Valuation and Discounting of Forest Ecosystem Services

Masayuki Sato, Kobe University, Japan

Rintaro Yamaguchi, National Institute for Environmental Studies, Japan

Abstract

Non-market valuation techniques have been applied to the valuation of ecosystem services. This piece of information can be utilized for estimating the shadow price of natural capital, defined as its marginal contribution to the discounted sum of future utility. In this paper, we not only value forest ecosystem services by their multiple functions, but also estimate the discount rate applied to forest ecosystem services, using an original dataset of two choice experiments regarding forest conservation policy. Our results suggest that regulating services as a public good are valued higher than provisioning services in Japan. Moreover, we also compute implicit discount rates that depend on the relative growth rate of natural capital. For policy application, it is advisable that ecosystem service valuation and natural capital valuation be prepared in a consistent manner. The implicit discount rates that combine consumption discounting and natural capital regeneration are more plausible than the usual consumption discount rate for evaluation of natural capital conservation project and design of payment for ecosystem services.

Key Words

Ecosystem services; Valuation; Multi-dimensional value; Natural capital; Discounting; Choice experiment

1. Introduction

The valuation of ecosystem services and natural capital has been gradually mainstreamed in the arena of environmental policy making. One reason for this is that it has been known that they contribute to human well-being in many ways, both objective and subjective (van der Ploeg and de Groot 2010).

Accordingly, the supply of ecosystem services valuation has also bloomed. The literature has inherited much from environmental valuation which is nicely summarized in, e.g., Freeman (1993), Boyer and Polasky (2004), Bin and Polasky (2005), and Hanley and Barbier (2009), among others. For the valuation of non-marketed ecosystem services, analysis based on revealed preference cannot be employed, so that stated preferences based on contingent valuation or choice experiment designs have been extensively used and improved over decades.

Quite apart from this, recent contributions to the literature of natural capital accounting by Arrow et al. (2003), Barbier (2009), among others, have clarified that the shadow price of natural capital, defined as its marginal contribution to the discounted sum of future utility, is the net present value (NPV) of ecosystem service flow from natural capital. Fenichel and Abbott (2014) proposed a framework which derives a formula for natural capital shadow price based on ecosystem service income and capital gains. They then apply the framework to practical fishery shadow pricing in the Gulf of Mexico.

These two separate literatures have not converged yet, but there have been some attempts to incorporate ecosystem service valuation to natural capital accounting (e.g., WAVES 2018). Like other capital income, the income-capital relationship should be dealt with in a consistent manner for natural capital. In particular, the NPV of ecosystem service flow income should constitute the numerator of natural capital shadow price (Fenichel and Abbott, 2014). Upon reckoning the NPV, the proper discount rate is the utility discount rate, adjusted for the regeneration of the natural capital. However, practical guidelines for connecting the flow-stock valuations, including the choice of the effective discount rate, have been absent.

In the current paper, we show an empirical attempt toward calculating natural capital shadow price by employing stated-preference valuation of an ecosystem service. More concretely, we examine willingness to pay (WTP) for an improvement of forest capital stock by conjoint analysis, using an originally collected dataset. A choice experiment survey has been designed in such a way that the timing of forest improvement policy is delayed marginally, among other policy attributes. By regressing WTP's on explanatories including policy timing and marginal growth rate of forest stock, we obtain an estimated effective discount rate for the NPV of forest capital.

The presented paper is organized as follows. The next section reviews relevant strands of the literature, particularly focused on ecosystem service valuation and discounting. In Section 3, we explain our data collection by social survey. Section 4 reports descriptive statistics and main regression results, including linear and mixed logit models. Section 5 concludes by remarking some immediate and future challenges.

2. Research background and Methods

2.1 Choice experiment for valuing forest ecosystem services

Japan is a country blessed with forests on a global basis, and 67% of the country is covered by forests. The coverage has been stable for very long period[1]. Figure 1 shows the trend of Japanese forest size from 2000-2011. As a whole, the size of Japanese forest has been stable, but it is found that the breakdown is slightly changing. The size of conifer forest is slightly decreasing and the broadleaf forest is getting bigger. It is a result of forest management policy (Tanaka et al. 2012)

