Roles of payments for ecosystem services in agro-food demands and welfare

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AbstractAgricultural food products are subjected to the provisioning service from ecosystems. Meanwhile, the vales of ecosystem service (ES) and natural species are marginal in the economy. Rising consumption of agro-food commodities causes excessive inputs of natural resources and then depletes them. This can mean greater ecosystem crisis and welfare losses in the economy. Additionally, payments for ecosystem services (PES) are of current interest as an economic measure for the nature conservation. However, what remains unclear is merit and demerit of PES on the agro-food consumption, welfare, i.e. general equilibrium effects. Thus, this study develops a method to understand the ES-biodiversity-economy interaction then to investigate the economy reform needed for sustainable development in the market with the biodiversity and ES goods. Thus, this study supposes a small economy in continental high income countries where major parts of the biodiversity and ES are from forests. A regression analysis shows that the bird species-forest area relationships depend on not only either island or continent but also GDP per capita. A CGE model is combined with the model and bottom-up technological information of the forest conservation. Then, this study defines the production function which describe that the forest conservation sector produce a composite goods of the forest conservation area, biodiversity, and ES. Analytical results show that additional payments for the biodiversity and ES may not always lead to the improvement of welfare and agriculture industry development. To solve the problem, the economy needs technological progress to conserve forest area in addition to PES.

Keywords: Biodiversity, ecosystem service, technological progress, welfare

This paper is intended for ‘*Consumer protection in the new scenarios*’.

1. Introduction

Food products are subjected to the provisioning service from ecosystems. However, the increase in food demand results in the depletion of natural resources and loss of biodiversity. Therefore, the agricultural food industry constantly faces the task of sustainable use of the finite natural resources.

By the way, ecosystem services (ES) has been getting lots of attention to enhance sustainable use of the natural resources. Ecosystems cover a wide range of services on the provisioning, supporting, regulating, and cultural elements, and all of which contribute to building of human well-being such as security, basic material for good life, health, good social relations, and freedom of choice and action (Millennium Ecosystem Assessment, 2005).

We all understand that a vital source of ecosystems is the diversity of species. Then, on the continents, large segment of the species lives in forest. Additionally, the species contributes to good quality of agricultural commodities and enhancement of human welfare throughout their consumption. However, little is known concerning how to assess socio-economic and ecological impacts of the species due to their complex web except for the following simple case studies.

For examples, the small-scale farming activity of organic agriculture enriches ES associated with biological soil formation, nutrient cycling in farmlands (Sandhu, *et al*., 2010). Then, non-market values of ES are higher in organic farming fields than in the conventional farming fields (*Sandhu*, et al., 2008). The ES-agriculture issues are in a closed space of the farmlands. On the other hand, the following is a transboundary issue between farmlands and forests in terms of land-use classification. Ricketts, *et al*. (2004) find that pollination by wild bees building a nest in the tropical forest increases coffee yields in farmlands and estimate its significant economic values in the Costa Rica's Environmental Service Payments Program.

Furthermore, payments for ecosystem services (PES) also gains increasingly attention as an economic measure for the conservation of natural resources and biodiversity with the advent of a successful forest conservation policy with PES in Costa Rica (Porras, *et al.*, 2013). However, what remain unclear are the impacts of PES on the agro-food sectors and economic welfare throughout the forest conservation, i.e. regional general equilibrium (GE) effects.

The studies of general equilibrium effects of ES and species habitat have only just begun by Carbone and Smith (2013) who investigate the acidification impacts on the fish habitat, recreation, and human health by use of a CGE model. The result shows that ES have significant roles of market outcomes as well as environmental outcomes. However, the model excludes the behavioral model of the producers who restore the environment deterioration, which makes it difficult to understand how much both the environmental conservation sector penetrates into the market and as a result the households obtain benefit from species habitat and ES. Thus, the investigation of economy-wide effects of PES has been limited to household preference with respect to the environmental issue. Moreover, we have no identified model to describe the species-forest area relationships which can be combined with CGE model. Therefore, there is room to improve CGE model so that we can deal with values of the conservation of species, ES associated with forest conservation.

Thus, this study first focuses on the bird species. A regression analysis is performed to determine the species-forest area relationships based on the Arrhenius model (1921). Subsequently, this study formulates the payments and productivity in terms of the biodiversity and ES provided by the forest conservation. By use of the developed model, this study elucidates how the regional economy should be reformed in the light of sustainable consumption demand of multiple goods including agricultural foods, welfare and biodiversity conservation. While adopting a utility function of household consumption (Carbone and Smith, 2013), this study supposes market access of the forest conservation producers who restore forests for biodiversity conservation and provides one of regulating ES, i.e. carbon dioxide absorptions. A top-down GE model is combined with the bottom-up information with respect to input for forest conservation and the productivity by technology. The putty-clay technology (Johansen, 1959; Babiker *et al.*, 2001) is applied to determine the capital accumulation. The penetration of technologies is numerically solved by the Böhringer and Rutherford scheme (2006).

