

Natural capitals for nature's contributions to people: the case of Japan

Kumagai, Junya and Wakamatsu, Mihoko and Hashimoto, Shizuka and Saito, Osamu and Yoshida, Takehito and Yamakita, Takehisa and Hori, Keiko and Matsui, Takanori and Oguro, Michio and Aiba, Masahiro and Shibata, Rei and Nakashizuka, Tohru and Managi, Shunsuke

4 January 2021

Online at https://mpra.ub.uni-muenchen.de/106239/ MPRA Paper No. 106239, posted 22 Feb 2021 10:56 UTC

Title page

Paper title: "Natural capitals for nature's contributions to people: the case of Japan"

Author's information (in order)

- Junya KUMAGAI: Urban Institute & Department of Civil Engineering, Kyushu University, Fukuoka, Japan Email: <u>kumagai.jiyunya.493@s.kyushu-u.ac.jp</u>
- 2. Mihoko WAKAMATSU: Department of Marine Policy and Culture, Tokyo University of Marine Science and Technology, Tokyo, Japan
- 3. Shizuka HASHIMOTO: Department of Ecosystem Studies, University of Tokyo, Tokyo, Japan
- 4. Osamu SAITO: Institute for Global Environmental Strategies, Kanagawa, Japan
- Takehito YOSHIDA: Department of General Systems Studies, University of Tokyo, Tokyo, Japan
- 6. Takehisa YAMAKITA: Yokosuka Headquarter, Japan Agency for Marine-Earth Science and Technology, Kanagawa, Japan
- Keiko HORI: United Nations University Institute for the Advanced Study of Sustainability, Tokyo, Japan
- 8. Takanori MATSUI: Graduate School of Engineering, Osaka University, Osaka, Japan
- 9. Michio OGURO: Forestry and Forest Products Research Institute, Matsunosato, Tsukuba, Japan
- 10. Masahiro AIBA: Research Institute for Humanity and Nature, Kyoto, Japan
- 11. Rei SHIBATA: Faculty of Agriculture, Niigata University, Niigata, Japan
- 12. Tohru NAKASHIZUKA: Forestry and Forest Products Research Institute, Matsunosato, Tsukuba, Japan

 Shunsuke MANAGI: Urban Institute & Department of Civil Engineering, Kyushu University, Fukuoka, Japan

Corresponding author: Junya KUMAGAI <u>kumagai.jiyunya.493@s.kyushu-u.ac.jp</u>

Acknowledgements

This work was supported by the Environment Research and Technology Development Fund (S-15, JPMEERF16S11500), and the Grant in Aid for Japan Society for the Promotion of Science (JSPS) Scientific Research (JP20H00648). Any opinions, findings, and conclusions expressed in this material are those of the authors and do not necessarily reflect the views of the sponsors.

Natural capitals for nature's contributions to people: the case of Japan

Abstract

Recently, natural capital has gained the attention of researchers and policymakers to promote sustainability. Previous studies have investigated the value of ecosystem services with respect to specific areas or species. Other studies have investigated the value of various types of ecosystem services and natural capital by integrating a number of findings using meta-analyses at the global level. Although these studies have provided information on either the global value of natural capital or the local value of specific subjects, there is little evidence on the country-specific values of natural capital in Japan, which will provide useful information for national environmental policies. We investigated the perceived values of terrestrial and marine natural capital in Japan using internet surveys and payment card methods. Data on various natural forms of capital were collected in a unified format and comparable manner. We found that some explanatory variables, such as perceived importance and visit frequency, as well as sociodemographic characteristics, are significant drivers of the willingness to pay (WTP), which maintains each aspect of natural capital. In addition, we conducted future predictions of terrestrial and marine natural capital. In addition, we conducted future predictions of terrestrial and marine natural capital using a scenario developed in a previous study. Our results indicate that Japan should follow a population dispersed scenario for the sustainable management of natural capital up to 2050.

Keywords: terrestrial natural capital; marine natural capital; willingness to pay; future prediction; sustainable development goals

Declarations

Funding: This work was supported by the Environment Research and Technology Development Fund (S-15, JPMEERF16S11500), and the Grant in Aid for Japan Society for the Promotion of Science (JSPS) Scientific Research (JP20H00648).

Conflicts of interest/Competing interests: On behalf of all authors, the corresponding author states that there is no conflict of interest.

Availability of data and material: Not applicable

Code availability: Not applicable

1. Introduction

Natural capital has gained the attention of researchers and policymakers as an essential component to promote sustainability for human well-being. In the field of sustainability science, the "strength" of sustainability depends on how we focus on natural capital. Strong sustainability is achieved if natural capital increases during a given period while weak sustainability can be achieved if a decrease in natural capital is sufficiently compensated by an increase in other types of capital, especially produced capital (Managi and Kumar, 2018; Noel and O'Connor, 1998).

While the principle underlying weak sustainability is that natural capital can be substituted by other types of capital, strong sustainability assumes that there are serious limitations on the substitutability between natural capital and other types of capital (Ekins et al., 2003). In this context, the concept of critical natural capital has been proposed, which refers to natural capital that plays an essential role in supporting human well-being sustainability and cannot be substituted by other types of capital in terms of its functions. Previous studies suggest that swamps, forest ecosystems, and marine ecosystems are examples of critical natural capital (Collados and Duane, 1999; Kagohashi, 2017; Daisy V. MacDonald et al., 1999; Noel and O'Connor, 1998).

Due to its non-substitutability, essential function, and process, these types of critical natural capital should be maintained with high priority. Nevertheless, some types of natural capital have been decreasing in recent years, especially marine and coastal natural capital, such as coral reefs, tidal flats, seaweed beds, and sand beaches. This indicates that some vital functions of natural capital that support sustainability have been deteriorating.

One effective method to prevent natural capital from declining and promote sustainability is to clarify the value of conserving these natural forms of capital. There are three main research paths that address the topic of valuing natural capital: ecosystem service valuation, inclusive wealth approach, and valuing nature's contributions to people.

A number of studies have investigated the values of natural capital by focusing on ecosystem services. Ecosystem service is a concept that clarifies and categorizes the benefits that human society derives from ecosystem functions (Costanza et al., 2017). Ecosystem services are mainly categorized into provisioning, regulating, supporting, and cultural services. Previous studies have calculated the willingness to pay (WTP) for growing or maintaining natural capital, such as forests, agricultural lands, coral reefs, oceans, and mangroves, in specific areas using stated preference methods. In addition, over the past 20 years, researchers have attempted to value natural capital at the global level (Costanza et al., 2017). These studies have investigated the value of various types of ecosystems that establish global natural capital using a meta-analysis based on the benefit transfer method (Costanza et al., 1997, 2014; de Groot et al., 2012).

The inclusive wealth index is another method for valuing natural capital (Managi and Kumar, 2018; UNU IHDP and UNEP, 2014). The inclusive wealth index has been proposed to measure sustainability

at global, national, and regional levels based on the sum of the total amount of produced capital, human capital, and natural capital. Some previous studies have investigated the amount of wealth at the country level (Managi and Kumar, 2018), prefectural level (Ikeda and Managi, 2019), and city level (Fujii and Managi, 2016). In the inclusive wealth framework, the value of natural capital can be calculated by multiplying the capital stock (e.g., the total size of the area of agricultural lands) and the shadow price, which is the marginal effect that a unit of a capital stock has on intergenerational wellbeing. The inclusive wealth approach also includes fisheries and minerals in the natural capital capital capital and ecosystem services from agricultural lands.

In addition to the valuation of ecosystem services and inclusive wealth, previous studies have advocated a novel approach to understand more of the relationship between people and nature. Díaz et al. (2018) proposed the concept of nature's contributions to people (NCP). This concept attempts to capture the human-nature relationship more comprehensively by emphasizing the importance of non-instrumental, cultural perspectives, such as indigenous knowledge, norms, and beliefs, regarding how to interact with nature. The NCP concept is characterized by what constitutes the connection between nature and human well-being and how they connect. The NCP approach assumes that nature is connected with well-being through instrumental and non-instrumental values that can or cannot be measured and allowed to overlap each other.

As the concept of NCP assumes, the cultural values of natural capital are frequently bundled with other types of values. For example, in Japan, seaweed beds provide people with seaweed as food. This can be recognized as a provisioning service; however, seaweed beds simultaneously support the Japanese-specific culture of eating seaweed. In addition, within the relationship between seaweed beds and the well-being of Japanese people, there are some other processes that occur, such as harvesting seaweed, cooking dishes with seaweed, and eating them. This process may be based on Japanese-specific local knowledge, norms, and beliefs about eating seaweed. In addition, in some rural areas in Japan, forests, agricultural lands, and the lives of agricultural communities harmonize and form a Japanese-specific landscape known as a Satoyama (Saito et al., 2019). This is one example of how some types of natural capital together create cultural value, along with the provisioning services of food and timber, by harmonizing with the lives of local residents. In addition, there is a Japanese specific leisure activity known as clamming in tidal flats. We can recognize that the tidal flat is not only characterized as a food supply service of shellfish, but also the service of providing leisure.

These perspectives reveal that natural capital has a country-specific relationship with culture and lifestyle, such that the perceived value of a certain type of natural capital may differ from country to country. Therefore, understanding the values of natural capital in Japan at the country level and a focus on the various types of natural capital that exist in Japan are important.

In this study, we focus on the values and determinants of terrestrial and marine natural capital in Japan. We estimate Japanese households' perceived value of natural capital considering their

provisioning, regulating, supporting, and cultural services, as well as some disservices. In addition, we predict the future of terrestrial natural capital in Japan at the municipality level to measure future sustainability up to 2050 based on a scenario suitable to natural capital projection (Saito et al., 2019). Simultaneously, we predict the ecological footprint in 2050 with respect to the change in the burden on the natural capital in each municipality. In addition to terrestrial natural capital, we predict the future of eelgrass beds and seaweed beds, which are main examples of marine natural capitals in Japan. Furthermore, we investigate the interconnectedness between natural capital and sustainable development goals (SDGs) using a network analysis to investigate the importance of natural capital for achieving SDGs. Figure 1 shows the overall framework of our analysis.

There are several contributions from our study. First, natural capital is categorized in a more detailed manner. In many previous studies, the values have been calculated in various categories, such as agricultural lands or forests as a whole, whereas a limited number of studies consider the difference, for example, between paddy fields and crop fields and between plantation forests and natural forests. In fact, natural forests have higher biodiversity than plantation forests (Brockerhoff et al., 2008), which may be partly attributable to a difference in the WTP between them.

The other contribution is that we predict future projections at the municipality level, which enables us to clarify the pathways that Japanese and local governments should follow to achieve a sustainable future. Some studies have focused on the value and future of natural capital in Japan at the prefectural level (Fujii et al., 2017; Ikeda and Managi, 2019). However, a limited number of studies predict the future of natural capital at the municipality level. Focusing on the future of natural capital at the municipality level allows us to clarify the differences in the future trends in natural capital between urban and rural areas within the same prefecture. This method can reveal the disparities in terms of the impact that population decline has on the maintenance of natural capital among municipalities in urban and rural areas in Japan.

The remainder of this paper is structured as follows. In section 2, we provide estimations of the WTP and its determinants, including an explanation of the questionnaire conducted to ask Japanese individuals about their WTP for 13 types of natural capital in Japan. In addition, the value per unit of each natural capital was estimated. Section 3.1 conducts future predictions of natural capital at the municipality level while section 3.2 presents the results of the prediction. We predict the future of terrestrial natural capital up to 2050 in Japan by incorporating the value per unit of each natural capital estimated in section 2 and data on the Japanese population and land use prediction (Hori, Saito, et al., 2020; Shoyama et al., 2019). This subsection clarifies how much future natural capital will be affected by the type of population and land use scenarios Japan will follow, considering the differences between urban and rural areas. Section 3.3 adds one more scenario where abandoned agricultural lands will be converted into forests, analyzing the impact of this conversion on future natural capital. Section 3.4 focuses on the ecological footprint, which sheds light on how much the burden of future consumption activities will change at the municipality level. Section 3.5 predicts the future of eelgrass beds and

seaweed beds in Japan, which are distributed on the coasts around Japan. Section 3.6 investigates the relationship between natural capital and SDGs, using the scenario and data from previous studies. Although we emphasize the importance of maintaining natural capital, it is not pragmatic to focus solely on natural capital to realize sustainability. To achieve sustainability in other fields, we will clarify how natural capital is related to each item of the SDGs. Section 4 discusses the results of the study and provides policy implications drawn from the results.



Fig. 1. Diagrams of overall framework of the analysis.

2. WTP estimation for terrestrial and marine natural capital in Japan

2.1. Surveyed natural capital

We focus on 13 types of natural capital for the targets that represent the agricultural, forest, and marine natural capital in Japan, which include paddy fields, crop fields, orchards, pastures, plantation forests, natural forests, seaside protection forests, coral reefs, seaweed beds, tidal flats, sand beaches, mangrove forests, and fishing grounds. All of these play essential roles in maintaining people's lives, culture, society, environment, and well-being in Japan. However, many of them, especially marine natural capital, have been decreasing in recent years. Figure A1 shows the recent trend in the amount of each natural capital.

The cultivated area for paddy fields occupies approximately 6.6% of the land area in Japan, supporting an essential part of the food supply by producing almost 100% of the rice consumed in

Japan (Natuhara, 2013). Besides their role in food production, paddy fields also have critical ecosystem services, such as regulating groundwater quantity and water quality, as well as flood and soil erosion control. Furthermore, previous studies have found that paddy fields maintain biodiversity by providing wetland habitats for many species, such as fish (Katano et al., 2003), insects (Mukai et al., 2005), frogs (Fujioka and Lane, 1997), and other wild animals (Natuhara, 2013). In contrast, paddies are also habitats for carriers of infectious diseases, such as mosquitos and ixodid ticks, which are possible vectors of Japanese encephalitis virus and SFTS virus, respectively (Kato et al., 2016; T. Tsunoda and Mori, 2000; Umenai et al., 1985). Rice-paddy acreage has been decreasing for at least the last five decades, with 1.58 million hectares in 2014.

The cultivated area for crop fields, orchards, and pastures is equivalent to 5.3% of the land area in Japan (MAFF, 2018). These agricultural lands play a role in producing wheat, barley, vegetables, beans, fruit, and pasture plants. They also have regulating services, such as water and soil control, and provide habitats for wild species, including mosquitos and ixodid ticks. The planted areas for crops, fruit, and forage/manure crops were 980, 230, and 1.02 million ha, respectively, in 2014.

The overall forest area in Japan is approximately 2.5 million hectares, which is equivalent to 67% of the land area (MAFF, 2017). Of the total forest area in Japan, plantation forests account for 41% and natural forests¹ account for 54%. Forests play a role mainly in producing timber, as well as in constructing habitats for various species, providing soil nutrients, preventing sediment disasters, controlling climate, and regulating water quality and quantity (Forestry Agency of Japan, 2010). Compared with plantation forests, natural forests usually maintain a higher level of biodiversity (Brockerhoff et al., 2008). In addition to these functions and benefits of forests, seaside protection forests play a vital role as a windbreak and preventing damage from tsunamis, storm surges, and salt pollution. Forests provide us with recreational sites for therapeutic walks, wild plant picking, and picnics. In contrast, forests are also habitats for hornet, ixodid, and wild animals that ravage crop fields.