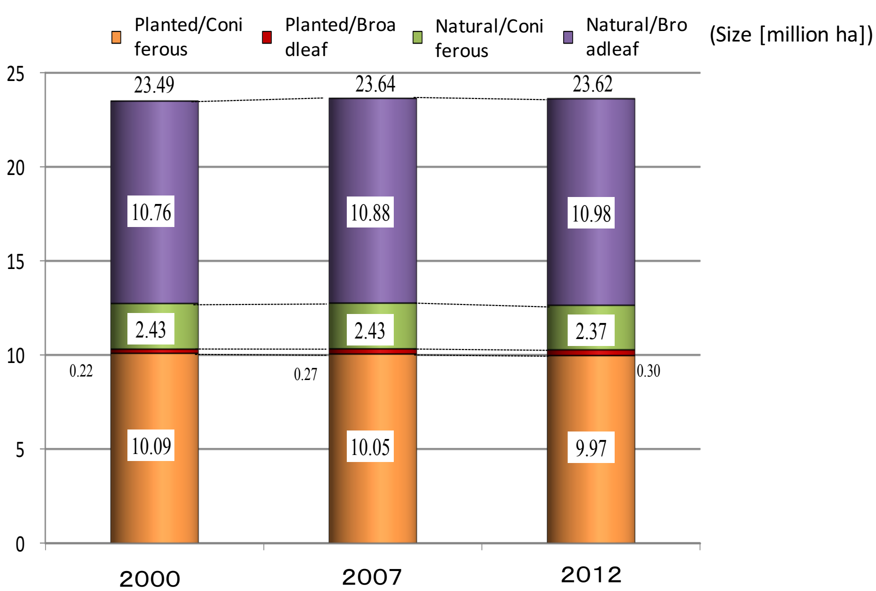

Figure 1. Change in forest size

Source: Report on Results of 2000 World Census of Agriculture and Forestry in Japan 2000

[1] The coverage itself has not been changed during this 100 years.

On forest conditions, Figure 2 suggests that the age of planted forest is getting old than natural forest because of the insufficient forest thinning. When the planting started, large demand for construction used to be expected, but after the competition with foreign timber, the Japanese forestry has been decreasing. As a result, it has become difficult to conduct an appropriate forest thinning in Japan.

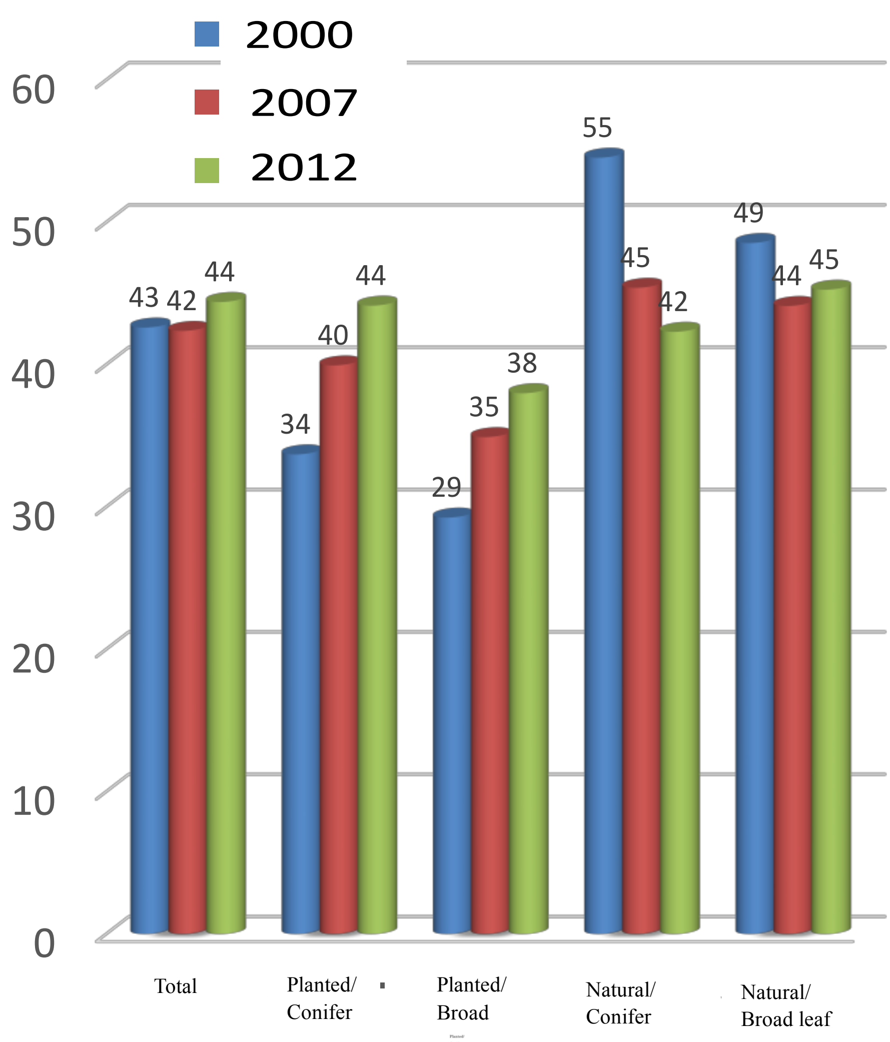

Figure 2 Age of forest

Source IBID

As these backgrounds imply, although Japan's forest has been providing rich ecosystem service, it should be concerned that the qualitative degradation of forests results in the deterioration of forest ecosystem services in Japan. To design the conservation policy, the valuation of forest ecosystem services is required with reference to characteristics of forest ecosystem in Japan.