2. The model

2.1 Species-area relationships

In the macroecology, the species-area relationships (SPARs) are best modeled as a power function which was early proposed by Arrhenius (1921).

$$S = c\ A^{z} \tag{1}$$

where S is species number, A is habitat area (kha), and z and c are constants. Eq. (1) is identified by use of observation data with sample size N ($i = 1, \cdots, N$) for the regression study. Preston formulates a similar bird species-area equation based on the island biogeography (1960) and then finds z-value as 0.262 by use of bird habitat data in the North American deciduous forests (1962).

Furthermore, SPARs may be better described by including categorical predictors. Rosenzweig (1995) and Gaston and Blackburn (2000) suggests that different regression slopes (z-values) came from different types of geographical areas (e.g., z-value is 0.11 in smaller areas as parts of the lager province areas, 0.32 in islands forming archipelago, and 0.66 in biotic regions).

This study indicates that Fig. 1 shows two facts: 1) The species-area plots generally fall into SPA distribution zone clarified by Preston (1960, a shaded area in Fig. 1); 2) there is room to study the existence of two SPARs with respect to income levels of countries (i.e., low income countries (LICs) and high income countries (HICs)) which are separated by the GDP per capita of the high income non-OECD countries; 20735 current US$ (the World Bank).

The data are collected from data base disclosed by the World Bank (the 2012 GDP per capita), and FAO (the 2012 forest area). However, the number of bird species in 1990 (WCMC) are used because of lack of current data which cover most countries. As a result, the number of countries with a full range of the data is 160. The corresponding basic statistics are shown in Table 1. The world distributions by categorized country group (LICs and HICs) are shown Fig. 2. This study identifies SPARs models of Eq. (1) with two categorical predictors related to the geographic condition as well as economic development.

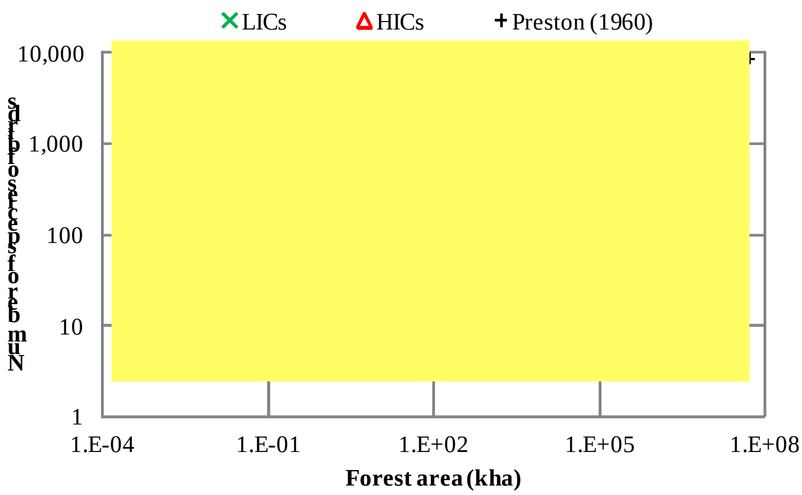

Fig. 1 SPARs of the world countries and the North America forests presented by Preston