Natural marine capital contributes mainly to the conservation of coastal biodiversity, the construction of habitats for various species, and providing people with a variety of food, such as fish, crab, shrimp, shellfish, and seaweed (Fisheries Agency of Japan, 2008; MOE, 2007; Spalding et al., 2010). Each marine and coastal natural capital contributes to sustainability by providing nursery areas for juvenile fish, climate control, water quality improvement, and coastline protection. Furthermore, marine and coastal natural capital contributes to residential well-being from a cultural perspective by providing us with places for recreation activities, such as swimming, diving, and snorkeling. In addition, seaweed beds support the unique Japanese food culture, such as eating sea urchins, kelp, and seaweed. Although marine natural capital sustains the well-being of people in Japan from the various aspects mentioned above, there are declining trends in marine natural capital (Fig. A1).

¹Natural forests are forests that have reproduced naturally and are composed of indigenous tree species. For details on the definition of natural forests established by the Japanese government, see Forestry Agency of Japan (2017).

2.2. Data

To estimate the WTP to maintain the targeted natural capital and identify its determinants, we used data from a survey that we originally conducted in Japan in February 2019. Through the internet, a sample of 7,556 Japanese individuals was collected. The aim of the survey was to investigate the value of various types of natural capital, consistent with the natural and agricultural environment of land and ocean in Japan. We asked respondents about their WTP to maintain each natural capital using payment card methods. The question about WTP included the 13 types of natural capital mentioned in the previous subsection. We additionally asked the respondents about their WTP to maintain overall natural environment in Japan to estimate the maximum amount of money that an average Japanese household can pay for the entire environmental conservation project in Japan. We also asked questions about respondents' behavior and perception that appeared to be the explanatory variables of the WTP values.

The wording of the questions on WTP were as follows: "How much is the maximum amount that you can pay annually from your household to maintain X?", where X is one of the 13 natural capital aspects mentioned above. The respondents selected one of the ranges displayed on the screen. Before selecting their WTP for each natural capital, the respondents were shown bar charts of the recent changes in the amount of natural capital (Fig. A1), a list of the ecosystem services provided by natural capital, and hypothetical amounts of decreases in natural capital without the implementation of a hypothetical project to maintain each natural capital (Table A1). Provisioning, regulating, supporting, and cultural services were included in the information on the ecosystem services of each natural capital.

We also provided some additional assumptions about hypothetical projects. First, when responding to payment for each natural capital, we assumed that the respondents have not paid for other natural capital. Second, the money that the respondents pay will be used only for the project to maintain each natural capital. Third, if the project will be conducted, not only the agreed household, but also all households will pay through taxes and price increases on relevant goods, among others. Finally, we assumed that the payments will continue for the next 10 years.

Furthermore, if respondents selected 0 JPY as their WTP for all of the items that we asked, they were asked why they did not want to pay. A certain percentage of the respondents selected the following: "I think I do not have any obligation to pay," "I'm worried about whether the money I paid will be used correctly," "I cannot decide from the information given," or "other." We identified these responses as protest responses. We excluded protest responses from our analysis. Figure 2 shows the distributions of the responses for the WTPs.



Fig. 2. Distribution of the response to WTP questions.

In addition, we questioned the frequency of visiting each natural capital and the perceived importance of each natural capital. These personal behaviors and perceptions related to natural capital appear to affect the WTP to maintain natural capital. Table 1 lists how frequently the respondents visit each natural capital. Table 2 summarizes the perceived importance of each natural capital.

Table 2 summarizes the other explanatory variables. We asked questions on the respondents' sociodemographic characteristics, such as gender, age, and household income, to utilize their answers as the explanatory variables for the WTP. We excluded respondents who selected "do not know" or "do not want to answer" in terms of their household income from our analytical sample. We also asked the respondents to report their residential area using an 8-digit regional mesh code based on standard grid squares (1 km \times 1 km resolution).

As an additional explained variable, we constructed a dummy variable that equals 1 if the respondent lives in an urban area. We regarded the municipalities whose populations are over 200,000 and daytime/nighttime population ratios of more than 0.98 as central cities while classifying central

cities and their adjacent municipalities as urban areas. These areas are recognized as the places where future populations will concentrate if Japan forms a compact society (Hori, Saito, et al., 2020). We also defined municipalities other than urban areas as rural areas. Approximately 60% of the respondents lived in urban areas.

To examine the relationship between geospatial variables and WTP, we combined secondary geospatial data from MLIT (2014) and MOE (2005) with the sample of our survey data. Specifically, we used the areas of paddy fields, other agricultural lands, and forests within 1 km grids in which the respondents' residences exist, as well as the distances to the nearest coral reefs, seaweed beds, tidal flats, sand beaches, mangrove forests, and coastal lines from the respondents' residences. Using these variables, we can test the hypothesis that the WTP to maintain each natural capital differs depending on whether the corresponding natural capital exists near the respondents' residential areas. Moreover, to consider whether there are regional differences in the WTP, we employed a frequently used Japanese regional classification, referred to as the eight regions, which divides Japan into Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku, and Kyushu/Okinawa.

Furthermore, we included City Biodiversity Index (CBI) data from MLIT (2016), which evaluates current situations in terms of the biodiversity at the municipality level and the extent to which the residents and local government in each municipality are active in the conservation of biodiversity. There are seven types of indices depending on we assess biodiversity and related activities. Out of the seven indices, we used scores 4, 6, and 7, which are calculated using local governments' answers to a questionnaire on biodiversity-related activities. Score 4 assesses how actively each local government conducts surveys of the number of animals and plants inhabiting their territory. Score 6 measures how much each local government encourages residents and organizations in their area to participate in activities related to biodiversity conservation.² These scores have standardized values with averages of 50 and standard deviations of ten among Japanese municipalities. We assigned the scores of the corresponding municipality to each respondent depending on where the respondent lives. Using these data, we can examine the relationship between the WTP for natural capital and how active local governments and residents are in biodiversity conservation.

Frequency of visits (%)	Paddy field	Crop field	Orchard	Pasture	Forest	Coral reef
Pass through sometimes	59.7	57.8	44.8	35.1	43.7	10.2
Less than once a year	5.0	5.3	14.2	11.7	10.2	10.9
Once a year-once a month	5.1	6.2	5.6	3.7	7.9	2.2
Once a month-once a week	2.4	4.0	2.0	1.5	3.7	0.6
Once a week-3 times a week	1.6	3.5	1.0	0.6	1.7	0.5
3 times a week-everyday	1.2	2.1	0.4	0.3	0.8	0.2

Table 1. Frequency of visiting each natural capital.

² For more detailed information on the City Biodiversity Index, see MLIT (2016).

Never been	24.9	21.0	32.0	47.2 32.0	75.4
Table 1. (continued)					
Frequency of visits (%)	Seaweed bed	Tidal flat	Sand beach	Mangrove forest	Sea (offshore)
Pass through sometimes	10.1	13.8	23.6	7.0	19.7
Less than once a year	6.8	11.2	27.3	7.0	24.4
Once a year-once a month	1.7	2.9	12.9	1.2	8.1
Once a month–once a week	1.0	0.7	2.3	0.7	2.2
Once a week-3 times a week	0.5	0.5	0.9	0.3	0.6
3 times a week-everyday	0.2	0.3	0.4	0.1	0.3
Never been	79.8	70.7	32.7	83.8	44.7

Table 2. Summary statistics ($n = 3,208^{b}$).

Variable	Mean value or % value
% Female	46.4%
% University graduate	54.4%
% Worker (incl. full-time and part-time)	74.5%
% Urban	61.8%
Average age (M/SD)	44.7/13.2
Average household size (M/SD)	2.7/1.3
Average number of children (M/SD)	0.47/0.85
Annual household income	
< 2 million JPY ^a	9.2%
2–3 million JPY	9.0%
3–4 million JPY	13.3%
4–5 million JPY	13.1%
5–6 million JPY	12.1%
6–7 million JPY	9.9%
7–8 million JPY	8.8%
8–9 million JPY	5.9%
9–10 million JPY	6.6%
10–15 million JPY	8.8%
15–20 million JPY	2.1%
20–30 million JPY	1.0%
\geq 30 million JPY	0.3%
Items that respondents perceive as important	
% Paddy field	48.6%
% Crop field	31.1%
% Orchard	7.8%
% Pasture	4.3%
% Plantation forest	15.0%
% Natural forest	46.3%
% Seaside protection forest	13.1%
% Coral reef	20.1%
% Seaweed bed	6.0%
% Tidal flat	8.7%
% Sand beach	9.5%
% Mangrove forest	4.4%
% Fishing ground	28.9%

Average area of each NC in $1 km^2$ grid (m ²)	
Paddy field (M/SD)	75755.8/156950.2
Other agricultural land (M/SD)	33796.5/85201.9
Forest (M/SD)	83794.2/170842.1
Average distance to each NC from residents (km)	
Coral reef (M/SD)	183.7/228.7
Seaweed bed (M/SD)	30.9/26.1
Tidal flat (M/SD)	41.0/47.3
Sand beach (M/SD)	18.9/22.5
Mangrove forest (M/SD)	851.8/378.8
Coastal line (M/SD)	18.3/23.4
The great respondents live in	
% Hokkoido	8 50%
% Tabala	8.570
% Tonoku	8.770 24.00/
	24.0%
	18.3%
	12.6%
% Chugoku	9.8%
% Shikoku	3.5%
% Kyushu/Okinawa	14.6%
City Biodiversity Index (CBI)	
Score 4	54.7/11.1
Score 6	57.6/12.5
Score 7	56.6/10.9

^a JPY (Japanese Yen) approximately equal to USD 0.009.

^b After the cleaning and data combination processes, we obtained 3,208 observations.

2.3. Estimation method

We analyzed the determinants of the WTP to maintain the 13 types of natural capital, along with maintaining the entirety of the natural environment, as it currently stands in Japan. Even after removing the protest responses from the analytical sample, approximately 20% of the respondents still showed zero WTP for most of the items, except for the overall nature of Japan.

Recent empirical studies have applied the zero-inflated ordered probit (ZIOP) model to ordinal dependent variables (Harris and Zhao, 2007). Some studies have shown the superiority of the ZIOP regression as opposed to the traditional ordered probit to provide less biased estimates when an ordinal dependent variable exhibits a high fraction of observations at zero (Bagozzi et al., 2012). These studies explain that the ZIOP model is preferred when the zeros are related to two distinct sources: one is referred to as an "always-zero" observation (e.g., a person who never pays for a certain natural capital, even if their income increases) and the other is a zero observation that may transition into a non-zero value (e.g., a person who might pay if their income increases). As the determinants of being an always-zero person are often different from the determinants of how much a person will pay, the standard

ordered probit model that does not consider the always-zero observation cannot precisely estimate such a situation.

This model assumed two latent dependent variables through the estimation process. The latent variable model is represented by the following equations:

$$r^* = \mathbf{x}' \boldsymbol{\beta} + \varepsilon, \tag{1}$$

$$y^* = \mathbf{z}' \boldsymbol{\gamma} + \boldsymbol{u}, \text{ and}$$
(2)

$$y = \begin{cases} 0 \text{ if } r^* \leq 0 \text{ or } y^* \leq 0, \\ j \text{ if } 0 < r^* \text{ and } \mu_{j-1} < y^* \leq \mu_j \ (j = 1, \dots, J-1), \\ J \text{ if } 0 < r^* \text{ and } \mu_{J-1} < y^* \end{cases}$$
(3)

where r^* is a latent variable representing the propensity to participate in the WTP decision, x is a vector of determinants for participation with unknown parameters, β , y^* is a latent variable related to an ordinal variable, y, taking the values $\{0, 1, 2, ..., J\}$, z is a vector of determinants of y with unknown parameters, γ . The terms ε and u are standard-normally distributed errors, and μ_j (j = 1, ..., J - 1) are unknown threshold parameters. The unknown parameters can be estimated by maximum likelihood estimation. As explanatory variables x and z, we include the sociodemographic variables described in the previous section. Equation (1) is a splitting equation that estimates the effects that covariates have on the probabilities of not being always-zero observations while Eq. (2) is an outcome equation that estimates the effects that the covariates have on the amount of the objective variable (Bagozzi et al., 2012).

In addition, we obtained two types of mean WTP estimations using our survey data. For the payment card method, there are two types of WTP estimations that have been frequently used in previous studies (Blaine et al., 2005). One is the Turnbull lower bound mean (LBM), which is calculated as follow:

$$LBM = \pi_0 p_0 + \sum_{i=1}^{k} \pi_i (p_i - p_{i-1}), \tag{4}$$

where π_i are the cumulative percentages of respondents who select the range of monetary value less than p_{i+1} and p_0 is the initial bid price (Turnbull, 1976). The other WTP estimation method is the Kristrom mean (Kriström, 1990), which is calculated as follows:

Kristrom mean =
$$LBM + \frac{p_0(1-\pi_0)}{2} + \sum_{i=1}^k \left\{ \frac{|\pi_i - \pi_{i-1}|(p_i - p_{i-1})}{2} \right\} + \frac{\pi_k(p^* - p_k)}{2},$$
 (5)

where p^* is the estimated price for each natural capital when π , the percentage that respondents pay, p, to maintain the natural capital, is equal to zero. An OLS regression of π_i on the natural log of p_i for each natural capital was conducted to obtain the predicted value of p^* , considering that there is an approximately linear relationship between π_i and $\ln(p_i)$ in our data. Kristrom's measure provides higher WTP estimates than LBM because the former assumes the distribution of the WTP between bid prices, but the latter uses lower bid prices without any assumption of the WTP distribution between bid prices (Lee et al., 2015).

2.4. Regression Results

Table 3 lists the results of the regression. The coefficients of the outcome equation can be interpreted as the effects that the explanatory variables have on the WTP amounts while the coefficients of the splitting equation imply the effects of the variables on the probabilities that the respondents are willing to pay more than zero.

In the splitting equation, the variables of gender, living urban areas, visit frequency, and perceived importance are significant determinants of the WTP for many natural capital categories. We found that female respondents are more likely to be willing to pay to maintain all 13 natural capital categories than males. Residents in urban areas tend not to pay to maintain some natural capital and the entire nature of Japan compared with residents in rural areas. The visit frequency, perceived importance, or both positively affected the WTP for most of the natural capital categories, except for orchards and pastures. In addition, the elderly are more likely to pay for some marine natural capital and the overall environment than younger people. In terms of the geospatial variables, only the areas of forests within a 1 km grid where respondents live positively affects the probability of the WTP for natural forest maintenance. The coefficients of the eight region dummies are mostly negative, where some are statistically significant, which indicates that the respondents living in the baseline area, i.e., Hokkaido, are more likely to be WTP to maintain natural capital than the residents in other areas. In terms of the CBI score, score 6 has a positive correlation with the probability of paying for agricultural lands, which indicates that, if a local government actively considers biodiversity conservation in their city planning, the residents of the municipality are more likely to pay to maintain agricultural land. In contrast, score 7 has a negative correlation with the probability of paying to maintain agricultural lands and forests, indicating that, if the local government encourages the residents and organizations in the municipality to join their activities related to biodiversity conservation, the residents are more likely to state zero WTPs for agricultural lands and forests.