For our dual purposes of valuation of multiple ecosystem services and estimation of discounting, we conduct choice experiment, as some services can only be valued by stated preference method. Choice experiments have been extensively used for estimating multi-attribute goods and has been recently applied to valuing environmental goods in particular. Forest is a textbook example of natural capital that yields multiple ecosystem services summarised in the Millennium Ecosystem Assessment (2005) (Figure 3).

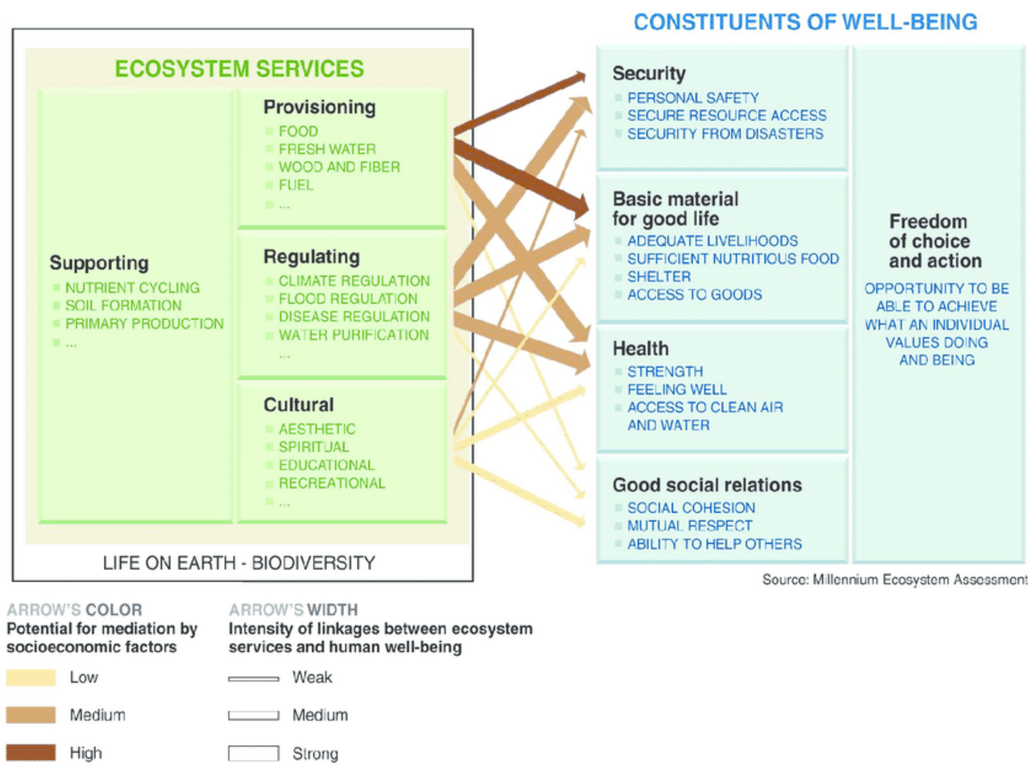

Figure 3 Various ecosystem services to be valued

In practicing forest ecosystem services valuation, such attributes as below have been focused in Japan (Gakujutsu kaigi, 2001):

1. Biodiversity conservation
2. Global environmental conservation
3. Land slide prevention/ Soil conservation
4. Water source preservation
5. Comfortable environment creation
6. Health and recreation
7. Culture

To date, valuation of goods with multiple attributes is considered to be best performed by conjoint analysis. However, one of the challenges of conjoint analysis of goods with multiple attributes is the information overload respondents face. Previous research showed that, if the number of attributes is more than several, the respondents cannot appropriately choose the answer in a consistent manner. A seminal study by Heiner (1983) found that when rational judgments break down and proposing the existence of the gap between an agent's competence and the difficulty of the decision problem is prominent. De Palma *et al*. (1994) placed the incompleteness of decision making abilities in the framework of traditional utility theory, and demonstrated that when the information processing capabilities of consumers are not high, any attempt to obtain maximum utility would result in failure. Wang and Li (2002) and Arentze *et al*. (2003) investigated the Heiner hypothesis and confirmed its existence with respect to the number of attributes.