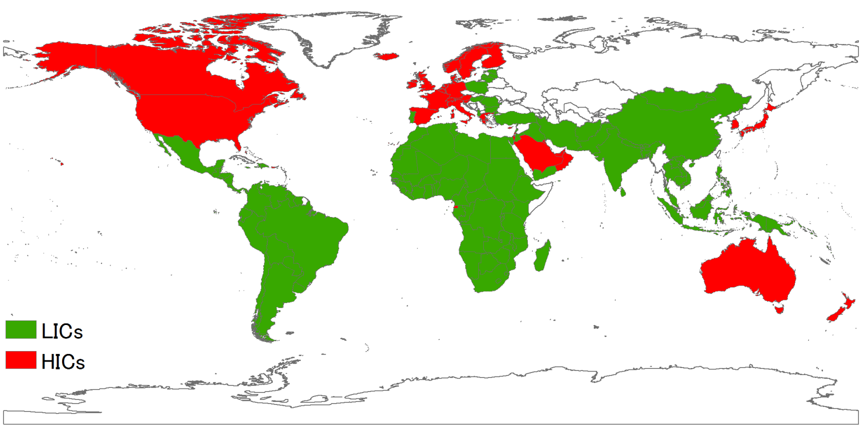

Fig. 2 World distribution of LICs and HICs

Table 1 Basic statistics of the data used for SPARs regression analysis

	Number of samples	Unit	Average	Standard deviation	Minimum	Maximum
Target countries	160					
Num. of species of birds		-	524.5	327.4	27	1695
Forest area		kha	19131.2	57942.5	0.3	519522
GDP per capita		Current US$	15716.8	20978.8	688	103859
Low income countries (LICs)	122					
Num. of species of birds		-	564.6	361.6	27	1695
Forest area		kha	17862.1	53840.9	0.9	519522
GDP per capita		Current US$	5961.9	4828.7	688	20175
High income countries (HICs)	38					
Num. of species of birds		-	424.1	120.7	222	768
Forest area		kha	24684.6	71792.8	0.3	310134
GDP per capita		Current US$	47805.3	21675.9	22391	103859

This study defines dummy variables which denotes an island country and a high income country as D_{is} and D_{hi} respectively, and then modify Eq. (1) with the following constants

$$c = \gamma_0 \ \gamma_2^{D_{hi}} \ \gamma_4^{D_{is}} \tag{2}$$

$$z = \gamma_1 + \gamma_3 D_{hi} + \gamma_5 D_{is} \tag{3}$$

where D_{hi} is 0 and 1 when country i is classified to LICs and HICs, respectively, and D_{is} is either 0 or 1 when country i is either a continent or an island, respectively. Constants γ_j (j = 1, ···, 5) correspond to coefficients of the following linear equation.

$$\ln s_i = \ln \gamma_0 + \gamma_1 \ln A_i + \underbrace{\ln \gamma_2 \ D_{hi\,i} + \gamma_3 \ D_{hi\,i} \ln A_i}_{income\ level\ effect\ terms} + \underbrace{\ln \gamma_4 \ D_{is\,i} + \gamma_5 \ D_{is\,i} \ln A_i}_{island\ effect\ terms} \tag{4}$$

Substituting observed data into the variables s_i and A_i in Eq. (4), Explaining variables are statistically selected and the parameters γ_i are estimated by the ordinary least squares (OLS) stepwise regression.

2.2 Introducing biodiversity and ES into CGE model

2.2.1 Household Utility

Biodiversity is a non-use goods and its value is too small in the economy. However, the biodiversity and ES have been reviewed in the light of global change and sustainable use of natural resources for another consumption goods production. To examine human preferences in terms of coexistence of species diversity conservation and economic development, we need to understand general equilibrium effects of species conservation. Thus, this study defines that the representative household utility consists of not only existing consumption goods including foods but also non-use goods of biodiversity and ES.

Suppose that the utility function is given as a function proposed by Carbone and Smith (2013) but the leisure is excluded (Fig. 3). ES are assumed as substitute goods of the consumer service (CS) goods such as eating out, travel, and medical services etc. Then, consider the substitutability between an increase of biodiversity (i.e. increasing number of species given by their habitat area conservation, *dH*) and aggregated goods which consists of consumption, CS, and ES goods. Constant elasticity substitute functions are assumed for these substitute relation with respect to ES and biodiversity.

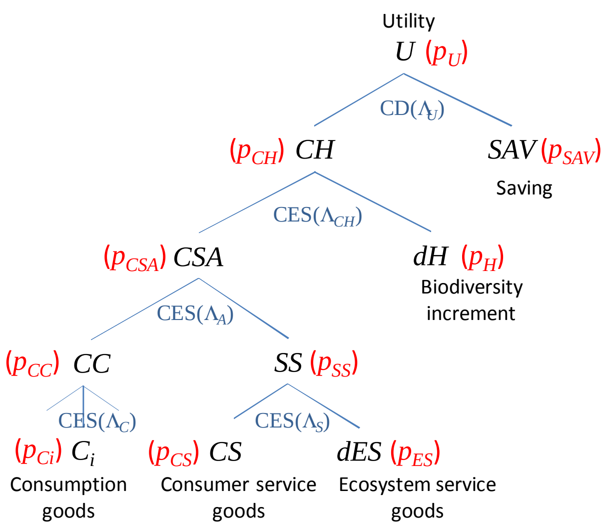

Fig. 3 Nesting structure of household utility

Note: variable *p* in bracket denotes the price of goods.