The coefficient estimates in the outcome equation reveal that the variables of gender, graduate, household size, household income, visit frequency, perceived importance, and area of residence can be the determinants for the WTP amounts to maintain much of the natural capital. Household income

and visit frequency positively influenced the all WTP amounts at the 1% significance level. Male and graduated respondents tended to state a higher WTP for many natural capital categories than females. Perceived importance also positively affected the WTP amounts for some natural capital. Only orchards and pastures were not influenced by perceived importance in terms of both the probability of paying for them and the WTP amounts. Household size negatively affected the WTP values for many of the natural capital categories. All of the estimated coefficients for the regional dummies were negative; many were statistically significant, which indicates that the WTP to maintain natural capital is higher among residents in the Hokkaido region compared with the other regions. In addition, the distance from the coast had a negative effects on the WTP to maintain seaside protection forests, tidal flats, mangrove forests, and fishing grounds. This implies that people living near the coast tended to state a higher WTP for these natural capital categories.

There are some differences between natural capital in which covariates may affect the WTP for each. For example, while the WTP amount for natural forests, coral reefs, seaweed beds, tidal flats, mangrove forests, and fishing grounds is higher among university graduates, other natural capital categories may not be related to educational background. There is a likelihood that higher education allows people to understand the importance of natural capital that has mainly indirect use value and non-use value with respect to their ecosystem services compared with agricultural lands and plantation forests that have a large direct use value. In addition, the WTP for coral reefs, seaweed beds, and mangrove forests were higher if the respondents had children while the other natural capital categories were not related to having children. One possible reason for the relationship between having children and a higher WTP for a certain natural capital is that children receive some environmental education on these natural capital categories. The parent may be affected by their children through their daily conversation in terms of their perceived values of nature.

Table 3.	ZIOP	regression	results.
14010 5.	LICI	regression	rebuitb.

Outcome Eq Female -0.157^{***} -0.166^{***} -0.130^{**} -0.0932^{**} -0.0696 -0.0883^{*} Age -0.00107 -0.00119 -0.00320^{*} -0.00115 -0.00276 -0.00252 -0.00276 Graduate 0.0686 0.0813 0.0754 0.0821 0.0618 0.0815^{*} 0.0709 Household size -0.0347 -0.0272 -0.0311 -0.0383 -0.0506^{**} -0.0347 -0.0324 Child 0.0412 0.0411 0.0413 0.0511 0.0517 0.0421 0.0273 Worker -0.000418 0.0164 0.0179 0.0248 -0.0506 -0.0123 -0.0369 Income 0.000448^{***} 0.000452^{***} 0.000433^{***} 0.000420^{***} 0.00041^{***} 0.00041^{***} 0.00041^{***} 0.000420^{***} 0.00041^{***} 0.00041^{***} Urban -0.000390 0.000828 -0.0173 -0.00785 0.0232 -0.00990 0.00509
Female -0.157^{***} -0.166^{***} -0.163^{***} -0.130^{**} -0.0932^{**} -0.0696 -0.0883^{*} Age -0.00107 -0.00119 -0.00320^{*} -0.00115 -0.00276 -0.00252 -0.00276 Graduate 0.0686 0.0813 0.0754 0.0821 0.0618 0.0815^{*} 0.0709 Household size -0.0347 -0.0272 -0.0311 -0.0383 -0.0506^{**} -0.0347 -0.0324 Child 0.0412 0.0411 0.0413 0.0511 0.0517 0.0421 0.0273 Worker -0.000418 0.0164 0.0179 0.0248 -0.0506 -0.0123 -0.0369 Income 0.000448^{***} 0.000452^{***} 0.000460^{***} 0.000433^{***} 0.000420^{***} 0.00041^{***} 0.00041^{***} Urban -0.000390 0.000828 -0.0173 -0.0785 0.0232 -0.00990 0.00509 Visit 0.159^{***} 0.140^{***} 0.185^{***} 0.203^{***} 0.0904^{***} 0.111^{***} 0.105^{***} Importance 0.180^{***} 0.130^{**} -0.00637 -0.135 0.0553 0.0859^{**} 0.0821 Area of paddy field $1.79e-07$ $4.122.07$ $2.326.07$ $2.326.07$ 0.0859^{**} 0.0821
Age -0.00107 -0.00119 -0.00320^* -0.00115 -0.00276 -0.00252 -0.00276 Graduate 0.0686 0.0813 0.0754 0.0821 0.0618 0.0815^* 0.0709 Household size -0.0347 -0.0272 -0.0311 -0.0383 -0.0506^{**} -0.0347 -0.0324 Child 0.0412 0.0411 0.0413 0.0511 0.0517 0.0421 0.0273 Worker -0.000418 0.0164 0.0179 0.0248 -0.0506 -0.0123 -0.0369 Income 0.000448^{***} 0.000452^{***} 0.000460^{***} 0.00043^{***} 0.000420^{***} 0.00041^{***} 0.00041^{***} Urban -0.000390 0.000828 -0.0173 -0.00785 0.0232 -0.00990 0.00509 Visit 0.159^{***} 0.140^{***} 0.185^{***} 0.203^{***} 0.0904^{***} 0.111^{***} 0.105^{***} Importance 0.180^{***} 0.130^{**} -0.00637 -0.135 0.0553 0.0859^{**} 0.0821 Area of paddy field $1.79e-07$ $4.122.07$ $2.322.07$ $2.322.07$ 0.0859^{**} 0.0821
Graduate 0.0686 0.0813 0.0754 0.0821 0.0618 0.0815^* 0.0709 Household size -0.0347 -0.0272 -0.0311 -0.0383 -0.0506^{**} -0.0347 -0.0324 Child 0.0412 0.0411 0.0413 0.0511 0.0517 0.0421 0.0273 Worker -0.000418 0.0164 0.0179 0.0248 -0.0506 -0.0123 -0.0369 Income 0.000448^{***} 0.000452^{***} 0.000460^{***} 0.00043^{***} 0.000420^{***} 0.00041^{***} 0.00041^{***} Urban -0.000390 0.000828 -0.0173 -0.00785 0.0232 -0.00990 0.00509 Visit 0.159^{***} 0.140^{***} 0.185^{***} 0.203^{***} 0.0904^{***} 0.111^{***} 0.105^{***} Importance 0.180^{***} 0.130^{**} -0.00637 -0.135 0.0553 0.0859^{**} 0.0821 Area of paddy field $1.79e-07$ $4.122.07$ $2.322.07$ $2.322.07$ 0.0859^{**} 0.0821
Household size -0.0347 -0.0272 -0.0311 -0.0383 -0.0506^{**} -0.0347 -0.0324 Child 0.0412 0.0411 0.0413 0.0511 0.0517 0.0421 0.0273 Worker -0.000418 0.0164 0.0179 0.0248 -0.0506 -0.0123 -0.0369 Income 0.000448^{***} 0.000452^{***} 0.000460^{***} 0.00043^{***} 0.000420^{***} 0.00041^{***} 0.00041^{***} Urban -0.00390 0.000828 -0.0173 -0.00785 0.0232 -0.00990 0.00509 Visit 0.159^{***} 0.140^{***} 0.185^{***} 0.203^{***} 0.0904^{***} 0.111^{***} 0.105^{***} Importance 0.180^{***} 0.130^{**} -0.00637 -0.135 0.0553 0.0859^{**} 0.0821 Area of paddy field $1.79e-07$ $4.122.07$ $2.322.07$ 0.7 $0.232.07$ 0.0859^{**} 0.0821
Child 0.0412 0.0411 0.0413 0.0511 0.0517 0.0421 0.0273 Worker -0.000418 0.0164 0.0179 0.0248 -0.0506 -0.0123 -0.0369 Income 0.000448*** 0.000452*** 0.000460*** 0.000433*** 0.000420*** 0.000401*** 0.000419*** Urban -0.000390 0.000828 -0.0173 -0.00785 0.0232 -0.00990 0.00509 Visit 0.159*** 0.140*** 0.185*** 0.203*** 0.0904*** 0.111*** 0.105*** Importance 0.180*** 0.130** -0.00637 -0.135 0.0553 0.0859** 0.0821 Area of paddy field 1.79e-07 - 4.122.07 2.332.07 0.00553 0.0859** 0.0821
Worker -0.000418 0.0164 0.0179 0.0248 -0.0506 -0.0123 -0.0369 Income 0.000448*** 0.000452*** 0.000460*** 0.000433*** 0.000420*** 0.000420*** 0.000411*** 0.000419*** Urban -0.00390 0.000828 -0.0173 -0.00785 0.0232 -0.00990 0.00509 Visit 0.159*** 0.140*** 0.185*** 0.203*** 0.0904*** 0.111*** 0.105*** Importance 0.180*** 0.130** -0.00637 -0.135 0.0553 0.0859** 0.0821 Area of paddy field 1.79e-07 4122.07 2.332.07 2.332.07 1.332.07
Income 0.000448*** 0.000452*** 0.000460*** 0.000433*** 0.000420*** 0.000410*** 0.000419*** Urban -0.000390 0.000828 -0.0173 -0.00785 0.0232 -0.00990 0.00509 Visit 0.159*** 0.140*** 0.185*** 0.203*** 0.0904*** 0.111*** 0.105*** Importance 0.180*** 0.130** -0.00637 -0.135 0.0553 0.0859** 0.0821 Area of paddy field 1.79e-07 - 4.622.07 4.122.07 2.332.07
Urban -0.000390 0.000828 -0.0173 -0.00785 0.0232 -0.00990 0.00509 Visit 0.159*** 0.140*** 0.185*** 0.203*** 0.0904*** 0.111*** 0.105*** Importance 0.180*** 0.130** -0.00637 -0.135 0.0553 0.0859** 0.0821 Area of paddy field 1.79e-07 - 4.620.07 4.120.07 2.330.07
Visit 0.159*** 0.140*** 0.185*** 0.203*** 0.0904*** 0.111*** 0.105*** Importance 0.180*** 0.130*** -0.00637 -0.135 0.0553 0.0859** 0.0821 Area of paddy field 1.79e-07 - - 2.320.07 - -
Importance 0.180*** 0.130** -0.00637 -0.135 0.0553 0.0859** 0.0821 Area of paddy field 1.79e-07 4620.07 4120.07 2.330.07 0.00000000000000000000000000000000000
Area of particulture land 4620.07 4120.07 2.320.07
Area of particularly 4620.07 4120.07 $2.320.07$
Area of forest $4.02007 + .12007 + .12007 + .12007 = 4.08 - 1.94 - 0.8 - 0.8 - 0.8 - 0.8 - 0.94 - 0.8 $
$\frac{1}{1000000} = \frac{1}{10000000000000000000000000000000000$
Hokkaida area (baseline)
$\frac{1}{2} \frac{1}{2} \frac{1}$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$
Kanto area -0.201 -0.188 -0.178 -0.151 -0.150 -0.124 -0.104 Club 0.270*** 0.262*** 0.190* 0.161* 0.160* 0.127 0.104**
Chubu area $-0.2/9$ -0.262 -0.186 -0.181 -0.160 $-0.15/$ -0.184
Kinki area $-0.248 -0.237 -0.208 -0.146 -0.182 -0.180 -0.198$
Chugoku area -0.361 -0.338 -0.305 -0.297 -0.275 -0.226 -0.336
Shikoku area -0.401 -0.303 -0.231 -0.196 -0.233 -0.248 -0.316
Kyushu/Okinawa area -0.228^{+1} -0.214^{+1} -0.206^{+1} -0.225^{+1} -0.223^{+1} -0.209^{+1} -0.262^{+1}
CBI score 4 -0.00328 -0.00254 -0.00302 -0.00402 -0.00185 -0.00240 -0.000509
CBI score 6 -0.00470 -0.00457 -0.00533 -0.00395 -0.00110 -0.00187 -0.00290
CBI score 7 0.00672° 0.00541 0.00703° 0.00540 0.000764 0.00167 0.00184
Splitting Eq
Female 0.534^{***} 0.760^{**} 0.614^{***} 0.740^{***} 0.314^{**} 0.281^{***} 0.322^{***}
Age -0.00314 -0.00659 -0.00468 -0.00657 0.00552 0.00253 0.00388
Graduate 0.105 0.0185 -0.00603 -0.0755 0.121* 0.102 0.113
Household size 0.0598 0.0847 0.0714 0.100° 0.0412 0.00708 -0.00639
Child 0.0329 0.0144 0.0745 0.0224 -0.00755 -0.0108 0.0344
Worker 0.00964 0.0134 -0.0268 -0.0907 0.0542 -0.0493 0.0181
Income -0.000137 -0.000172 -0.000207^{*} -0.000204^{*} $-4.78e-05$ $5.53e-05$ $-1.64e-05$
Urban -0.155^* -0.193^* -0.117 -0.176 -0.0921 -0.123 -0.102
Visit 0.0767** 0.0414 0.0247 0.0479 0.140*** 0.201*** 0.144***
Importance 0.720*** 0.373*** -0.0814 0.393 0.566** 0.568*** 0.371***
Area of paddy field 7.56e–09
Area of agricultural land 8.78e–07 4.34e–07 1.09e–07
Area of forest 1.88e-07 7.19e-07** 4.54e-07
Distance to coastal line -0.0163
Hokkaido area (baseline)
Tohoku area -0.198 -0.136 -0.0984 -0.0240 -0.171 -0.263 -0.224
Kanto area -0.307^* -0.368 -0.363 -0.297 -0.240^* -0.346^{**} -0.288^{**}
Chubu area -0.290 -0.225 -0.323 -0.303 -0.193 -0.229 -0.247*
Kinki area -0.467^{**} -0.509^{*} -0.473^{*} -0.607^{**} -0.375^{**} -0.477^{***} -0.397^{***}
Chugoku area -0.413^{**} -0.373 -0.500^{*} -0.456 -0.255 -0.537^{***} -0.342^{**}
Shikoku area -0.308 -0.542^{*} -0.567^{*} -0.474 -0.281 -0.526^{**} -0.360^{*}
Kvushu/Okinawa area -0.223 -0.310 -0.296 -0.146 -0.117 -0.137 -0.0171
CBI score 4 0.00317 0.00246 0.00313 0.00392 0.00189 0.00425 3.79e–05
CBI score 6 0.0133^{**} 0.0167^{**} 0.0133^{*} 0.0141^{*} 0.00577 0.00544 0.00351
CBI score 7 -0.0168^{**} -0.0191^{**} -0.0181^{**} -0.0170^{**} -0.00977^{**} -0.0136^{**} -0.00510
Constant 0.902^{**} 1.377^{***} 1.576^{***} 1.532^{***} 0.522^{*} 1.047^{***} 0.890^{***}
Observations 3.103 3.104 3.095 3.093 3.107 3.116 3.111