The approaches taken in the above research are focused on the size of the variance of the error term (the smallness of the scale parameter). In addition, Swait and Adamowicz (2001a,b) demonstrate that the loss of consumer ability to make accurate choices was observed in parallel with increasing choice complexity.

To avoid the limitation of the analysis these previous studies presented, we adopt partial-profile conjoint analysis to reduce the number of attributes. Using these techniques, we estimate the relative weight of seven attributes shown in Table 1.

Table 1 Forest ecosystem services valued in this study

1	Water source recharge
2	Land slide prevention

3	Ecology conservation
4	Timber supply
5	Recreation
6	Global warming prevention
7	Cost

In conducting the survey, we provide the explanation for each attribute as follows:

1) Water source recharge: After raining in the forests, the rainwater soak into the ground and slowly dissipate and eventually spill out from the forests. Hence forests contribute to mitigate the flood right after the raining spree, as well as mitigating drought under the opposite conditions. In addition, when the water transverses in the ground, water is purified and obtains minerals in exchange, thereby the water quality improves. This function is called water source recharge.
2) Land slide prevention: The soil in forest is covered by trees, undergrowth and fallen leaves. It absorbs the shock of rainfall and prevent the spill-out of soils. The roots of forest deeply extend to the underground and rock clacks. By fixing the border between soil and bedrock, landslides are mitigated. This function is called landslide prevention.
3) Ecology conservation: Forests provide the nurturing place to live for various plants, animals, insects, fungi and microorganisms conforming the ecosystem. The diversity is important because it stabilizes the forest ecosystem, and consequently the ecosystem services for human lives and economies are maintained. This function is called ecology conservation.
4) Timber supply: Forests provides the timber resources for housing, furniture, etc. If the timber is cut, afforestation and adequate management make the forest reproduce the timber sources. This function is called timber supply.
5) Recreation: People can enjoy hiking, camping, refreshing etc. in the forests. This function is called recreation, also known as household production.
6) Global warming prevention: Forests absorb the CO_2 by photosynthesis and contribute to the prevention of global warming. This function is called global warming prevention.

After the explanation of each attribute in the questionnaire, the respondents answer their current knowledge and recognition about these functions. In addition, they are asked how important they think each attribute can be. These questions are placed as a preliminary for answering the main choice question for conjoint analysis, whose sample choice sets are shown in Figure 4.

Attributes	Option 1	Option 2	Option 3	None
Water source recharge	75% of current level (25% decrease)	Status quo	150% of current level (50% increase)	-
Land slide prevention	75% of current level (25% decrease)	125% of current level (25% increase)	Status quo	-
Global warming prevention	75% of current level (25% decrease)	150% of current level (50% increase)	Status quo	-
Ecology conservation	75% of current level (25% decrease)	150% of current level (50% increase)	125% of current level (25% increase)	-
Expenditure	JPY 2,000	JPY 20,000	JPY 5,000	-

Figure 4. A sample of question of partial profile Choice Experiments

In this research, we assume the random utility function (1) to estimate WTP for forest ecosystem services.

$$U_{in} = V_{in} + \varepsilon_{in} (1)$$

where U_{in} is utility when iundividual *n* chooses alternative *i*, and V_{in} is an observable portion of U_{in} by the exhibited attributes and ε_{in} is an error term assumed Independent and Identical distribution (iid) of Type 1 Extreme Value (IIDEV1).

The choice question requires respondents to choose the most prefereble alternatives in the choice set. Using the random utility function (1) , the probability that respondent n chooses alternative i from choice set C_n is written as:

$$P_{in} = prob(U_{in} > U_{jn}, for\ all\ j \in C_n) \qquad (2)$$

which is transformed into:

$$\begin{aligned} P_{in} &= prob(V_{in} + \varepsilon_{in} > V_{jn} + \varepsilon_{jn}, \, for\, all\; j \in C_n) \\ &= prob(V_{jn} - V_{in} < \varepsilon_{in} - \varepsilon_{jn}, \, for\, all\; j \in C_n) \end{aligned} \quad (3)$$

Based on the equation (3), McFadden (1974) showed that the conditional logit model is identified as equation (4):

$$P_{in} = \frac{\exp(V_{in})}{\sum_j \exp(V_{jn})} \quad (4)$$

By using maximum likelihood method, we estimate the utility parameter in Vin, which represent the weight of each attribute.