Solving expenditure minimization problems for each substructure goods consumptions, the price p_U of household utility U can be written as follows.

$$p_U = \phi_U^{-1}\left\{\gamma_U^{-1}\left(\alpha_{CSA}^{\sigma_{CH}}\left(\alpha_{CC}^{\sigma_A}\left(\sum_i \alpha_{Ci}^{\sigma_C}\, p_{Ci}^{(1-\sigma_C)}\right)^{\frac{(1-\sigma_A)}{(1-\sigma_C)}} + \alpha_{SS}^{\sigma_A}\left(\alpha_{CS}^{\sigma_{SS}}\, p_{CS}^{(1-\sigma_{SS})} + \alpha_{ES}^{\sigma_{SS}}\, p_{ES}^{(1-\sigma_{SS})}\right)^{\frac{(1-\sigma_A)}{(1-\sigma_{SS})}}\right)^{\frac{(1-\sigma_{CH})}{(1-\sigma_A)}} + \alpha_H^{\sigma_{CH}}\, p_H^{(1-\sigma_{CH})}\right)^{\frac{1}{(1-\sigma_{CH})}}\right\}^{\gamma_U} \times \left\{(1-\gamma_U)^{-1} p_{SAV}\right\}^{(1-\gamma_U)} \quad (5)$$

where ϕ_U is the scale parameter, α and σ are the distribution parameters and substitution elasticity for substitute goods in each nesting, respectively, and γ_U: is the value share of consumptions in the Cobb-Douglas utility function.

2.2.2 Forest conservation and composite goods

Suppose that producers apply multiple technologies to conserve forests and receive extra payments for the corresponding biodiversity conservation and ES production as well as the payment for forest conservation. Each technological production process can be defined as two stage productions (the bottom-up (BU) production process in Fig. 4). Denote a certain technology by a subscript *n*. The first stage describes that the producers input production factors (labor *L* and capital *K*) and intermediate goods *XX* to produce the composite goods *zz* appropriate to the conserved forest area *RA*. In the second stage, the composite goods *zz* are transformed into three heterogeneous goods, i.e. the conserved forest area *RA*, and increments of the biodiversity and ES obtained by the forest conservation (*dh* and *dES*, respectively). The two production processes are assumed as the zero-profit problem:

$$p_{zz,n} - \left(ay_{L,n} w + ay_{K,n}\, r_{K,n} + \sum_j ax_{j,n} p_j + \mu_n\right) = 0 \quad \perp zz_n \quad \text{for 1st stage} \quad (6)$$

$$\left(p_{z,RA}\, RA_n + p_h\, dh_n + p_{es}\, dES_n\right) - p_{zz,n}\, zz_n = 0 \quad \text{for 2nd stage} \quad (7)$$

where $ay_{L,n}$, $ay_{K,n}$, and $ax_{j,n}$ are the input coefficients of labor, capital, intermediate goods to produce *zz*, respectively, $p_{zz,n}$ is the price of composite goods *zz* produced by the technology *n*, *w* is wage, r_K is the rent of capital, p_j is the price of goods *j*, μ is the specific technological rent, and $p_{z,RA}$, p_h, and p_{es} are the prices of the conserved forest area RA_n, increments of biodiversity and ES (dh_n and dES_n). For the second stage, we need a production function $zz_n = f\,(RA_n, dES_n, dh_n)$ as described later.

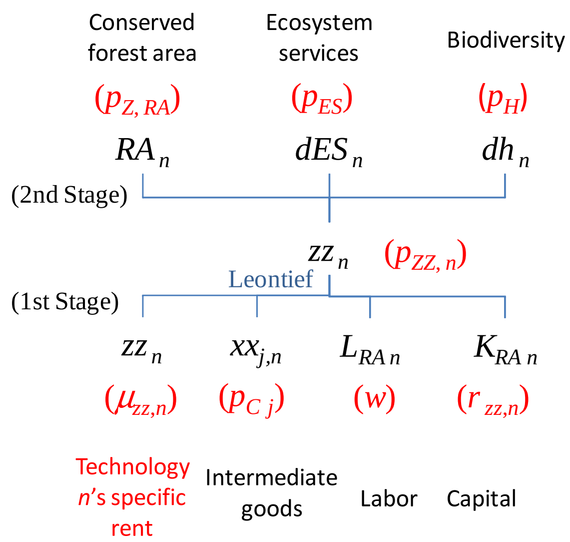

Fig. 4 Two stage structures of forest conservation with a specific technology

Suppose that the different technology conserve forests of the same quality for biodiversity and ES per unit forest area. In the existing market, the producers conserve forest area RA_n. Then, the biodiversity and ES which will be provided by the conservation are unrecognized as additional market goods. Therefore, the non-use goods of dh_n and dES_n disappear and then the composite goods are equal to the area of forest conservation; $zz_n = RA_n$.