**** p<0.01, ** p<0.05, * p<0.1

Table 3. (continued)							
Variable	Coral reef	Seaweed bed	Tidal flat	Sand beach	Mangrove	Fishing ground	Whole nature
Outcome Eq							
Female	-0.0447	-0.0967^{**}	-0.0998^{**}	-0.139***	-0.0155	-0.137^{***}	-0.0882^{**}
Age	0.000958	-0.00191	-0.00345^{*}	-0.00201	0.00111	-0.00124	0.00278^{*}
Graduate	0.0892^{**}	0.0826^{*}	0.0915^{*}	0.0442	0.139***	0.0856^{*}	0.107***
Household size	-0.0442^{**}	-0.0462^{**}	-0.0346	-0.0363^{*}	-0.0589^{**}	-0.0409^{*}	-0.0421**
Child	0.0781**	0.0548^{*}	0.0344	0.0384	0.0619^{*}	0.0384	0.0546^{*}
Worker	-0.0104	0.0294	0.0587	0.0748	-0.0224	0.0480	0.0315
Income	0.000389***	0.000411***	0.000442***	0.000364***	0.000413***	0.000380***	0.000550***
Urban	0.000487	-0.0279	-0.0166	-0.0144	0.0238	0.00322	-0.0191
Visit	0.167***	0.156***	0.0893***	0.112***	0.171***	0.0879***	
Importance	0.0375	0.0797	0.216***	-0.0397	0.287***	0.126***	
Distance to coral reef	0.000753	010797	0.210	010037	0.207	01120	
Distance to seaweed bed	0.000755	-0.0236					
Distance to tidal flat		0.0250	0.0302				
Distance to sand heach			0.0502	_0.0282			
Distance to mangrove forest				0.0202	0.0927*		
Distance to coastal line	_0.0235		-0.0535*		-0.0532**	_0.0434*	
Hokkaido area (baseline)	-0.0235		-0.0555		-0.0332	-0.0434	
Toboku area	0.245**	0.275**	0.285**	0.266**	0.260**	0 230**	0 233**
Vente ence	-0.245	-0.275	-0.285	-0.200	-0.200	-0.239	-0.233
Chubu area	-0.140	-0.117	-0.115	-0.128	-0.0330	-0.131	-0.101
Cinubu area	-0.147	-0.132	-0.173	-0.178	-0.128	-0.241	-0.200
	-0.181	-0.107	-0.172	-0.206	-0.0410	-0.247	-0.209
Chugoku area	-0.258	-0.247	-0.243	-0.264	-0.0587	-0.331	-0.150
Snikoku area	-0.307	-0.205	-0.228	-0.222	-0.180	-0.290	-0.240
CDL 4	-0.248	-0.272	-0.304	-0.307	-0.138	-0.353	-0.135
CBI score 4	-0.00257	-0.00233	-0.00168	-0.00106	-0.00301	-0.002/1	-0.00130
CBI score 6	-0.00/25	-0.00184	-0.00159	-0.00238	-0.00694	-0.00343	0.000258
	0.00552	0.00344	0.00198	0.00258	0.00582	0.00451	-0.00186
Splitting Eq	· · · · · · · · · · · · · · · · · · ·	0.001***	0.04=***	0.00***	· · · · · · · · · · · · · · · · · · ·	0.00(***	0.001
Female	0.277	0.321	0.345	0.208	0.525	0.326	0.231
Age	0.00400	0.00477	0.00689	0.00511	0.00629	0.00207	0.0156
Graduate	0.0887	0.113	0.0690	0.121	-0.105	0.126	-0.177
Household size	0.0356	0.0280	0.0193	0.0258	0.167**	0.0425	0.116
Child	-0.0292	-0.0166	0.000491	-0.00991	-0.0757	0.0147	-0.169
Worker	0.000497	-0.0380	-0.0871	-0.0642	0.0297	-0.0856	0.0113
Income	8.82e–05	7.38e–05	5.84e-05	0.000127*	-0.000189	-9.41e-05	-2.38e-05
Urban	-0.0695	-0.151**	-0.188***	-0.153***	-0.115	-0.213**	-0.428**
Visit	0.146***	0.101***	0.172***	0.183***	0.185**	0.119***	
Importance	0.904***	0.759***	0.772***	0.522***	4.279	0.728^{***}	
Distance to coral reef	0.0383						
Distance to seaweed bed		-0.0371					
Distance to tidal flat			0.0493				
Distance to sand beach				0.00678			
Distance to mangrove forest					-0.442		
Distance to coastal line	-0.00320		-0.00995		0.112	0.0500	
Hokkaido area (baseline)							
Tohoku area	-0.141	-0.170	0.0441	-0.103	-0.158	-0.277	3.633
Kanto area	-0.0259	-0.189	-0.109	-0.191^{*}	-0.379	-0.371^{**}	-0.192
Chubu area	-0.124	-0.177	-0.0945	-0.0752	-0.302	-0.166	0.195
Kinki area	-0.0924	-0.312^{**}	-0.231	-0.264^{**}	-0.674^{*}	-0.463^{***}	-0.268
Chugoku area	-0.115	-0.242^{*}	-0.0608	-0.168	-0.859^{**}	-0.330^{*}	-0.418
Shikoku area	-0.200	-0.237	-0.0145	-0.0549	-0.884^{*}	-0.450^{**}	-0.279
Kyushu/Okinawa area	0.0288	-0.0216	0.140	0.0141	-0.475	0.0320	-0.147
CBI score 4	-0.00529^{*}	0.00174	0.00190	0.00155	-0.00831	0.00450	0.00326
CBI score 6	0.00385	-0.00101	-0.000177	-0.000694	0.00903	0.00339	-0.00618
CBI score 7	-0.000947	-0.00391	-0.00260	-0.00209	-0.00132	-0.00848	-0.00765
Constant	0.312	0.868***	0.389	0.423	3.758^{*}	0.820**	2.125****
Observations	3,092	3,084	3,084	3,089	3,086	3,087	3,145

*** p < 0.01, ** p < 0.05, * p < 0.1*Note:* the distance to coastal line is excluded from the equation of seaweed bed and sand beach because it is strongly correlated with the distance to seaweed bed and the distance to sand beach.

2.5. Mean WTP estimation

Table 4 lists the mean WTP estimates of natural capital. In general, the Kristrom mean estimates are slightly higher than the Turnbull LBM. The rightmost column in Table 4 shows the unit WTP per hectare or ton. The unit WTP is substantially affected by the hypothesized decreasing amount. The hypothesized decreasing amounts were assumed to be higher if the total amount of the corresponding natural capital was larger. From these perspectives, the estimated unit WTPs are higher among the natural capital categories with small total amounts. Besides that, there are some unique findings from the results of the mean WTP estimates. For example, even though the hypothesized decreasing amount of natural forests is smaller than that of plantation forests, the WTP to prevent a decrease by the hypothesized amount is higher among natural forests than plantation forests. In addition, considering the rate of decline, seaweed beds have a lower WTP compared with other marine natural capital.

	TT 1 1 1	Mear	n WTP (2019 US\$/h	ousehold/year)
	Hypothesized amount of decrease	Turnbull LBM	Kristrom mean	Unit Kristrom mean (10 ⁻³ per ha or 10 ⁻³ per t)
Paddy	12,500 ha	11.0 (9.8–12.2)	11.8 (10.5–13.0)	0.941
Crop	7,500 ha	10.8 (9.6–12.0)	11.6 (10.3–12.9)	1.546
Orchard	5,000 ha	9.5 (8.4–10.6)	10.3 (9.2–11.5)	2.063
Pasture	2,500 ha	9.0 (7.9–10.0)	9.8 (8.7–10.9)	3.922
Plantation forest	18,000 ha	9.2 (8.2–10.3)	10.1 (8.9–11.2)	0.559
Natural forest	10,000 ha	10.7 (9.5–11.8)	11.6 (10.4–12.8)	1.163
Seaside forest	22 ha	10.1 (9.0–11.2)	11.0 (9.8–12.2)	499.296
Coral reef	70 ha	9.8 (8.7–10.9)	10.7 (9.5–11.8)	152.361
Seaweed bed	2,000 ha	8.5 (7.5–9.5)	9.3 (8.2–10.4)	4.658
Tidal flat	99 ha	8.3 (7.3–9.3)	9.2 (8.1–10.2)	92.621
Sand beach	56 ha	8.9 (7.9–10.0)	9.8 (8.7–10.9)	175.565
Mangrove	1.5 ha	9.0 (7.9–10.0)	9.8 (8.7–11.0)	6562.749
Fishing ground	178,000 t	9.6 (8.5–10.7)	10.5 (9.3–11.6)	0.059
Whole nature	-	34.9 (32.7–37.1)	40.4 (36.0–44.8)	_

Table 4. Mean WTP estimates for maintaining the hypothesized amount of each NC.

The values in parentheses are 95% confidence intervals based on Blaine et al. (2005) and Vaughan and Rodriguez (2001).

3. Natural capital prediction and its importance to sustainability

3.1. Scenarios and methodology

We conducted a future prediction of the amount of natural capital in 2050 at the municipality level. The scenario prediction of natural capital makes it possible to evaluate which pathways will lead to a more sustainable future.

For our prediction, we applied the scenarios developed by the Predicting and Assessing Natural Capital and Ecosystem Services (PANCES), which is a 5-year research project with the goal of developing national scale future scenarios mainly to assess future changes in natural capital and ecosystem services (Saito et al., 2019). The scenarios diverge depending on two drivers: investments in infrastructure and population. While infrastructure development and disaster management can be conducted on an ecosystem basis (e.g., the use of green infrastructure and renewable energy) or man-made basis (e.g., the use of conventional infrastructure, optimization of conventional power generation), population is likely to be either concentrated in urban areas or dispersed throughout rural areas. Different combinations of these two factors produce the following four scenarios, in addition to a business-as-usual (BAU) scenario: a natural capital-based compact society (NC), a natural capital-based dispersed society (ND), a capital-based compact society (PC), and a produced capital-based dispersed society (PD). The PANCES project has already made predictions of the population distribution and land use changes by 2050 for each scenario (Hori, Saito, et al., 2020; Shoyama et al., 2019).

We used these data for population and land use prediction as input values for our natural capital prediction. The land use prediction data were constructed as a thematic map on a 1 km grid level (Shoyama et al., 2019). Each cell is categorized into any of the following: (1) residential area, (2) paddy field, (3) cropland, (4) other agricultural land, (5) abandoned farmland, (6) grassland and bush, (7) natural forest, (8) secondary forest, (9) plantation forest, and (10) others. We used the number of cells categorized as paddy field, cropland, other agricultural land (including orchard and pasture), plantation forest, natural forest, and secondary forest within each region at the municipality level to predict the natural capital area in 2050 for each scenario. The population projection data describe the Japanese population distribution in 2050 at a 500 m grid level on the condition that Japanese society will follow any of the scenarios of population dispersion: extreme case compact society, middle case compact society, or business as usual (Hori, Saito, et al., 2020). Using these data, we estimated the household number of each municipality in 2050, which is necessary to calculate the shadow price of each natural capital for each scenario. We assumed that the NC and PC scenarios promote an extreme case compact society while the ND and

PD scenarios lead to an extreme case dispersed society in terms of the population distribution.

The WTP values estimated from our survey data were the amounts of money that households can pay annually for the next 10 years from 2020 to maintain natural capital. To calculate the total amount of natural capital in monetary value, we calculated the shadow price per hectare based on the annual WTP per household. First, we obtained the number of households in 2050 for each scenario and each region, as follows:

Number of households_{sr} = Population_{sr} ×
$$\left(\frac{Number of households_{2015,r}}{Population_{2015,r}}\right)$$
, (6)

where *s* refers to the five scenarios (= BAU, NC, ND, PC, or PD) and *r* refers to the municipality (1,880 available observations). The source of the population data was the PANCES population projection data (Hori, Saito, et al., 2020). We assumed that the ratio of number of households to population in each municipality will not change from 2015 to 2050.

Next, we calculated the shadow price of each natural capital with reference to Managi and Kumar (2018) and UNU IHDP and UNEP (2014) as follows:

$$SP_{isr} = \sum_{t=1}^{\infty} \left\{ WTP_{2019,ir} \times \frac{GDP_{2050}}{GDP_{2019}} \times Number \ of \ households_{sr} \times \frac{1}{(1+\delta)^t} \right\},\tag{7}$$

where SP_{isr} is the shadow price of natural capital *i* for scenario *s* and municipality *r*, defined as the 2019 US\$ per hectare value, and $WTP_{2019,ir}$ is the mean WTP to prevent natural capital *i* from decreasing one hectare among the people living in municipality *r*. For the WTP value, we calculated the Kristrom mean value (Eq. (5)) under the assumption that the mean WTP is different by region and type of municipality (urban or rural). We created 16 subsamples by dividing our sample into eight regions in Japan and categorizing each municipality into urban or rural areas (e.g., Hokkaido urban, Hokkaido rural, and Tohoku urban). Then, Kristrom's mean WTPs were estimated among the 16 subsamples. Finally, one of the 16 types of WTP values was assigned to each corresponding municipality.

The GDP prediction data was derived from the Shared Socioeconomic Pathways (SSP) 2 from Riahi et al. (2017), which assumes that GDP in Japan will maintain a low growth rate until 2050. This GDP scenario is suitable for PANCES scenarios because PANCES assumes low economic growth in Japan toward 2050 among all their scenarios. We use 5% as a discount rate, δ , to obtain the discounted present values for each natural capital stock in the same manner as Ikeda and Managi (2019) and UNU IHDP and UNEP (2014). Finally, the shadow price can be calculated as the sum of the discounted present value in year *t*.