2.2 Choice experiment for valuing discounting factors

In addition to the analysis on the weight of attributes of forest ecosystem services, we analyse the weight of timing of ecosystem service flows. Related to the issue on inter-temporal choice, especially time preference, choice experiment is applied to investigate the degree of discounting for future cost and benefit. Ramsey equation suggests that consumption discount rate is identified as equation (5)

$$\rho = \delta + \eta \times g \qquad (5)$$

where ρ is consumption discount rate, δ is pure time preference, η is elasticity of marginal utility and g is growth rate of consumption. Each term is interpreted as follows:

- δ : reward for waiting for one year. It is also a extinction risk.
- $\eta \times g$: Additional unit of money in one year later has less value than that in today because g is generally positive.
- η : Elasticity of substitution between consumption of today and future. It is the degree of relative risk aversion or intergenerational inequality aversion.

Dasgupta (2008) assumed $g = 1.3\%$ and Stern (2006) assumed $\delta = 0.1$ and $\eta = 1$. These assumption results in $\rho = 0.1 + 1 \times 1.3 = 1.4\%$, for example. It can be generally argued that discount rates for public projects are lower than those applied to private projects. This is a normative approach to decide the consumption discount rate with ethical assumption of pure time preference and elasticity of marginal utility.

On the other hand, Nordhaus (1994) argued for a descriptive approach to the discount rate using DICE model for integrated valuation model for climate change. He assumes $\eta = 1$ but δ is calculated by calibrating the model to conform to the real interest rate observed in the market. The consumption discount rate works out to be something like $\rho = 3.5 + 1\times 1.3 = 4.8\%$.

Recently, the Ramsey equation is revised with consideration of the environmental goods and quality. When the relative scarcity of the environment is introduced in the utility function, the Ramsey equation becomes equation (6):

$$\rho = \delta + \left[(1-\gamma)\eta + \gamma \frac{1}{\sigma}\right]\times g + \left[\gamma\left(\eta - \frac{1}{\sigma}\right)\right]\times g_E \qquad (6)$$

where g_E is growth rate of environmental goods, σ is elasticity of substitution in CES utility function. If substitution between consumption goods and environmental goods is limited ($\sigma < 1$), the discount rate decrease because the increase of the value of environmental goods compared with consumption goods in future deterioration of the environment (Hoel and Sterner 2007; Sterner and Persson 2008).

In this study, when we argue the value of future ecosystem services, we assume $\mathrm{U}(s, x(s))$ denote benefit of ecosystem service flow from a unit of natural capital, s, say forest per hectare. s is assumed to evolve according to $\dot{s} = G(s) - f(s)$, where $G(s)$ and $f(s)$ are growth of natural capital and human intervention (but omitted in the model). $x(s)$ is economic program that embodies human behavioral feedback. Social well-being is defined as the NPV of the infinite stream of utility flows, $V(s(t)) := \int_t^\infty U\left(s(\tau), x(s(\tau))\right) e^{-\delta(\tau - t)} d\tau$, where $\delta > 0$ is the pure rate of time preference or the utility discount rate. Omitting the time notation, the shadow price of a unit of natural capital can be expressed by

$$p(s) = \frac{U_S(s, x(s)) + \dot{p}(s, x(s))}{\delta - G_S(s)}, \qquad (5)$$

where U_S stands for the annual ecosystem income. G_S is the derivative of the regeneration of natural capital.

In this research, having a potential forest conservation project in mind, we have conducted a nationwide survey of forest ecosystem service valuation. Same with the valuation of attribute, we adopt conjoint analysis with attributes 1) project size of forest; 2) the forest age of the project; 3) timing of the project; and 4) cost of the project. The attribute of forest age is related to the growth rate. In the questionaire, the respondents are informed that younger forests have higher growth rate. The attribute of project timing is related to the time preference regarding ecosystem services. It can be interpreted that people who want to enjoy the ecosysytem services have higher discount rate. Table 2 showes the summary of attiributes and levels for the quiestion of choice experiments.

Table 2 Attributes and levels for choice experiments

Attributes	Level 1	Level 2	Level 3	Level 4	Level 5
Project size	20 ha	40 ha	60 ha	80 ha	100 ha
Forest age	Sapling	10 years	20 years	40 years	60 years
Project effective period	30 years from2019	30 years from 2023	30 years from 2028	30 years from 2033	30 years from 2038
Annual cost	JPY4,000 per household	JPY6,000 per household	JPY8,000 per household	JPY10,000 per household	JPY12,000 per household

The alternatives are made by combining the attribute level, conforming the choice set for each question. The respondents are required to choose the best alternative in the choice set. Our questionnaire was developed by using the results from one pre-test and related previous researches. Using a cyclical design based on an orthogonal fractional factorial, we generated 5 choice sets, each consisting of three alternative profiles, for each respondent. A total of 5,343 respondents with approximated similarity of proportion in age and gender with population in all the prefectures in Japan. An example of choice question appears like Table 3.