However, in the market which recognizes species habitat and ES as the additional goods associated with the forest conservation, dh and dES can be given as a function of RA: $zz_n = f\,(RA_n, dES_n(RA_n), dh_n(RA_n))$. Taking the SPARs equation (1) into a consideration, the derivative of Eq. (1) gives a relational expression between dh_n and RA_n.

$$dh_n = zh\,RA_n / A = k_h\,RA_n \qquad (8)$$

where $dh_n = ds$, $RA_n = dA$, and $k_h = zh/A$. Suppose then that the increment of ES is a linear function of the conserved forest area.

$$dES_n = k_{es} \, RA_n \tag{9}$$

Consider a production function of the composite goods of the biodiversity, ES, and the area forest conservation. Suppose that the composite goods are produced with a consistent rule in terms of productivity. Fig. 5 illustrates three types of changes in the productivity of between the composite goods zz_n and the area of forest conservation ra_n.

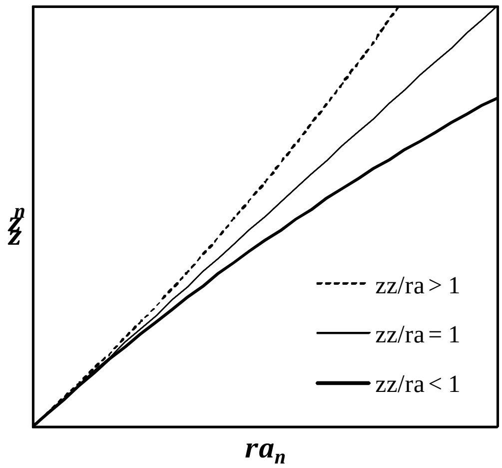

Fig. 5 Productivity of composite goods of biodiversity, ES, and forest conservation

First, when the biodiversity and ES don't contribute to the composite goods, the amount of composite goods is equal to the area of conserved forest (zz_n/ra_n = 1). Second, the case of $zz_n/ra_n > 1$ describes that the producers needs to input more production factors so that they can produce more composite goods zz_n for a certain forest area conservation ra_n; the productivity of composite goods declines. Third, the case of $zz_n/ra_n < 1$ describes that the producers input less production factors and then produce less composite goods for a certain forest area conservation, which indicates the achievement of productivity gain. For examples, the above characteristics can be defined as a production function as follows.

$$zz_n = ra_n \exp\left(\alpha \, dh_n\left(ra_n\right) + \beta \, des_n\left(ra_n\right)\right) \tag{10}$$

where and α and β are the contributing rate of the biodiversity and ES to the composite goods zz_n, respectively. Substituting Eq. (8) and Eq. (9) into Eq. (10), the production function can be written as follows.

$$zz_n = ra_n \exp\left(\left(\alpha k_{h,n} + \beta k_{es,n}\right) ra_n\right) \tag{11}$$

In Eq. (11), the decline and improvement of the productivity are described when the sign of $\alpha k_{h,n} + \beta k_{es,n}$ is positive and negative, respectively.

Suppose that biodiversity and ES are introduced as the market goods in the economy and the productivity of forest conservation sector is improved by the consideration of concurrently produced goods of biodiversity and ES. Fig. 6 shows the corresponding shift of partial equilibrium (the path from point E_0 to E_1). Suppose penetration of two technologies applied for the forest conservation (n = 1, 2). In the business as usual (BAU), the market ignores goods of the biodiversity and ES ($\alpha = \beta = 0$) and the technologies conserve forest areas of $ra_{n,0}$ at the unit production costs $mc_{n,0}$. The unit production cost can be given as a total sum of the product of input coefficient and price with respect to the labor, capital, and intermediate goods.

$$mc_n^* = \left(ay_{L.n}^* w + ay_{K.n}^* \; r_{K,n} + \sum_j ax_{j,.n}^* p_j\right) \tag{12}$$

where the input coefficients are transformed by the substitution of Eq. (11) into Eq. (6) as follows.

$$ay_{m.n}^* = ay_{m,n}\, e^{\left(\alpha k_{h,n} + \beta k_{es,n}\right) ra_n} \quad (m = K, L) \tag{13}$$

$$ax_{j,.n}^* = ax_{j,n}\, e^{\left(\alpha k_{h,n} + \beta k_{es,n}\right) ra_n} \tag{14}$$

Eq. (13) and Eq. (14) indicate that the unit production cost is smaller or larger than the production cost of BAU when the exponential part $\left(\alpha k_{h,n} + \beta k_{es,n}\right)$ is smaller or larger than 0. Assume the prices of the production factors as the same as BAU prices. In the case of a negative value of $(\alpha k_{h,n} + \beta k_{es,n})$, the unit production cost becomes smaller and the productivity of zz_n improves.