To obtain the total amount of each natural capital i in municipality r for scenario s, we calculated

the total hectare of each natural capital in each municipality using the land use prediction data. The data for land use are from Shoyama et al. (2019), which were formed as a thematic map at the 1 km grid level. In this data, there is no information on the hectare value of each natural capital within a grid. For example, if natural forest occupies the largest area within a grid, it is categorized as a natural forest grid even if there is also a smaller area of plantation forest or agricultural land within this grid. Therefore, we first need to estimate the hectare value of natural capital *i* within each grid categorized as natural capital *i*, as follows:

Area per cell_i =
$$\frac{Total area_i}{Number of cells_{2019,i}}$$
, (8)

where *Area per cell_i* is the area of natural capital *i* per cell, *Total area* is the current area size of each natural capital (the values are shown in Fig. A1), *number of cells*₂₀₁₉, and i is the number of land use cells corresponding to natural capital *i* in Japan. As 2019 values are not available from the land use prediction data, we assumed that the land use situation in 2019 was the same as that in the 2020 BAU scenario. Then, we obtained the total area of natural capital *i* in municipality *r* in 2050 for scenario *s* (*Area*_{isr}) as follows:

$$Area_{isr} = Number of \ cells_{isr} \times Area \ per \ cell_i.$$
(9)

Finally, we obtained the total amount of natural capital i in municipality r for scenario s in monetary terms using the following equation:

$$Natural \ capital_{isr} = SP_{isr} \times Area_{isr}.$$
 (10)

The unit of SP_{isr} is the 2019 US\$ per hectare and the unit of $Area_{isr}$ is hectare. Therefore, the unit of *Natural Capital* is the 2019 US\$. We calculated the total amount of terrestrial natural capital in municipality r for scenario s by summing the amount of all of the natural capital in each municipality as follows:

$$Terrestrial \ natural \ capital_{sr} = \sum_{i} Natural \ capital_{isr}, \tag{11}$$

where *i* includes five types of natural capital: paddy fields, crop fields, other agricultural lands, plantation forests, and natural forests.

3.2. Prediction results

Figure 3 shows the results of the terrestrial natural capital prediction. The bar chart shows the total value of terrestrial natural capital for each scenario in rural and urban areas. Whichever pathways Japanese society will follow, the total value of terrestrial natural capital in rural areas will decrease from 2019 to 2050. In urban areas, only the natural capital-based society will enhance the value of terrestrial natural capital.

Figure 3 indicates that rural areas are likely to be affected by whether Japan will follow a compact or dispersed scenario while urban areas appear to be influenced by whether the scenario is natural capital-based or produced capital-based. The population in rural areas becomes higher with the promotion of a dispersed society, which leads more people to invest in the natural capital of rural areas. In addition, the natural capital-based society will maintain more agricultural lands and forests in urban areas, leading to a higher value of natural capital. Consequently, the natural capital-based dispersed (ND) society will sustain the highest total value of terrestrial natural capital among all scenarios.

Figure 4 shows the distribution of terrestrial natural capital with the promotion of the ND society. This indicates that the ND scenario leads many municipalities in Japan to maintain moderate to large values of terrestrial natural capital. Figure A2 in the **Appendix** shows maps of the distribution of terrestrial natural capital for all scenarios. These maps show that more municipalities sustain terrestrial natural capital in dispersed societies than in compact societies. Figure A3 in **Appendix** shows the predicted value of each natural capital.



Fig. 3. Scenario prediction of terrestrial natural capital in 2019 US\$.



Fig. 4. The distribution of terrestrial natural capital in 2019 US\$ for ND scenario.

3.3. Converting abandoned agricultural lands into forests

As the number of farmers is decreasing due to population decline, aging, and social changes, abandoned agricultural land is increasing, especially in rural areas. According to MAFF (2020), abandoned agricultural land increased from 244,000 ha in 1995 to 423,000 ha in 2015. In such a situation, the abandonment of agricultural land and its impact on biodiversity have attracted the attention of researchers and practitioners. Some studies have argued that the abandonment of farmland is one of the factors that causes the loss of biodiversity and ecosystem services (Kleijn and Báldi, 2005; Osawa et al., 2013; Tsunoda and Enari, 2020). Under these circumstances, many studies have argued the effectiveness of converting abandoned agricultural land into forests by active afforestation or

rewilding (MacDonald et al., 2000; Navarro and Pereira, 2012; Tsunoda and Enari, 2020). The conversion of abandoned land into forest should have a significant potential to recover functions, such as protecting soil and water resources and enhancing biodiversity. Therefore, analyzing how much benefit can be expected when abandoned agricultural land in Japan is converted to forests from ecosystem services, natural capital stock, and national land conservation perspectives is worthwhile.

This subsection reveals the future of natural capital stock in Japan if abandoned agricultural land is converted to forests during the period between 2030 and 2050. We calculated the increase in the monetary value of natural capital stock generated by the conversion of abandoned agricultural land into forests, considering five scenarios developed by PANCES.

First, using the land use prediction map from Shoyama et al. (2019), we detected all cells that are categorized as abandoned farmland as of 2030 for each PANCES scenario (BAU, NC, ND, PC, and PD). Shoyama et al. (2019) assumed that, in the BAU scenario, cultivated area will continue to decrease, which causes an increase in abandoned farmland. The natural capital-based scenario intervenes by managing unused land, converting abandoned agricultural land into cropland, other agricultural land, and secondary forest. In contrast, the produced capital-based scenario does not conduct such management for unused land. Therefore, a larger area of abandoned agricultural land will remain in the produced capital-based scenario than in the natural capital-based scenario. In addition, agricultural land and plantation forests are maintained more in the dispersed scenario than in the compact scenario than in the compact scenario.

Next, we developed scenarios for the conversion of abandoned agricultural lands into forests. Three scenarios were constructed depending on the balance between plantation forests and secondary forests: (1) all into plantation forests, (2) all into secondary forests, and (3) into plantation and secondary forests. In scenario (1), all detected cells categorized as abandoned farmland as of 2030 will be converted into plantation forests by 2050. In contrast, all abandoned farmland will be converted into secondary forests in scenario (2). Scenario (3) assumes that, if the population within a circle with a radius of 5.5 km around an abandoned agricultural land is over 500, the abandoned land becomes a plantation forest and, if under 500, the abandoned land becomes a secondary forest. Under this assumption, approximately half of abandoned agricultural lands in Japan become plantation forests while the other half becomes secondary forests.

Then, we calculated the increase in monetary value of terrestrial natural capital by converting abandoned agricultural lands into forests for each of the five PANCES scenarios and the three conversion scenarios developed above. We first obtained the areas of plantation forest generated by the conversion in each municipality by multiplying the number of cells converted into plantation forests in each municipality by the hectare value of each cell of plantation forest calculated in Eq. (8). This same method was applied to secondary forests to obtain the areas of secondary forest generated. We then multiplied the shadow prices of plantation forest and natural forest estimated in Eq. (7) by the

generated areas of plantation forest and natural forest, respectively. Finally, we estimated the increases in the monetary value of natural capital for each scenario by converting abandoned land into forest.

Figure 5 shows the results of the estimated values of the increases in terrestrial natural capital via the conversion of abandoned agricultural lands into forests. The values were summed within rural and urban areas. We found that the secondary forest-only scenario yielded the highest increase in terrestrial natural capital. The main reason is that the WTP to maintain 1 ha of natural forest is approximately twice as high as 1 ha of plantation forest (see Table 4), which leads to a higher shadow price for secondary forests. In terms of the differences between the PANCES scenarios, the values of the increases in terrestrial natural capital are higher in the produced capital-based scenarios compared with the natural capital-based society in Japan. This implies that there is a greater potential for enhancing natural capital via the conversion of abandoned agricultural land into forest in a produced capital-based society than in a natural capital-based society. In particular, the produced capital-based compact society has the greatest potential to enhance natural capital from abandoned agricultural lands in urban areas.

We found that the maximum value of the increase in natural capital via the conversion corresponds to approximately 1% of the total value of terrestrial natural capital in Japan (Fig. 3). This maximum increase can be realized when Japanese society follows a capital-based compact society and all abandoned agricultural lands will be converted into secondary forests from 2030 to 2050 (1.04% increase in rural areas and 1.14% in urban areas). In contrast, when Japanese society follows a natural capital-based society, increases in natural capital via the conversion of abandoned agricultural land into secondary forests becomes approximately 0.2–0.3% of the total value of terrestrial natural capital in Japan.



Fig. 5. Increases in natural capital values (above) and carbon stocks (below) by conversion of abandoned agricultural lands into forests.

In addition, we calculated the increase in the carbon stock from the conversion of abandoned agricultural lands into forests. By increasing the amount of carbon stock in forests, CO_2 can be reduced and the impacts from climate change may be mitigated. Therefore, the conversion of abandoned farmland into forests may contribute to climate change mitigation.

First, we calculated the amount of carbon stock per hectare in the major plantation and secondary forests in Japan³. Our estimation yields 108.896 Mg C/ha as the carbon stock of Japanese cedar (*Cryptomeria japonica*), which occupies the largest share (44%) of plantation forests in Japan (Forestry Agency, 2017). In addition, the estimated carbon stock of oak (*Quercus*), the major natural forest in Japan, is 92.397 Mg C/ha. We applied these estimated values for Japanese cedar and oak to the carbon stock of plantation forests and secondary forests, respectively.

Then, we estimated an increase in the total carbon stock via the conversion of abandoned farmlands into forests for each scenario. The increase in the carbon stock was calculated by multiplying the values of the carbon stock per hectare by the areas of forests gained from the conversion of abandoned farmlands.

³ We adopted the same method used in Egusa et al. (2020) to calculate the amount of carbon stock per hectare. In terms of the parameters required for this calculation, timber volume was extracted from the National Forest Inventory data from the Japan Forestry Agency (<u>http://www.rinya.maff.go.jp/j/keikaku/tayouseichousa/</u>). Other parameters were obtained from the National Institute for Environmental Studies website (<u>http://www-gio.nies.go.jp/aboutghg/nir/2020/NIR-JPN-2020-v3.0 J GIOweb.pdf</u>).

The lower charts in Fig. 5 describe the estimated increase in carbon stock for each scenario. Unlike the monetary values, the increase in carbon stock becomes the largest in the plantation forest-only scenario. In addition, rural areas can acquire a larger increase in their carbon stock from the conversion of abandoned farmlands than urban areas. In terms of the PANCES scenarios, the PC pathway can realize the largest growth in the carbon stock because of the largest total area of abandoned farmlands.

3.4. Ecological footprint prediction

This subsection focuses on what happens to the environmental burden caused by human activities at the municipality level in the future. To calculate the future environmental burden, the ecological footprint is a useful index. The concept of the ecological footprint is widely recognized as one of the measures of environmental burden since it was first proposed nearly 30 years ago (Rees, 1992).

Hori, Shirahama, et al. (2020) estimated the environmental burden at the grid level in Japan as of 2011 using the ecological footprint index. Using data on the ecological footprint and PANCES population data (Hori, Saito, et al., 2020), we predicted the future environmental burden at the municipality level by 2050 if the Japanese population distribution conforms to any of the following scenarios: extreme compact society (Com), extreme dispersed society (Dis), or business as usual (BAU). The prediction equation is as follows:

$$EF_{sr} = EF \ per \ person_{2011\,r} \times Population_{sr},$$
 (12)

where EF_{sr} is the total value of the ecological footprint in municipality r for scenario s (gha) and EFper person₂₀₁₁, and r is the average ecological footprint per person in municipality r in 2011 (gha/person). Hori et al. (2020) assumed that the amount of consumption of various goods differs by municipality. Therefore, the ecological footprint per person is also different at the municipality level. The value of *Population_{sr}* was obtained from the data reported in Hori, Saito, et al. (2020). Equation (12) assumes that only the change in population in the area induces the change in the ecological footprint in each municipality. We also assumed that the ecological footprint per person in each municipality will be constant from 2011 to 2050.

Figure 6 shows the results of the ecological footprint prediction. The bar chart at the bottom displays the total gha values of the ecological footprint in rural and urban areas in 2011 and 2050 with the three scenarios.

Irrespective of the scenario that the Japanese population will conform to, the total value of the ecological footprint will decrease from 2011 to 2050 because the total population in Japan will decrease by 2050. This declining trend is notable, especially in rural areas. Different pathways produce a

variation in the total value of the ecological footprint between rural and urban areas. In rural areas, the ecological footprint becomes higher with the promotion of the BAU or dispersed scenario, whereas the ecological footprint in urban areas will be higher with a compact society. Compared with a compact society, a dispersed society induces a moderate to large value for the ecological footprint in a larger number of municipalities.



Fig. 6. Scenario prediction of ecological footprint (gha). The thresholds of color classification of the maps are based on seven quantiles for 2011 values.

3.5. Eelgrass and seaweed bed prediction

In addition to the terrestrial natural capital, we predict the future of some coastal natural capital using the PANCES scenarios. We focused on area changes of eelgrass beds and seaweed beds, which are the main ecosystems of the sea distributed on the coasts around Japan.

We used the data of the distribution of eelgrass and seaweed beds collected at 10km grid level by the Ministry of the Environment (1994). An estimation model was created by a machine learning by the gradient boosting machine (GBM) for predicting the area of eelgrass beds and seaweed beds. We included latitude, longitude, water temperature, coastline length, chlorophyll a, coastal farmland rate,

wave intensity, tide size, coastal population, and predicted water quality (NO3) as explanatory variables.⁴ Among them, water quality was estimated by using H2O's GBM on R with driver variables including the population, land use, topography, and meteorological conditions. When interpolating the water quality value to seaside, we used a predicted value if the predicted value exists within the 10km grid. If there are multiple predicted values exist, we used the weighted average value based on the product of area size and precipitation. If the value does not exist within the grid, the value of the nearest estuary was used. The contribution rate of each variable on the size of the area of eelgrass beds and seaweed beds in Japan is shown in Figure 7.

We predicted the area size of eelgrass beds and seaweed beds at 10km grid level in 2050 by each PANCES scenario (NC, ND, PC, PD). Figure 8 and Figure 9 shows the predicted distributions of eelgrass beds and seaweed beds for each scenario. In the estimation of area size, water quality, coastal population and coastal farmland rate are varied between scenarios. Only the grids in which eelgrass beds or seaweed beds exist were used to eliminate the bias in the estimates. In addition, there are error values between actual current area sizes and the values of predicted current area sizes from estimation. To correct such biases, we firstly calculated the change rates from the predicted current values to the predicted values for each scenario in 2050. Then, we multiplied the change rates for each scenario with the actual current values and obtained adjusted version of predicted values of the area size of eelgrass and seaweed beds for each of the scenarios. Therefore, the results reflect the relative difference between scenarios rather than the quantitative change in absolute values.

⁴ Data source: water temperature from MIROC5

https://journals.ametsoc.org/jcli/article/23/23/6312/32720/Improved-Climate-Simulation-by-MIROC5-Mean-States; coastline length from MLIT (2014); chlorophyll a from NASA (2018); coastal farmland rate from Shoyama et al. (2019); wave intensity from CERA-20C <u>https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/cera-</u>20c; tide size from Integrated Climate Data Center (ICDC, icdc.cen.uni-hamburg.de) University of Hamburg <u>https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2013JC009766</u>; coastal population from Hori, Saito, et al. (2020).



Fig. 7. Contribution rate of each variable on the size of the area of eelgrass beds and seaweed beds.



Fig. 8. Predicted distribution of eelgrass beds by scenarios (ha).



Fig. 9. Predicted distribution of seaweed beds by scenarios (ha).

