular destination for repeated visits. With some variation depending on the purpose of visit, the mean value of the distance between the place of residence and the visited area remained within nearly 100 km to additional few dozen km. The most common reason for visiting was 'tourism and leisure' overall, and this response represented a higher percentage among metropolitan area residents visiting a rural area. Thus, under the 'natural capital-based compact' scenario, which requires the participation of citizens from metropolitan areas in natural capital management, an effective policy would be to encourage residents in areas located less than 100 and few dozen km from metropolitan cities to engage in activities (including voluntary activities) to support agriculture, forestry or fisheries containing elements related to tourism and recreation.

Policy Recommendation 6

6. Local biodiversity strategies and action plans (LBSAPs)

Local biodiversity strategies and action plans (LBSAPs) (Fig. 6) play a vital role as locally contextualized science-policy interfaces. The development and implementation of LBSAPs create opportunities for local stakeholders to collaborate and thereby to promote locally-contextualized actions that contribute to national and global biodiversity goals.

We conducted a questionnaire survey of the municipalities across Japan that have already developed LBSAPs. The survey obtained 387 valid responses from government officials, as well as from the experts engaged in the committees for the development of LBSAPs of 66 (out of the 67) municipalities. A multiple regression analysis using the effort levels to strengthen relevant organisational structure, process and outputs as the independent variables, and the abundance of relevant evidence base and their use in the LBSAP documents as the dependent variable yielded the following results: Efforts to strengthen the organisational structure, process and outputs relating to LBSAPs facilitate collective understanding among officials and experts of available evidence base, thereby accelerating the use of these evidences in the LBSAP documents. A platform-type arrangement that involves experts and multiple sectors was found particularly effective. Among other factors, the role of the committees that mobilized a sector-wide involvement including the government, expert and businesses was found important. In particular, the involvement of multiple sectors within local government, including agriculture, education and infrastructure services, in the LBSAP development increased the range of the ecosystem services identified in the LBSAP document. This can provide an important step to mainstream biodiversity into these sectors.

Fig. 6
Examples of the Local Biodiversity Strategies and Action Plans
(From left to right, Isumi, Kyoto, Sado and Toyooka cities)

Policy Recommendation 7

7. Tradeoffs and synergies between climate change policies and ecosystem conservation policies at national level

This study examined tradeoffs and synergies between three environmental policies in Japan that could positively or negatively affect each other. The three policies are, climate change mitigation policies, adaptation policies, and ecosystem conservation policies (Kameyama, 2019).

There was a possibility of tradeoff between climate mitigation and ecosystem conservation policies in the area of installment of renewable energy facilities (Table 1). Most energy must be supplied by renewable energy in order to reach the long term emission goal of "net-zero" by the end of this century at latest. A procedure to check mega solar panels and other facilities are not harming ecosystem is required to avoid tradeoffs between the two environmental goals. Replacement of incorporation of rice straw into soil by composting is said to be effective to reduce methane emissions, but was suggested to harm ecosystems in rice paddies.

Meanwhile synergies between climate mitigation and ecosystem conservation policies were found in industry sector reducing emissions, transportation sector reducing exhaust gas, and forest conservation. Especially, forest conservation is effective for multi-purposes; sequestering carbon, water retention function in case of heavy rainfall, and conserving ecosystem.

As for tradeoffs between climate adaptation and ecosystem policies, there was a concern in the agriculture sector, where more pesticide may be used to respond to warmer climate. Also, in the area of disaster prevention, many measures such as building dykes along rivers and seashores are listed under adaptation policies, but there was no mention of consideration for ecosystem conservation.

Synergies between adaptation and ecosystem conservation policies were found in the fields of nature protection, water environment, and urban design. Adaptation policies related to nature protection emphasize importance of habitat monitoring, which is also effective for ecosystem management. Also, mainstreaming adaptation strategies in urban designs promotes biodiversity in the area.

Plan for Global Warming Countermeasures (2016)		National Biodiversity Strategy (2012)										
Sector	Sub-section	Ecosystem network	Conservation of restricted areas	Nature rehabilitation	Environmental impact assessment	Forests	Rural areas	Cities	Rivers & marshlands	Coasts & ocean	Agriculture & fisheries	Eco-tourism
A. Industry					☺			△				
B. Commercial and other businesses	Efficient use of local energy (underground heat)							△				
	Others (heat island countermeasures)							☺				
C. Residential	Energy efficiency improvements of houses and buildings							△				
D. Transportation	Improving fuel efficiency of vehicles	☺	☺	☺								
	Increasing use of public transportation and bicycles						☺	☺				
E. Energy transformation	Solar PV	√		√	√	√	√					
	Wind power (on shore)	√		√	√	√	√					
	Wind power (off shore)		√						√	√		
	Geothermal	√	√	√	√							
	Hydro power		√	√	√				√			
	Biomass	√	√			△	△					
F. GHG other than carbon dioxide	Methane (from agriculture)		√								△	
G. Carbon sequestration	Forest management	☺	☺			☺						
	Sustainable forestry	△	△	△							☺	
	Promotion of lumber and biomass	☺	☺			☺						
	Greenery in urban area							☺				
	Decarbonization of urban planning and socioeconomic system						☺	☺				

Note: Only those sectors that had relations with biodiversity strategy are shown in the table.

☺ = possibility of synergies
√ = possibility of tradeoffs
△= possibility of consequence either synergies or tradeoffs

Table 1
Tradeoffs and synergies between climate change mitigation and ecosystem conservation policies

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