Table 3 An example of choice questions

Attributes	Option 1	Option 2	Option 3	None

Area	10ha	30 ha	20 ha	-
Average tree age	10 years	1 year	60 years	-
Policy becomes effective in	FY 2038	FY 2023	FY 2038	-
Expenditure	JPY 12,000	JPY 10,000	JPY 12,000	-

In the questionnaire, respondents are acknowledged that:

- This project is either to plant trees or to prevent the decrease or rundown of existing forests in your prefecture.
- The effect of the project appears after the preparation period. The length of preparation period depends on the planning of the project. Note that the effect will not appear without the project.
- The types of trees are different among the alternatives. Note that younger trees rapidly grow and absorb more CO_2. Trees older than 20 years provide the ecosystem services of timber production, land slide protection and water resource recharge.
- Policy becomes effective (i.e., benefit arises) only after conservation activity has completed. Expenditure is collected every year and to be spent only for the purpose of this forest project in your residential prefecture. Policy effect is assumed to last for 30 years. Note that your payment starts from the next year in spite of regardless of effective period of the project, and ends with the last year of period. Also, note that payment decreases your current expenditure at your disposal.

In order to understand the scenario correctly, the visual timetable is provided to respondents (Figure 5).

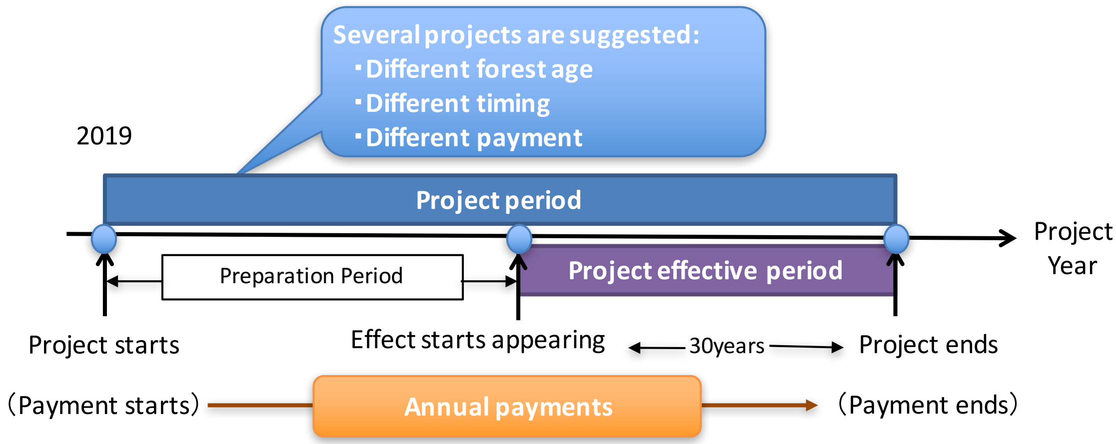

Figure 5. Time table of the project

3 Data collection

The data for valuing each forest ecosystem service was collected in December 2016 by social survey using internet. All the 47 prefectures in Japan are under study, and 6,843 respondents are sampled with considering the same proportion of gender and age of population. The respondents were asked to make a choice for 8 times repeatedly. As a result, the number of observation is 54,744 in the econometric analysis.

The data for time discounting was collected in December 2018 by using web survey. Respondents were randomly chosen from over 18-year-old people in all the prefectures in Japan. The respondent is sampled in order to represent the gender and age of the population. We obtained 5,343 responses. Each respondent answered five choice questions after recognizing the functions of forest ecology. We have dropped the incomplete answers. As a result, the number of observation is 20,605 in the econometric analysis.

4 Results and discussion

Firstly, we conducted maximum likelihood method to estimate each coefficient of attributes assumed in Table 1. The estimation result is shown in Table 4.

Table 4 Estimation results of choice experiments for discounting ecosystem service

	Coefficient	Std.err.	t value
Water source recharge	0.0131***	0.0002	52.862
Land slide prevention	0.0121***	0.0003	46.185
Ecology conservation	0.0084***	0.0003	33.367
Timber supply	0.0051***	0.0003	19.566
Recreation	0.0038***	0.0003	14.455
Global warming prevention	0.0113***	0.0003	43.900
Cost	-0.0914***	0.0011	-83.964
Mean Log likelihood	-1.47126		
Number of Obs.	54,744		

Note: *** represents 1% significant level

All coefficient of ecosystem services is estimated. The theoretical consistency is confirmed that ecosystem services are goods (positive signs), and cost attribute affects negatively on utility. Based on the estimation result, we can calculate the marginal willingness to pay (MWTP) for each ecosystem service (Table 5).

Table 5 Marginal Willingness to Pay (MWTP) for each ecosystem service improvement

	MWTP (JPY)
Water source recharge	143.6
Land slide prevention	132.2
Ecology conservation	92.0
Timber supply	56.0
Recreation	41.0
Global warming prevention	123.9

Note: 1 USD is approximately 111 JPY as of May 2019.