Table 5 shows the results of the prediction in the hectare values. The R-squared for the model of eelgrass beds was 0.28, and that of seaweed beds was 0.20. Climate change will decrease the predicted values of eelgrass and seaweed beds for all scenarios. As a whole, we found only small differences in the predicted values between the scenarios compared to the difference by whether climate change will happen or not. In terms of eelgrass beds, natural capital-based scenario can maintain larger area size than produced capital-based scenario. Additionally, population dispersed scenario keeps larger areas than compact scenario. As a result, ND scenario can keep the largest area of eelgrass beds. In terms of seaweed beds, dispersed scenario can maintain larger area size than compact scenario, which is similar to eelgrass beds. However, produced capital-based scenario can keep the largest area size than natural capital-based scenario. Thus, PD scenario can keep the largest area of seaweed beds.

Table 5. Predicted values of the size of the area of eelgrass and seaweed beds.

	Climate Change	1994	Predicted	RMSE	MAE	\mathbb{R}^2	NC	ND	PC	PD
Eelgrass beds	No	37295	47963	0.68	0.55	0.28	36188	36980	35270	36164
(ha)	Yes						35966	36745	35001	35888
Seaweed beds	No	138966	50943	0.74	0.55	0.20	136070	138022	137424	139080
(ha)	Yes						131876	133768	133242	134847

Table 6 shows the total values of eelgrass beds and seaweed beds in 2019 US\$ that are calculated by using estimated mean WTP (Table 4), hectare values (Table 5) and natural capital approach (described in Eq. (7) and Eq. (10)). We set two scenarios in estimating the shadow prices and total values of eelgrass and seaweed beds. First scenario is total population scenario, in which all people living in Japan are assumed to value all eelgrass beds and seaweed beds existed in Japan. Second scenario is coastal population scenario, in which people living in the municipalities facing the ocean value all eelgrass beds and seaweed beds. As a whole, the relative difference in monetary values between PANCES scenarios are similar to that in the area sizes. Climate change will slightly decrease both the monetary values of eelgrass beds and seaweed beds. It is found that ND pathway maintain the highest values of eelgrass beds and PD maintain the highest values of seaweed beds.

	_					
	Climate Change	2019ª	NC	ND	PC	PD
Eelgrass beds	No	393.450	374.307	381.625	364.811	373.199
(total population)	Yes		372.003	379.194	362.022	370.354
Seaweed beds	No	73.729	70.780	71.632	71.485	72.181
(total population)	Yes		68.598	69.424	69.309	69.984
Eelgrass beds	No	150.715	138.060	143.552	134.557	140.382
(coastal population)	Yes		137.210	142.637	133.529	139.312
Seaweed beds	No	28.243	26.107	26.945	26.366	27.152
(coastal population)	Yes		25.302	26.115	25.564	26.325

Table 6. Predicted values of eelgrass and seaweed beds in e10 2019US\$.

^a We assumed that the size of the area of eelgrass beds and seaweed beds in 2019 is same as that in 1994.

3.6. Natural capital for SDGs

While previous studies have found that natural capital plays an essential role in promoting sustainability and human well-being (Costanza et al., 2017; Díaz et al., 2018), the relationship between natural capital and other issues important to sustainability is still unclear. This subsection reveals the importance of natural capital in terms of achieving SDGs, globally recognized as one of the concrete measures to realize sustainability, as this concept has been proposed within the 2030 Agenda for Sustainable Development of the United Nations Development Programme (UNDP). SDGs consist of 17 goals and 169 targets for poverty and hunger eradication; promotion of peace, justice and human rights; realization of pro-environmental economic growth; and global prosperity (United Nations, 2015). There are also 244 indicators to measure the progress of each goal (United Nations, 2017).

Previous studies have investigated how the SDG indicators are interconnected with each other. Matsui et al. (2019) conducted a network analysis of the correlations among the Japanese-specific localized version of SDG indicators at the prefectural level. They found that the SDG indicators form a nexus, i.e., a network of connections, correlating with each other, where some indicators (e.g., the average annual value of nitrogen oxides, Internet diffusion rate, and proportion of forested land) have relatively strong relations with many other indicators. If natural capital is essential for sustainability, it also appears to be associated with the SDG indicators. In this subsection, we include natural capital in the nexus of SDG indicators and clarify the interconnectedness between natural capital and SDGs. We used data from Matsui et al. (2019) and incorporated the data on natural capital into the nexus of SDG indicators (May 2018 version). We examined the correlation of the (1) overall natural capital and (2) WTP for maintaining 13 natural capital types, as well as the overall Japanese environment, with Japanese-specific SDG indicators at the prefectural level. Table A2 in the **Appendix**⁵ lists the definitions of each SDG indicator. The score of each SDG indicator was standardized as a z-value. The sign of the indicator was adjusted to be positive if the indicator shows the higher achievement level of each goal.

First, we analyzed the relationship between natural capital and the inclusive wealth index (IWI) with the SDG indicators. The IWI is another index measuring sustainability that can be calculated at global, national, and regional levels. The IWI consists of produced capital, human capital, and natural capital, where the total wealth can be calculated as the sum of these forms of capital in the inclusive wealth framework (Managi and Kumar, 2018; UNU IHDP and UNEP, 2014). We used IWI data from Ikeda and Managi (2019), which include produced capital per capita, human capital per capita (education and health), and natural capital per capita at the prefecture level in Japan. Natural capital from their data consists of agricultural land, timber, and non-timber forest.

Figure 10 shows the results of the network analysis. The color and width of each connection between variables describe the sign and strength of the relationship based on Pearson's correlation coefficients. The red color refers to a positive relation while blue refers to negative. The size of each node indicates the strength of the connection with other indices. Natural capital (NatC) is more strongly related to the SDG indicators than artificial capital (PrdC), human capital (HumC), education capital (EduC), health capital (HeaC), and inclusive wealth (IWI). Specifically, natural capital has a negative correlation with index 14.4.1, which refers to the possible magnitude of fishery resources preservation. The negative correlation indicates that prefectures with abundant natural capital have higher rates of catch increase compared with the previous year. Figure A4 in the **Appendix** shows the correlation heatmap among these variables.

⁵ For more detailed information on the data for the localized SDGs indicators, see Matsui et al. (2019).



Fig. 10. Network between SDGs indicators and inclusive wealth index (the detail about each goal and indicator is shown in Table A2).

Next, we analyzed the interconnectedness between the WTP to maintain terrestrial and marine natural capital and the SDG indicators at the prefectural level. The data for the WTP amounts from our survey were used, whose values were averaged by prefecture. Figure 11 shows the results of the network analysis. All WTPs have positive correlations with several SDG indicators, such as 1.1.1 (reducing the relative poverty rate), 9.c.1 (internet usage rate), and 10.4.1 (labor productivity). In contrast, the WTPs have a negative correlation with some SDG indicators, such as 3.2.2 (reducing neonatal mortality), 11. 6.2.2 (reducing the number of days when the photochemical oxidant (Ox) concentration during the day is 0.12 ppm or more), and 11.6.2.3 (reducing the average annual value of NO_x). Figure A5 in the **Appendix** shows the correlation heatmap between these variables.



Fig. 11. Network between SDGs indicators and WTPs for maintaining natural capitals (the detail about each goal and indicator is shown in Table A2).

4. Discussion

4.1. Insights from the results

In this study, we used several approaches to investigate the values, determinants, future, and relations for the SDGs of natural capital in Japan. Our ZIOP regression provided several intuitive findings, e.g., household income, visit frequency, and perceived importance positively affect the WTP amount to maintain all or many of the natural capital types. In contrast, some estimated coefficients showed significant effects, whose interpretation should be discussed. Moreover, we revealed the importance of promoting a natural capital-based dispersion scenario to achieve the future sustainability of terrestrial natural capital. In addition, the conversion of abandoned agricultural lands into forests has the potential to achieve a maximum 1% increase in the value of terrestrial natural capital. The network analysis revealed the interconnectedness between natural capital and SDG indicators at the prefectural level.

Residents in urban areas are less likely to pay for some natural capital than those in rural areas.

One of the possible reasons is that urban residents may not feel as though they reap as much of the benefits from natural capital as rural residents who are likely to have spent more time surrounded by nature. This is consistent with evidence from previous studies showing that the less experience an individual has with nature, the lower their attachment to nature and their willingness to conserve nature (Miller, 2005; Soga et al., 2016; Zhang et al., 2014). There are also significant regional differences in the WTP for all natural capital types. Specifically, residents in Hokkaido showed both high probability and high WTP amounts for many natural capital types as compared with residents from other regions. Considering that this result was obtained after adjustments for the economic situation and personal attributes, the residents of the Hokkaido region have unique pro-environmental attitudes and awareness of natural capital conservation. The abundant nature in the Hokkaido region may lead to high environmental awareness among the residents. In addition, residents near coasts state higher WTPs for some coastal natural capital. Here, respondents living near the ocean may feel more familiar with coastal natural capital than respondents living far from the ocean.

We also found that the city biodiversity index has effects on the WTP for some natural capital. The coefficient of score 7 indicates that residents are more likely to state a zero WTP for agricultural lands and forests if the local government encourages residents and organizations in the municipality to join their activities related to biodiversity conservation. One of the possible interpretations is that, as the participants of environmental activities have already paid some amount of money and time for these activities, they may believe that they do not need to contribute more money.

In terms of future predictions of terrestrial natural capital, among the PANCES scenarios, the natural capital-based dispersed pathway leads to the highest amount of natural capital in 2050. Therefore, this implies that Japan should follow a natural capital-based dispersed scenario for the sustainable management of natural capital. In contrast, the dispersed scenario will also induce a larger number of municipalities with a high ecological footprint, especially among rural areas. However, the total value of the overall ecological footprint in Japan is not substantially affected by the differences in the scenarios.

In addition, the conversion of abandoned cultivated land into forests leads to an increase in terrestrial natural capital and an increase in the carbon stock in Japan. These results imply that the proper management of abandoned agricultural lands contributes not only to the maintenance of natural capital, but also to the mitigation of climate change in the future.

Moreover, we predicted the future of some marine natural capitals. We found that eelgrass beds and seaweed beds can be maintained more up to 2050 if Japan follows the population dispersion scenario compared to compact scenario. It implies that a policy aimed at population dispersion to rural areas can lead to better results in terms of coastal natural capital maintenance in Japan.

Based on the network analysis, natural capital from the inclusive wealth framework has a negative correlation with the conservation of marine resources. This implies the importance of discussing methods to simultaneously conserve agricultural lands, forests, and fisheries resources. The WTPs for

agricultural, forest, and marine natural capital are also connected with some SDG indicators. For example, the Internet usage rate has a positive correlation with the WTPs for all natural capital. This implies the likelihood that the Internet plays a role in disseminating knowledge on the importance of natural capital and increasing its valuation. In contrast, the WTP has a negative correlation with the air quality. There is a possibility that a high level of air pollution leads residents to place a higher value on natural capital.

The major limitation of our study is that we were unable to conduct future predictions of marine natural capital because of the limited data availability on marine natural capital that can be used for predictions. Natural marine capital types are intricately intertwined with various elements, such as water temperature, water quality, and fish catches, as compared with terrestrial natural capital, which renders future predictions more difficult. Although we estimated the WTPs to maintain a certain amount of marine natural capital, future predictions are a critical topic that should be the focus of future studies.

Another limitation is that the WTP data were collected only from Japanese residents. However, natural capital in Japan can also be valuable to nonresidents. For example, tourists from foreign countries can benefit from the leisure and cultural value of Japanese natural capital. In addition, CO₂ absorption by forests can mitigate the impacts of global warming, which should be viewed at a global level. Furthermore, as tidal flats in Japan are the habitats of migratory birds (Iwamatsu et al., 2007), the decline in tidal flats will impact the ecosystems of other countries and regions. For such reasons, focusing only on Japanese residents may yield an underestimation of the value of natural capital. Incorporating such nonresident value into the calculation of natural capital should be another focus of future studies.

4.2. Policy implications

Our natural capital projections show that population concentration in urban areas accelerates the decline in natural capital in local municipalities in rural areas. This can be explained by the decrease in residents who manage natural capital in these areas. More terrestrial and marine natural capitals can be maintained by implementing policies aimed at population dispersion and attracting people to rural areas. In addition, converting abandoned farmland into forests in rural areas can yield a potential 0.2–1% increase in terrestrial natural capital, which can significantly contribute to climate change mitigation by increasing carbon stocks.

Based on these aspects, promoting population dispersion to maintain more natural capital in Japan should be effective. Therefore, we focused on the types of policies that can successfully promote population dispersion. One method is to implement policies aimed at promoting migration. According to Matsushita et al. (2019), elderly people in Japan attach great importance to the natural environment in their surroundings as a factor when selecting their places of residence. This indicates that local

governments in rural areas can encourage the migration of elderly by appealing to the abundant natural environment, as well as improving health care and welfare services. The migration of young people is also important for the effective maintenance of natural capital in rural areas. Hori, Saito, et al. (2020) argue that attractive employment opportunities and livable environments are key to the influx of young people.

However, as the population of Japan is declining overall, a push by all local governments to maintain their population by increasing permanent residents is not pragmatic. Recently, dual residence has attracted the interest of policy makers and has been promoted by the Japanese government (cite MLIT) as one measure to secure human resources to provide manpower for local communities and natural capital management. Specifically, dual residence refers to any lifestyle in which one individual or one household has two (or more) bases of residence. For example, a person who lives in an urban area on weekdays can spend time in a rural area on the weekend. This person can enjoy various benefits from this lifestyle, such as the healing of the body and mind in an environment with abundant nature. Local governments can benefit from such a person in terms of human resources, economic effects, and natural capital management. To more easily disseminate opportunities for dual residence, it is necessary to improve work flexibility by, for example, promoting telework.

Another important measure that can promote population dispersion is introducing better transportation networks. Developing road networks and public transportation sufficient not only to improve the livability of local areas, but also to promote dual residence may be effective. In general, residents in rural areas highly depend on private cars rather than public transportation because of a lack of sufficient public transportation networks (Pucher and Renne, 2005). In such a situation, introducing autonomous vehicles may be one solution to improve transport networks in rural areas. Rural residents are more willing to utilize autonomous vehicles than urban residents (Hilgarter and Granig, 2020). This implies that the spread of autonomous vehicles has significant potential to promote optimal population distributions for the sustainable management of natural capital in rural areas.

In conclusion, population dispersion is one of the key measures to maintain natural capital, especially in rural areas. To sustainably manage natural capital in Japan, the policies mentioned above should be implemented to maintain the optimal population of municipalities in rural areas. In addition, further analysis is necessary to clarify the effectiveness of policies aimed at migration and dual residence to maintain natural capital.

Appendix

















Fig. A1. Trends of NCs in Japan. *Data source*: Fisheries Agency of Japan (2008), Forestry Agency of Japan (2010, 2017), Kokubu et al. (2017), MAFF (2018), MOE (2007, 2017), Spalding et al. (2010), Sugiawan et al. (2017), Udo et al. (2016).



Fig. A1. (continued)

Table A1. NCP and decreasing scenario presented to respondents.