In BAU, the equilibrium point E_0 shows that the sum of each technological production ($RA_0 = \Sigma ra_{n0}$) is equivalent to the household demand of conserved forest area $D_0(p_{RA})$ with a price $p_0^* = p_{z,RA}$. The equilibrium state is determined so that the sum of producer surplus (PS) and consumer surplus (CS) maximizes. However, the equilibrium price of the composite goods of the forest conservation, biodiversity, and ES p_1^* is described as a price per unit area of the forest conservation. Substituting dH of Eq. (8) and dES of Eq. (9) into Eq. (7), the corresponding price is given as a total sum of element prices of the composite goods.

$$p_1^* = p_{z,RA} + k_h p_h + k_{es} p_{es} \tag{15}$$

As a result, the case of $(\alpha k_{h,n} + \beta k_{es,n}) < 0$ transfers the equilibrium point from E_0 to E_1.

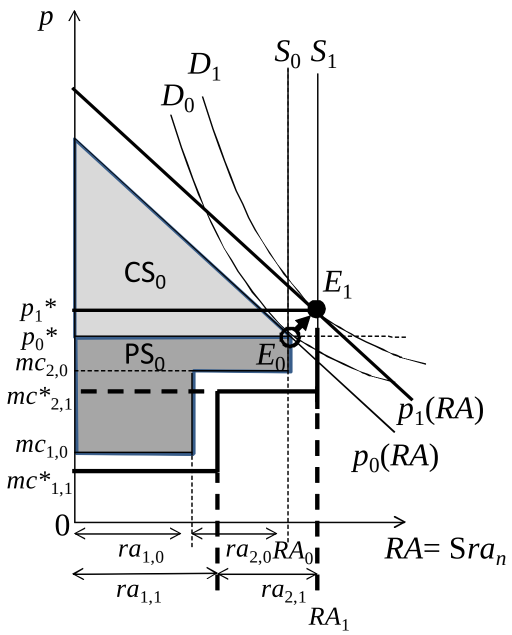

Fig. 6 Partial equilibrium in the forest conservation sector with BU description

The equilibrium point is numerically solved based on the Böhringer and Rutherford scheme (2006) which is applied to the penetration of new energy production. In BU calculation, the conserved forest area by technology ra_n is determined to satisfy the maximization of (PS + CS) subject to the capital formation constraint described later, given the prices with respect to p^* and mc^* from TD calculation of the CGE model. The conserved forest area and the capital solved by the BU calculation are substituted into the CGE model to determine other economic activities and prices. Calculations of the BU and TD models are alternately performed until the total error of solved variables satisfies a tolerance.

2.2.3 Capital formation

This study considers the inter-temporal capital formations; the period between time $t = 0$ and $t = 1$. The calculation is based on the putty-clay technology developed by Johansen (1959), and which are applied to the GHG emissions prediction and policy analysis (Babiker *et al.*, 2001). The procedure is a common to all industries and technologies. For the sector denoted by j (or technology by n), the vintage of non-malleable capital in the next time $t = 1$ is made up of the capital remaining after depreciation of vintage capital and new capital in the present period $t = 0$.

$$K_j^{v,t=1} = \left(1 - \delta_j\right)\left(K_j^{v,t=0} + K_j^{n,t=0}\right) \tag{16}$$

where superscripts v and n denote the vintage capital and new capital, respectively, δ_j is the depreciation rate, and the total sum of sectoral new capital is equal to the investment in the present period $I_{t=0}$

$$\sum_j K_j^{n,t=0} = I_{t=0} \tag{17}$$

The sectoral capital is allocated to satisfy the zero-profit condition that the rental price of the sector j must be equal to the rental price of new capital r^n, given a positive new capital formation.

$$\left(r^{n,t} - r_j^t\right)K_j^{n,t} = 0 \quad \perp \quad K_j^{n,t} > 0 \tag{18}$$

2.2.4 The CGE model

Suppose the economy of a closed perfect competitive market with six industrial sectors: the agriculture (AG), forestry (FO), fisheries (FI), consumer services (CS), forest conservation (RA), and the rest of industry (ROI). The sectors produce their homogenous goods with a homogenous technology except for the forest conservation sector. This is a top-down (TD) production process. Assume that the forestry sector is independent of the forest conservation sector because the forestry sector engages in deforestation to supply wood materials for building and energy sources. Fig. 8 illustrates the sectoral production process except for the forest conservation sector.