The value in Table 5 implies the relative weight of each ecosystem service. The highest weight is put on the water source recharge. The household is willing to pay JPY143.6 for 1% improvement of water source recharge. Subsequently, the landslide prevention, global warming prevention and ecology conservation have higher priority among forest ecosystem services. From this, we can see that high values are attached to regulating services of forest ecosystem in Japan. On the other hand, provisioning service, i.e. timber supply, has lower weight than regulating services. It seems consistent with the current situation that forestry industry is losing its scale in Japanese economy due to lack of competitiveness toward the world and labor power. However, it should be noted that the social survey was conducted with the general citizens in Japan, and not limited to forest industry persons who are obviously interested in timber supply function.

As for the second results of choice experiment for estimating discount rate, the result is shown in Table 6.

Table 6 Estimation results of choice experiments for discounting ecosystem service

	Coefficient	Std.err.	t value
Area	0.00904***	0.00037	24.23
Average tree age	0.00018	0.00053	0.34
Afforestation	0.09740***	0.02897	3.36
Timing of project effect	-0.01156***	0.00137	-8.45
Expenditure	-0.00026***	0.000003	-64.6
No-choice	-2.5839***	0.05666	-45.6
Mean Log likelihood	-24,202.55		
Number of Obs.	20,605		

Note: *** represents 1% significant level

To consider the difference between afforestation of sapling and preserving bearing trees, we introduce the afforestation dummy in the model. With forest age, it represents the types of forests in the project.

As Table 6 shows, the coefficient of average tree age was not statistically significant. Other coefficients are statistically significant and consistent with expected signs. Positive coefficient of Area represent that the broader preservation of forest contributes to utility of peoples as all else being equal. Positive coefficient of afforestation implies that planting sapling has special meaning compared to bearing trees, high growth rate as well considering the average tree age has not significant coefficient.

We are paying special attention to the coefficient of timing of project effect. It has statistically negative sign. It represents that earlier enjoyment of ecosystem service is preferable, and this also implies the discount rate of future ecosystem services is positive. This is consistent with standard economic theory but we are focusing on the magnitude of the rate. Based on the estimation result, we can compute the implicit discount rates that correspond to $\delta - G_S(v)$ in eq. (2). As we can see the ratio of coefficient of project timing and cost,

Coeff. of project timing / Coeff. of cost = -0.01156 / -0.00026 = 44.6

This implies that one year front loading of project timing equals to the economic value of JPY 44.6. The profile is made with the levels shown in Table 2, it is averagely calculated that the value of one year front loading equal to 0.6% of average annual payment. It's interpreted as discount rate of forest ecosystem service in one year later.

In addition, the resulting unit WTP for forest conservation of (additionally) expanding 1 ha forest area works out to US$3.20 (Note: US$1 = JPY 114 as of Nov, 2018). Also, earlier implementation of the project by one year turned out to be equivalent to expanding the project area by 1.12ha. The timing of ecosystem service provides a valuation about current conservation of forest stock as a source of future well-being.

5 Conclusion

With the qualitative deterioration of forest ecosystem in Japan, it is required to conserve and improve the forest resources. In order to discuss the conservation policy, the economic valuation of forest ecosystem function is needed. With regard to the economic valuation of ecosystem stock and services, we conducted social survey and analysed shadow price estimates of ecosystem services. Our results suggested that regulating services as a public good are valued higher than provisioning services in Japan.

This result is related to the current situation of forestry in Japan. The forest industry has been losing its size and it has become difficult to manage through operations in forestry industry. However, the regulation services as public goods for ordinal people are still important. Our result implies that payment for ecosystem services scheme is needed in current situation in Japan to conserve the forest ecosystems.

In addition, this paper computes implicit discount rates that depend on the relative growth rate of natural capital. It is advisable that ecosystem service valuation and natural capital valuation be prepared in a consistent manner, in which proper discount rates might be different from the discount rate in ordinal project evaluation. Our design of choice experiment can reveal implicit discount rates that combine consumption discounting and natural capital regeneration. The value of 0.6% as discount rate is quite lower value comparing to ones used in the private and public projects. However, recent discussion on social discount rate applied for global environmental problem, e.g. CO_2 damage, proposes to use 0.1% (Stern review). Our estimation has similar value with the social discount rate for long-term global environmental problem. This implies Japanese people evaluate the forest ecological function has same characteristic with environmental goods like prevention of global warming. In other word, it is considered that intergenerational equity is reflected in the discounting future forest ecosystem services in Japan. It is required to consider the consistency of intergenerational distribution of benefit and cost of ecosystem conservation.