Natural capital	Ecosystem services	Hypothesized amount of decrease
Paddy	1. Production of rice	12,500ha (0.8%) decrease
	2. Regulation of groundwater quantity	
	3. Regulation of flood	
	4. Regulation of water quality	
	5. Prevention of soil erosion	
	6. Maintenance of soil nutrients	
	7. Creation of habitat for fish, insects, frogs and wild animals	
	8. Creation of habitat for mosquito, which transmit Japanese	
	encephalitis	
	9. Creation of habitat for tick, which transmit SFTS virus	
Crop	1. Production of wheat, vegetables and beans	7,500ha (0.8%) decrease
	2. Regulation of groundwater quantity	
	3. Regulation of flood	
	4. Regulation of water quality	
	5. Prevention of soil erosion	
	6. Maintenance of soil nutrients	
	7. Creation of habitat for fish, insects, frogs and wild animals	
	8. Creation of habitat for mosquito, which transmit Japanese	
	encephalitis	
	9. Creation of habitat for tick, which transmit SFTS virus	
Orchard	1. Production of fruits	5,000ha (2.2%) decrease
	2. Regulation of groundwater quantity	
	3. Regulation of flood	
	4. Regulation of water quality	
	5. Prevention of soil erosion	
	6. Maintenance of soil nutrients	
	7. Creation of habitat for fish, insects, frogs and wild animals	
	8. Creation of habitat for mosquito, which transmit Japanese	
	encephalitis	
	9. Creation of habitat for tick, which transmit SFTS virus	
Pasture	1. Production of fodder	2,500ha (0,25%) decrease
I usture	2 Regulation of groundwater quantity	2,50014 (0.2570) decrease
	3 Regulation of flood	
	4 Regulation of water quality	
	5 Prevention of soil erosion	
	6 Maintenance of soil nutrients	
	7. Creation of habitat for fish insects from and wild animals	
	8 Creation of habitat for mosquito, which transmit Japanese	
	encenhalitis	
	9 Creation of habitat for tick, which transmit SETS virus	
Plantation forest	1 Provision of timber	18 000ha (0.2%) decrease
I failtation forest	2. Mitigation of global warming by absorbing CO2	13,000lla (0.270) decrease
	2. Regulation of global warming by absorbing CO2	
	4. Regulation of groundwater quantity	
	4. Regulation of groundwater quantity	
	6. Regulation of water quality	
	7. Provision of soil nutrients by litterfall	
	 Provision of soil numerity by internali Provention of soil ansaign 	
	 O. Mointenance of a illustriante 	
	9. Maintenance of soil nutrients	
	10. Creation of habitat of insects and wild animals	
	11. Provision of recreational sites for therapeutic walk, wild	
	plants picking and picnic	
	12. Creation of habitat for hornet	
	13. Creation of habitat for tick, which transmit SFTS virus	
	14. Creation of habitat for wild animals which cause crop	

	damage	
Natural forest	1. Provision of timber	10,000ha (0.1%) decrease
	2. Production of wild game meat	
	3. Mitigation of global warming by absorbing CO2	
	4. Regulation of temperature by evapotranspiration	
	5. Regulation of groundwater quantity	
	6. Regulation of flood	
	7. Regulation of water quality	
	8. Provision of soil nutrients by litterfall	
	9. Prevention of soil erosion	
	10. Maintenance of soil nutrients	
	11. Creation of habitat of insects and wild animals	
	12. Provision of recreational sites for therapeutic walk, wild	
	plants picking and picnic	
	13. Creation of habitat for hornet	
	14. Creation of habitat for tick, which transmit SFTS virus	
	15. Creation of habitat for wild animals which cause crop	
	damage	
Seaside protection forest	1. Windbreak and prevention of damage by tsunami, storm	22ha (0.04%) decrease
Ĩ	surge, salt pollution	
	2. Mitigation of global warming by absorbing CO2	
	3. Regulation of temperature by evapotranspiration	
	4. Regulation of groundwater quantity	
	5. Regulation of flood	
	6. Regulation of water quality	
	7. Provision of soil nutrients by litterfall	
	8. Prevention of soil erosion	
	9. Maintenance of soil nutrients	
	10. Creation of habitat of insects and wild animals	
	11. Provision of recreational sites for therapeutic walk, wild	
	plants picking, picnic and so on	
	12. Creation of habitat for hornet	
	13. Creation of habitat for tick, which transmit SFTS virus	
	14. Creation of habitat for wild animals which cause crop	
	damage	
Coral reef	1. Increasing fish catch	70ha (0.2%) decrease
	2. Mitigation of global warming by absorbing CO2	
	3. Regulation of water quality	
	4. Creation of habitat for fish and shellfish	
	5. Prevention of coastal erosion	
	6. Provision of recreational places for snorkeling, diving,	
	glass-bottom boat and so on	
Seaweed bed (including rocky	1. Increasing catch of abalone and sea urchin, kelp and	2,000ha (1.9%) decrease
shore)	seaweed, and Hijiki	
	2. Mitigation of global warming by absorbing CO2	
	3. Regulation of water quality	
	4. Prevention of coastal erosion	
	5. Creation of habitat of fish, shellfish and wild animals	
	6. Provision of recreational sites for fishing and gathering	
	shellfish and crabs	
Tidal flat (including Eelgrass bed)	1. Increasing catch of clams	99ha (0.2%) decrease
	2. Mitigation of global warming by absorbing CO2	
	3. Regulation of water quality	
	4. Creation of habitat of fish, shellfish and wild animals	
	5. Provision of recreational sites for clamming, birdwatching,	
	and so on	
Sand beach	1. Provision of sand	56ha (0.2%) decrease

	2. Regulation of water quality	
	3. Regulation of groundwater quantity	
	4. Provision of recreational sites for swimming and playing on	
	the beach	
	5. Generation of wind-blown sand and salt damage	
Mangrove forest	1. Provision of timber	1.5ha (0.2%) decrease
	2. Mitigation of global warming by absorbing CO2	
	3. Regulation of temperature by evapotranspiration	
	4. Regulation of groundwater quantity	
	5. Regulation of flood	
	6. Regulation of water quality	
	7. Provision of soil nutrients by litterfall	
	8. Prevention of soil erosion	
	9. Maintenance of soil nutrients	
	10. Creation of habitat of insects and wild animals	
	11. Prevention of coastal erosion	
	12. Prevention of damage by strong wind and storm surge	
	13. Provision of recreational sites for canoe and so on	
	14. Creation of habitat for mosquito	
	15. Easy to be polluted by solid waste	
Fishing ground	1. Provision of diversified marine products	178,000t (0.2%) decrease
	2. Regulation of water quality	
	3. Provision of recreational places for fishing and so on	
	4. Supporting marine ecosystems and material circulation	



Fig. A2. Scenario prediction of terrestrial natural capital (2019 US\$).



Fig. A3. Scenario prediction of each terrestrial natural capital in rural and urban area.

Table A2. Definition of localized SDGs indicators (Matsui et al., 2019).

01. No poverty

01.1.1 Relative poverty rate (number of households with annual income less than 1.22 million yen / number of all households)

01.2.1 Relative poverty rate (number of households with annual income less than 1.22 million yen / number of all households)

02. Zero hunger

- 02.1.1 Total patient proportion in malnutrition or vitamin deficiency
- 02.2.1 Percentage of people with developmental disabilities

03. Good health and well-being

- 03.1.1 Maternal mortality rate
- 03.2.1 Under-five mortality rate
- 03.2.2 Neonatal mortality
- 03.3.2 TB incident rate
- 03.3.3 Malaria mortality rate
- 03.4.1 Mortality of cardiovascular disease, cancer, diabetes
- 03.4.2 Suicide rate
- 03.6.1 Mortality from road traffic accidents
- 03.a.1 Smoking rate
- 03.c.1 Number of doctors per population

04. Quality education

- 04.2.2 Nursery utilization rate
- 04.5.1 Parity index

05. Gender equality

- 05.5.1 Percentage of women in prefectural assembly
- 05.5.2 Percentage of female executives
- 05.b.1 Percentage of people who own mobile devices

06. Clean water and sanitation

- 06.5.1 Number of waterworks per population
- 06.a.1 Sewerage cost per population
- 06.b.1 Sewer business start-up rate

07. Affordable and clean energy

- 07.1.1 Electricity energy consumption per population
- 07.2.1 New energy power generation ratio
- 07.3.1 Gross regional product per energy consumption

08. Decent work and economic growth

- 08.1.1 Gross regional product per capita
- 08.2.1 Gross regional product per workers
- 08.5.2 Unemployment rate
- 08.10.1 Number of banks per population

09. Industry, innovation and infrastructure

- 09.2.1.1 Gross value added of manufacturing industry per gross regional product
- 09.2.1.2 Gross value added of manufacturing industry per population
- 09.2.2 Percentage of manufacturing workers
- 09.4.1 CO2 emissions from manufacturing industry per gross value added
- 09.5.1 Research and development costs per gross regional product
- 09.5.2 Number of researchers per million

- 09.a.1 Ratio of civil engineering expenses to annual expenditure
- 09.b.1 Gross value added of the electrical machinery / equipment manufacturing industry per total gross value added at office with 4 or more employees
- 09.c.1 Internet usage rate

10. Reduced inequalities

10.4.1 Labor productivity

11. Sustainable cities and communities

- 11.1.1 Percentage of homeless people
- 11.5.2 Disaster recovery costs as a percentage of annual expenditure
- 11.6.2.1 Annual average value of PM2.5
- 11.6.2.2 Number of days when the photochemical oxidant (Ox) concentration during the day was 0.12 ppm or more
- 11.6.2.3 Annual average value of NO_x
- 11.6.2.4 Annual average value of SO₂

12. Responsible consumption and production

- 12.4.2 Hazardous waste rate
- 12.5.1 Recycling rate

13. Climate action

13.1.1 Percentage of victims of natural causes such as disasters

14. Life below water

14.4.1 Rate of change in catch and aquaculture yield

15. Life on land

- 15.1.1 Percentage of forested area
- 15.2.1 Number of forestry test instructors per population
- 15.4.1 Percentage of biological conservation area
- 15.5.1 Number of endangered species per area

16. Peace, justice and strong institutions

- 16.1.1 Number of murder recognition cases per population
- 16.9.1 Percentage of population under 5

17. Partnerships for the goals

- 17.4.1 Real debt service ratio
- 17.6.2 Internet broadband subscription household ratio
- 17.8.1 Internet usage rate



Fig. A4. Correlation heatmap among inclusive wealth index and localized SDGs indicators.



Fig. A5. Correlation heatmap among WTPs for natural capitals and localized SDGs indicators.

References

- Bagozzi, B. E., Hill, D. W., Moore, W. H., & Mukherjee, B. (2012). Modeling Two Types of Zeros in Ordinal Data : The Zero-inflated Ordered Probit (ZiOP) Model in Conflict Research *.
- Blaine, T. W., Lichtkoppler, F. R., Jones, K. R., & Zondag, R. H. (2005). An assessment of household willingness to pay for curbside recycling: A comparison of payment card and referendum approaches. *Journal of Environmental Management*, 76(1), 15–22. https://doi.org/10.1016/j.jenvman.2005.01.004
- Brockerhoff, E. G., Jactel, H., Parrotta, J. A., Quine, C. P., & Sayer, J. (2008). Plantation forests and biodiversity: Oxymoron or opportunity? *Biodiversity and Conservation*, *17*(5), 925–951. https://doi.org/10.1007/s10531-008-9380-x
- Collados, C., & Duane, T. P. (1999). Natural capital and quality of life: A model for evaluating the sustainability of alternative regional development paths. *Ecological Economics*, 30(3), 441– 460. https://doi.org/10.1016/S0921-8009(99)00020-8
- Costanza, R., Arge, R., Groot, R. De, Farber, S., Hannon, B., Limburg, K., Naeem, S., Neill, R. V.
 O., Paruelo, J., Raskin, R. G., Sutton, P., Costanza, R., & Groot, D. (1997). Massey Research
 Online The Value of the World 's Ecosystem Services and Natural Capital. *Nature*, 387(6630), 253–260.
- Costanza, R., de Groot, R., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., Farber, S., & Grasso, M. (2017). Twenty years of ecosystem services: How far have we come and how far do we still need to go? *Ecosystem Services*, 28, 1–16. https://doi.org/10.1016/j.ecoser.2017.09.008
- Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S. J., Kubiszewski, I., Farber, S., & Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change*, 26(1), 152–158. https://doi.org/10.1016/j.gloenvcha.2014.04.002
- de Groot, R., Brander, L., van der Ploeg, S., Costanza, R., Bernard, F., Braat, L., Christie, M., Crossman, N., Ghermandi, A., Hein, L., Hussain, S., Kumar, P., McVittie, A., Portela, R., Rodriguez, L. C., ten Brink, P., & van Beukering, P. (2012). Global estimates of the value of ecosystems and their services in monetary units. *Ecosystem Services*, 1(1), 50–61. https://doi.org/10.1016/j.ecoser.2012.07.005
- Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., Hill, R., Chan, K. M. A., Baste, I. A., Brauman, K. A., Polasky, S., Church, A., Lonsdale, M., Larigauderie, A., Leadley, P. W., van Oudenhoven, A. P. E., van der Plaat, F., Schröter, M., Lavorel, S., Aumeeruddy-Thomas, Y., Bukvareva, E., Davies, K., Demissew, S., Erpul, G., Failler, P., Guerra, C. A., Hewitt, C. L., Keune, H., Lindley, S., & Shirayama, Y. (2018). Assessing nature's contributions to people. *Science*, *359*(6373), 270–272.