The agriculture and forestry sectors produce their goods with constant input ratios of the labor, capital, and intermediate goods (i.e., the Leontief production function) and earn their profits at the maximum. As a result, this condition can be replaced by the zero-profit condition. Next, other industry (FI, CS, and ROI) can be also given as similar equations of the zero-profit condition at the top nesting in Fig. 7, i.e., the inputs of intermediate goods $XX_{j,i}$ and composite production factors Y_i. However, this study considers the substitutability between the labor and capital, which is defined as the Cobb-Douglas production function. Additionally, the production function of fisheries includes the amount of fish resources based on the Schaefer-Gordon production function: $Y_{FO} = L_{FO}^{\gamma_{FO}} K_{FO}^{1-\gamma_{FO}} XM_{FO}$. Finally, the zero-profit conditions by sector ($j = AG, FO, FI, CS, ROI$) are written as follows.

$$p_{z,i} - \left(ay_{L,i} w + ay_{K,i}\ r_i + \sum_j ax_{j,i} p_{j_n} \right) = 0 \quad \left(i = AG, FO \right) \tag{19}$$

$$p_{z,i} - \left(ay_{Y,i} p_{Y\,i} + \sum_j ax_{j,i} p_{j_n} \right) = 0 \quad \left(i = FI, CS, ROI \right) \tag{20}$$

where $ay_{Y,i}$ is the input coefficient of composite production factors.

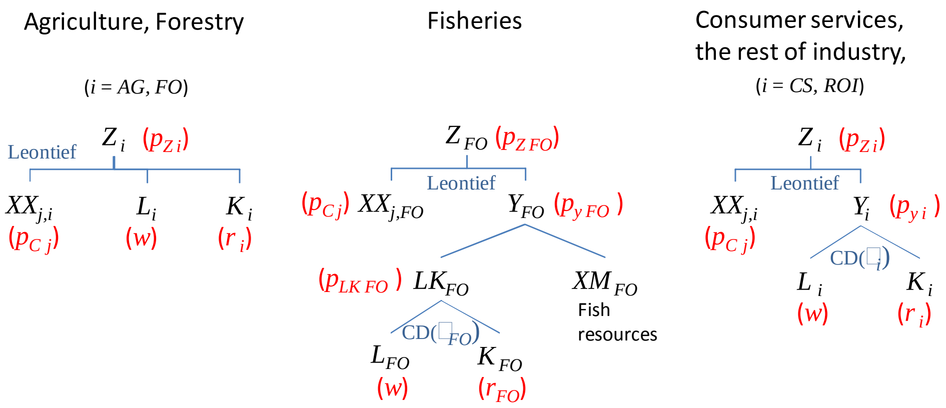

Fig.7 Production structure in the agriculture, forestry, fisheries, ROI, and CS

For market clearing conditions, the supply-demand relationship of consumer goods are described as follows.

$$Z_i = \sum_j XX_{i,j} + \sum_n xx_{i,n} + C_i + SA_i \quad (i = AG, FO, FI, CS, ROI) \tag{21}$$

where SA_i is the saving for sector i and is allocated at the constant ratio of total saving, which is determined by the Cobb-Douglas function : $SA_i = p_{SAV}(\gamma_{SA,i}/p_{c,i})SAV$.

The forest conservation area supplied by the forest conservation sector is assumed to be not consumption goods but accumulation goods or stocks without depletion. Then, forest conservation is demanded by the households but by industrial sectors. The supply amount of forest conservation is equal to its demand as the saving or investment.

$$\sum_n ra_n = SA_{RA} \tag{22}$$

The supply amounts of the biodiversity increment and ES attached to the forest conservation and these are equal to the household demands dH and dES, respectively.

$$\sum_n dh_n = dH \tag{23}$$

$$\sum_n des_n = dES \tag{24}$$

For the production factor, the market-clearing condition of labor and capital are described as follows.

$$\sum_i L_i + \sum_n L_{RA\,n} = \overline{L} \tag{25}$$

$$\sum_i K_i^n + \sum_n K_{RA\,n}^n = SAV \tag{26}$$

where $\overline{L}$ is the endowment of labor. The new capital must be determined under the condition that the demand of sectoral capital K_i^d is equal to the sum of vintage capital and new capital.