References

Arrow, K. J., Dasgupta, P., & Mäler, K. G. (2003). "Evaluating projects and assessing sustainable development in imperfect economies", *Environmental and Resource Economics*, 26(4), 647-685.

Arrow K. J., Croppe, M. L., Gollier, C., Groom, B., Heal, G. M., Newellk, R. G., Nordhaus, W. D., Pindyck, R. S., Pizeryy, W A., Portney, P. R., Sterner, T, Tol, R. S. J. and Weitzman, M. L. (2014) "Should Governments Use a Declining Discount Rate in Project Analysis?", *Review of Environmental Economics and Policy*, 8 (2), pp. 145–163.

Arentze, T., A. Borgers, H. Timmermans, R. DelMistro (2003), "Transport stated choice responses: effects of task complexity, presentation format and literacy", *Transportation Research E*, 39, pp. 229-244.

Bin O, Polasky S (2005). Evidence on the amenity value of wetlands in a rural setting. *J Agric Appl Econ*, 37(3), 589–602.

Boyer T, Polasky S (2004). "*Valuing urban wetlands: a review of non-market valuation studies"*, *Wetlands*, 24(4), pp.744–755

Dasgupta, P. (2008) "Discounting climate change", *Journal of Risk and Uncertainty*, 37, pp.141–69.

De Palma, A., G. M. Myers, Y. Y. Papageorgiou(1994), "Rational Choice Under an Imperfect Ability to Choose", *American Economic Review*, 84, 3, pp. 419-440

Fenichel, E. P., & Abbott, J. K. (2014) "Natural capital: from metaphor to measurement", *Journal of the Association of Environmental and Resource Economists*, 1(1/2), pp.1-27.

Freeman, AMIII (1993). *The measurement of environmental and resource values: theory and methods*, Resources for the Future, Washington, DC

Gakujutsu kaigi (2001) *Report on valuation of mulit-functions of agriculture and forest on global environment and human life* (in Japanese).

Hanley, N. and Barbier, E. B. (2009) *Pricing Nature: Cost-Benefit Analysis and Environmental Policy*, Edward Elgar

Heiner, R. A. (1983), "The Origin of Predictable Behavior", *American Economic Review*, 73, 4, pp. 560-595.

Hoel, M. and Sterner, T. (2007) "Discounting and relative prices", *Climatic Change*, 84(3-4), pp.265–280.

McFadden, D. (1974), "Conditional logit analysis of qualitative choice behavior" in P. Zarembka (ed), *Frontiers in Econometrics*, New York, Academic Press.

Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-Being: Synthesis*. Island, Washington, DC.

Ninan, K. N. and Inoue, M (2013), "Valuing forest ecosystem services: Case study of a forest reserve in Japan," *Ecosystem Services*, 5, pp. 78-87.

Nordhaus, W. D. (1994) *Managing the global commons: The economics of climate change*, MIT Press.

Stern, N. (2006) *The economics of climate change: The Stern review*, Cambridge University Press.

Sterner, T. and Persson, U. M. (2008) "An Even Sterner Review: Introducing Relative Prices into the Discounting Debate", *Review of Environmental Economics and Policy*, 2(1), pp.61–76.

Swait, J. and W. Adamowicz (2001a), "Choice Environment, Market Complexity, and Consumer Behavior: A Theoretical and Empirical Approach for Incorporating Decision Complexity into Models of Consumer Choice", *Organizational Behavior and Human Decision Processes*, 86, 2, pp.141-167.

Swait, J. and W. Adamowicz (2001b), "The Influence of Task Complexity on Consumer Choice: A Latent Class Model of Decision Strategy Switching", *Journal of Consumer Research*, 28, pp.135-148.

Turner RK, Daily GC (2008) "The ecosystem services framework for natural capital conservation", *Environmental and Resource Economics*, 39(1):25–35

Van der Ploeg, S. and de Groot, R.S. (2010) *The TEEB Valuation Database. Foundation for Sustainable Development*, Wageningen, the Netherlands.

Wan, D. and J. Li (2002), "Handling Large Numbers of Attributes and/or Levels in Conjoint Experiments", *Geographical Analysis*, 34, 4, pp.350-362.

WAVES (2018), available at http://www.wavespartnership.org accessed on January 25, 2019

Yamaguchi (2013) "Discounting, Distribution and Disaggregation: Discount Rates for the Rich and the Poor with Climate as a Source of Utility", *Scottish Journal of Political Economy*, 60(4), pp. 440-459.

Yamaguchi, R. (2019) "Intergenerational discounting with intragenerational inequality in consumption and the environment", *Environmental and Resource Economics*, forthcoming.