https://doi.org/10.1126/science.aap8826

- Egusa, T., Kumagai, T., & Shiraishi, N. (2020). Carbon stock in Japanese forests has been greatly underestimated. *Scientific Reports*, *10*(1), 1–9. https://doi.org/10.1038/s41598-020-64851-2
- Ekins, P., Simon, S., Deutsch, L., Folke, C., & De Groot, R. (2003). A framework for the practical application of the concepts of critical natural capital and strong sustainability. *Ecological Economics*, 44(2–3), 165–185. https://doi.org/10.1016/S0921-8009(02)00272-0
- Fisheries, A. (2008). Current status and problems of seaweed beds and tidal flats. Retrieved from https://www.jfa.maff.go.jp/j/study/kikaku/moba_higata/pdf/1siryou.pdf
- Forestry, A. (2010). Annual Report on Trends in Forest and Forestry in Japan Fiscal Year 2009. Retrieved from https://www.rinya.maff.go.jp/j/kikaku/hakusyo/21hakusho/190411.html
- Forestry, A. (2017). Current status of forest resources. Retrieved from https://www.rinya.maff.go.jp/j/keikaku/genkyou/h29/index.html
- Fujii, H., & Managi, S. (2016). An evaluation of inclusive capital stock for urban planning. *Ecosystem Health and Sustainability*, 2(10), 1–11. https://doi.org/10.1002/ehs2.1243
- Fujii, H., Sato, M., & Managi, S. (2017). Decomposition analysis of forest ecosystem services values. *Sustainability (Switzerland)*, 9(5). https://doi.org/10.3390/su9050687
- Fujioka, M., & Lane, S. J. (1997). The impact of changing irrigation practices in rice fields on frog populations of the Kanto Plain, central Japan. *Ecological Research*, 12(1), 101–108. https://doi.org/10.1007/BF02523615
- Harris, M. N., & Zhao, X. (2007). A zero-inflated ordered probit model, with an application to modelling tobacco consumption. *Journal of Econometrics*, 141(2), 1073–1099. https://doi.org/10.1016/j.jeconom.2007.01.002
- Hilgarter, K., & Granig, P. (2020). Public perception of autonomous vehicles: A qualitative study based on interviews after riding an autonomous shuttle. *Transportation Research Part F: Traffic Psychology and Behaviour*, 72, 226–243. https://doi.org/10.1016/j.trf.2020.05.012
- Hori, K., Saito, O., Hashimoto, S., Matsui, T., Akter, R., & Takeuchi, K. (2020). Projecting population distribution under depopulation conditions in Japan: scenario analysis for future socio-ecological systems. *Sustainability Science*. https://doi.org/10.1007/s11625-020-00835-5
- Hori, K., Shirahama, S., Hashimoto, S., Saito, O., Matsui, T., & Haga, C. (2020). Exploring the Spatial Scale for Construction of "Regional Circulating and Ecological Sphere" by Ecological Footprint Indicator.
- Ikeda, S., & Managi, S. (2019). Future inclusive wealth and human well-being in regional Japan: projections of sustainability indices based on shared socioeconomic pathways. *Sustainability Science*, 14(1), 147–158. https://doi.org/10.1007/s11625-018-0589-7

Iwamatsu, S., Suzuki, A., & Sato, M. (2007). Nereidid polychaetes as the major diet of migratory

shorebirds on the estuarine tidal flats at Fujimae-Higata in Japan. *Zoological Science*, 24(7), 676–685. https://doi.org/10.2108/zsj.24.676

- Kagohashi, K. (2017). Critical natural capital and sustainability. *Review of Environmental Economics and Policy Studies*, 10(2), 18–31. https://doi.org/https://doi.org/10.14927/reeps.10.2 18
- Katano, O., Hosoya, K., Iguchi, K., Yamaguchi, M., Aonuma, Y., & Kitano, S. (2003). Species diversity and abundance of freshwater fishes in irrigation ditches around rice fields. *Environmental Biology of Fishes*, 66(2), 107–121. https://doi.org/10.1023/A:1023678401886
- Kato, H., Yamagishi, T., Shimada, T., Matsui, T., Shimojima, M., Saijo, M., Oishi, K., Abe, M., Wada, M., Umekita, K., Kamekou, M., Tanioka, D., Sanada, I., Kuwai, T., Tanaka, Y., Shigetou, K., Homma, Y., Yamamoto, C., Yamauchi, M., Hayashi, S., Watanabe, S., Kitao, A., Takatsu, H., Nakanishi, Y., Koguro, K., Watanabe, M., Uehara, N., Kaneko, M., Yamanaka, A., Murakami, Y., Konishi, T., Sakamoto, A., Harada, M., Yamamoto, K., Hayashi, T., Kondo, N., Suemori, K., Ogawa, T., Nakazawa, R., Yamamoto, Y., Miyahara, M., Senba, T., Maruhashi, T., Fukushi, S., Tani, H., Yoshikawa, T., & Morikawa, S. (2016). Epidemiological and clinical features of severe fever with thrombocytopenia syndrome in Japan, 2013-2014. *PLoS ONE*, *11*(10), 2013–2014. https://doi.org/10.1371/journal.pone.0165207
- Kleijn, D., & Báldi, A. (2005). Effects of set-aside land on farmland biodiversity: Comments on Van Buskirk and Willi. *Conservation Biology*, 19(3), 963–966. https://doi.org/10.1111/j.1523-1739.2005.00603.x
- Kokubu, H., Ishii, Y., Miyazaki, H., & Yabe, T. (2017). Estimation of carbon storage in tidal flat and Zostera Marina bed in Ise Bay, toward a blue carbon evaluation. *Journal of Japan Society* of Civil Engineers, SER. B2 Coastal Engineering, 73(1), 2–7. https://doi.org/10.2208/kaigan.73.I_1261
- Kriström, B. (1990). A Non-Parametric Approach to the Estimation of Welfare Measures in Discrete Response Valuation Studies. *Land Economics*, 66(2), 135–139. https://doi.org/10.2307/3146363
- Lee, J. S., Mogasale, V., Lim, J. K., Carabali, M., Sirivichayakul, C., Anh, D. D., Lee, K. S., Thiem, V. D., Limkittikul, K., Tho, L. H., Velez, I. D., Osorio, J. E., Chanthavanich, P., da Silva, L. J., & Maskery, B. A. (2015). A multi-country study of the household willingness-topay for dengue vaccines: Household surveys in Vietnam, Thailand, and Colombia. *PLoS Neglected Tropical Diseases*, 9(6), 1–15. https://doi.org/10.1371/journal.pntd.0003810
- MacDonald, D., Crabtree, J. R., Wiesinger, G., Dax, T., Stamou, N., Fleury, P., Gutierrez Lazpita, J., & Gibon, A. (2000). Agricultural abandonment in mountain areas of Europe: Environmental

consequences and policy response. *Journal of Environmental Management*, *59*(1), 47–69. https://doi.org/10.1006/jema.1999.0335

- MacDonald, Daisy V., Hanley, N., & Moffatt, I. (1999). Applying the concept of natural capital criticality to regional resource management. *Ecological Economics*, 29(1), 73–87. https://doi.org/10.1016/S0921-8009(98)00051-2
- Managi, S., & Kumar, P. (2018). *Inclusive Wealth Report 2018*. Routledge. https://doi.org/10.4324/9781351002080
- Matsui, T., Kawawake, A., Iwami, A., Masuhara, N., & Takashi, M. (2019). Structure Analysis of SDGs Network Based on NEXUS Approach. *Journal of Japan Society of Civil Engineers, Ser. G (Environmental Research)*, 75(6), II_39-II_47. https://doi.org/https://doi.org/10.2208/jscejer.75.6 II 39
- Matsushita, T., Kitsuki, A., & Managi, S. (2019). A study on residential choice of elderly people in Japan. Journal of Japan Society of Civil Engineers, Ser. D3 Infrastructure Planning and Management, 75(5), I_347-I_352.
- Miller, J. R. (2005). Biodiversity conservation and the extinction of experience. *Trends in Ecology and Evolution*, 20(8), 430–434. https://doi.org/10.1016/j.tree.2005.05.013
- Ministry of Agriculture, F. and F. (2017). Current situation of forest resources. Retrieved August 8, 2020, from https://www.rinya.maff.go.jp/j/keikaku/genkyou/h29/index.html
- Ministry of Agriculture, F. and F. (2018). Statistics of cultivated area and crop acreage. Retrieved from https://www.maff.go.jp/j/tokei/kouhyou/sakumotu/menseki/
- Ministry of Agriculture, F. and F. (2020). Current situation and countermeasures of devastated farmland. Retrieved from

https://www.maff.go.jp/j/nousin/tikei/houkiti/Genzyo/PDF/Genzyo_0204.pdf

- Ministry of Land, Infrastructure, T. and T. (2014). National Land Numerical Information. Retrieved from http://nlftp.mlit.go.jp/ksj/
- Ministry of Land, Infrastructure, T. and T. (2016). Biodiversity index among urban cities. Retrieved August 18, 2020, from https://www.mlit.go.jp/common/001152339.pdf
- Ministry of the Environment. (1994). The Report of the Marine Biotic Environment Survey in the 4th National Survey on the Natural Environment. Retrieved from https://www.biodic.go.jp/reports/4-12/r00a.html
- Ministry of the Environment. (2005). Natural Environmental Information GIS. Retrieved from http://gis.biodic.go.jp/webgis/
- Ministry of the Environment. (2007). Round-table conference on conservation and use of sea areas related to national and quasi-national parks. Retrieved from https://www.env.go.jp/nature/koen_umi/

- Ministry of the Environment. (2017). Annual Report on Environmental Statistics 2017. Retrieved from http://www.env.go.jp/en/statistics/e2017.html
- Mukai, Y., Baba, N., & Ishii, M. (2005). The water system of traditional rice paddies as an important habitat of the giant water bug, Lethocerus deyrollei (Heteroptera: Belostomatidae). *Journal of Insect Conservation*, 9(2), 121–129. https://doi.org/10.1007/s10841-005-3488-z
- NASA Goddard Space Flight Center, Ocean Ecology Laboratory, O. B. P. G. (2018). Moderateresolution Imaging Spectroradiometer (MODIS) Aqua Chlorophyll Data. https://doi.org/data/10.5067/AQUA/MODIS/L3M/CHL/2018
- Natuhara, Y. (2013). Ecosystem services by paddy fields as substitutes of natural wetlands in Japan. *Ecological Engineering*, *56*, 97–106. https://doi.org/10.1016/j.ecoleng.2012.04.026
- Navarro, L. M., & Pereira, H. M. (2012). Rewilding Abandoned Landscapes in Europe. *Ecosystems*, 15(6), 900–912. https://doi.org/10.1007/s10021-012-9558-7
- Noel, J. F., & O'Connor, M. (1998). Strong sustainability and critical natural capital. In M.
 O'Connor (Ed.), *Valuation for sustainable development: Methods and policy indicators* (pp. 75–97). Cheltenham/Northampton: Edward Elgar.
 https://doi.org/10.4337/9781782544708.00012
- Osawa, T., Kohyama, K., & Mitsuhashi, H. (2013). Areas of increasing agricultural abandonment overlap the distribution of previously common, currently threatened plant species. *PLoS ONE*, 8(11), 1–9. https://doi.org/10.1371/journal.pone.0079978
- Pucher, J., & Renne, J. L. (2005). Rural mobility and mode choice: Evidence from the 2001 National Household Travel Survey. *Transportation*, 32(2), 165–186. https://doi.org/10.1007/s11116-004-5508-3
- Rees, W. E. (1992). Ecological footprints and appropriated carrying capacity: What urban economics leaves out. *Environment & Urbanization*, *4*(2), 121–130. https://doi.org/10.1177/095624789200400212
- Riahi, K., van Vuuren, D. P., Kriegler, E., Edmonds, J., O'Neill, B. C., Fujimori, S., Bauer, N.,
 Calvin, K., Dellink, R., Fricko, O., Lutz, W., Popp, A., Cuaresma, J. C., KC, S., Leimbach, M.,
 Jiang, L., Kram, T., Rao, S., Emmerling, J., Ebi, K., Hasegawa, T., Havlik, P., Humpenöder,
 F., Da Silva, L. A., Smith, S., Stehfest, E., Bosetti, V., Eom, J., Gernaat, D., Masui, T., Rogelj,
 J., Strefler, J., Drouet, L., Krey, V., Luderer, G., Harmsen, M., Takahashi, K., Baumstark, L.,
 Doelman, J. C., Kainuma, M., Klimont, Z., Marangoni, G., Lotze-Campen, H., Obersteiner,
 M., Tabeau, A., & Tavoni, M. (2017). The Shared Socioeconomic Pathways and their energy,
 land use, and greenhouse gas emissions implications: An overview. *Global Environmental Change*, 42, 153–168. https://doi.org/10.1016/j.gloenvcha.2016.05.009

Saito, O., Kamiyama, C., Hashimoto, S., Matsui, T., Shoyama, K., Kabaya, K., Uetake, T., Taki, H.,

Ishikawa, Y., Matsushita, K., Yamane, F., Hori, J., Ariga, T., & Takeuchi, K. (2019). Codesign of national-scale future scenarios in Japan to predict and assess natural capital and ecosystem services. *Sustainability Science*, *14*(1), 5–21. https://doi.org/10.1007/s11625-018-0587-9

- Shoyama, K., Matsui, T., Hashimoto, S., Kabaya, K., Oono, A., & Saito, O. (2019). Development of land-use scenarios using vegetation inventories in Japan. *Sustainability Science*, 14(1), 39– 52. https://doi.org/10.1007/s11625-018-0617-7
- Soga, M., Gaston, K. J., Yamaura, Y., Kurisu, K., & Hanaki, K. (2016). Both direct and vicarious experiences of nature affect children's willingness to conserve biodiversity. *International Journal of Environmental Research and Public Health*, 13(6). https://doi.org/10.3390/ijerph13060529
- Spalding, M., Kainuma, M., & Collins, L. (2010). World Atlas of Mangroves. London, UK: Routledge.
- Sugiawan, Y., Islam, M., & Managi, S. (2017). Global marine fisheries with economic growth. *Economic Analysis and Policy*, 55, 158–168. https://doi.org/10.1016/j.eap.2017.08.004
- Tsunoda, H., & Enari, H. (2020). A strategy for wildlife management in depopulating rural areas of Japan. *Conservation Biology*, *34*(4), 819–828. https://doi.org/10.1111/cobi.13470
- Tsunoda, T., & Mori, K. (2000). No distributional association between the tick Haemaphysalis longicornis (Acari: Ixodidae) and plant surface area. *Ecological Research*, *15*(3), 357–359. https://doi.org/10.1046/j.1440-1703.2000.00353.x
- Turnbull, B. W. (1976). The empirical distribution function with arbitrarily grouped, censored and truncated data. *Journal of the Royal Statistical Society*, *B37*(3), 290–295.
- Udo, K., Takeda, Y., & Yokoo, Y. (2016). Relationship between potential sediment supply from river to sea and beach erosion in Japan. *Journal of Japan Society of Civil Engineers, SER. B2 Coastal Engineering*, 72(2), 799–804. https://doi.org/10.2208/kaigan.72.I_799
- Umenai, T., Krzysko, R., Bektimirov, T. A., & Assaad, F. A. (1985). Japanese encephalitis: Current worldwide status. *Bulletin of the World Health Organization*, *63*(4), 625–631.
- United Nations. (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. New York.
- United Nations Department of Economic and Social Affairs Statistics Devision. (2017). SDG indicators. Retrieved August 20, 2020, from https://unstats.un.org/sdgs/indicators/indicators-list/
- UNU IHDP and UNEP. (2014). Inclusive Wealth Report 2014 Measuring Progress Toward Sustainability. Cambridge: Cambridge University Press. https://doi.org/10.1108/ijshe.2012.24913daa.006

- Vaughan, W. J., & Rodriguez, D. J. (2001). Obtaining welfare bounds in discrete-response valuation studies: Comment. *Land Economics*, 77(3), 457–465. https://doi.org/10.2307/3147136
- Zhang, W., Goodale, E., & Chen, J. (2014). How contact with nature affects children's biophilia, biophobia and conservation attitude in China. *Biological Conservation*, *177*, 109–116. https://doi.org/10.1016/j.biocon.2014.06.011