$$K_i^v + K_i^n = K_i^d \tag{27}$$

The households are endowed with primary factors of labor and capital. Their income *M* consists of the factor payments and rents on the capacity of forest conservation technology.

$$M = w\overline{L} + \sum_i \left(r_i K_i^v + r_k^n K_i^n\right) + \sum_n \left(r_n K_n^v + r_n^n K_n^n\right) + \sum_n \mu_n \ ra_n \tag{28}$$

Then, the households maximize their utility *U* subject to the income.

$$M = p_U U \tag{29}$$

3. Problem setting

3.1 Scenario analysis

This study examines the general equilibrium effects of the biodiversity and ES enhanced by the forest conservation and then clarifies the condition required to gain the better welfare and agricultural market in the light of the productivity and technological regulation in the forest conservation.

Thus, suppose the economy with payments for non-use goods of the existence of species, or biodiversity, and ES, which is a counterfactual economy in the sense that the households don't pay for those goods in the existing economy. As shown in Table 2, this study defines four scenarios with respect to the forest conservation development and two active technologies and one inactive technology in the sector.

BAU treats the forest conservation sector (RA) as a single goods producer of the forest conservation. Namely, the producer's price is equal to the price of forest conservation. For BU technologies, the sector accumulates capital so that the lowest cost technology can penetrate. Then, the technologies conserve the forest at a constant productivity, i.e. no technological progress.

Case 1 represents that the sector produces the composite goods of the area of conserved forests, biodiversity, and ES, and receives compensation as the price including surcharges of biodiversity and ES. The assumption of the technological penetration and productivity is the same as BAU.

Next, case 2 and case 3 are the same as case 1 in the sense that the sector produces the composite goods. However, the cases consider technological progress, i.e., the improvement of productivity. The maximum improvement rate of productivity is assumed as 10% in case 2 and 20% in case 3. In addition, both the cases regulate penetration of the existing technology up to the present level, by which a new environmental friendly but more costly technology denoted by $n = 3$ penetrates.

Table 2 Scenario definition

Considerations	Household utility includes biodiversity and ES	Impose surcharge of payments of biodiversity and ES for forest conservation (p_h, p_{es})	The forest conservation sector	
			Regulate conventional technology penetration	Technological level (productivity)
BAU	Yes	No, $p^* = p_{z,RA}$	No	The same as the present level
Case 1		YES, $p^* = p_{z,RA} + k_h p_h + k_{es} p_{es}$	No	
Case 2			Yes, the present capacity at a maximum	Improve up to 10%
Case 3				Improve up to 20%

3.2 The economy

3.2.1 Input-output tables

Suppose a small regional economy in the continent HICs. The economy consists of the representative households of one million populations, and six industrial sectors mentioned above. The initial input-output (IO) tables are set according to the following assumptions (Table 3).

The 2005 Kyoto prefectural IO tables in Japan are simplified. The IO tables are consistent with the Kyoto IO tables in terms of the sectoral composition ratio of IO and the household demands. Table 3 indicates that the GDP per capita amounts to four million JPY (or 33333 USD in the case that the foreign exchange 120 JPY/USD), which means that the economy is classified as a region in HICs. However, the forest conservation sector is not found in the Kyoto IO tables. Thus, this study assumes that the sector initially conserves a 10 % of the degraded forest land area, i.e. 500 ha, by use of two separate technologies (n = 1, 2 in Table 4). The technology denoted by n = 3 is initially inactive because the production unit cost exceeds the initial market price of forest conservation and the rent is negative value.

Table 3 Input-output tables in unit of 10,000 JPY

	Agriculture	Forestry	Fisheries	Rest of industry	Consumer services	Forest conservation	Comsumption	Fixed capital formation	Value of production
Agriculture	1,000,000	2,000	0	2,988,000	1,000,000	0	2,000,000	10,000	7,000,000
Forestry	1,000	40,000	0	508,000	50,000	3,000	100,000	200,000	902,000
Fisheries	0	0	5,000	194,700	200,000	0	200,000	300	600,000
Rest of industry	1,996,000	259,700	244,500	106,927,800	20,000,000	20,000	142,000,000	70,000,000	341,448,000
Consumer services	3,000	300	500	18,996,200	1,000,000	0	30,000,000	0	50,000,000
Forest conservation	0	0	0	0	0	0	0	50,000	50,000
Labor	3,000,000	570,000	300,000	61,833,300	22,750,000	12,000			
Capital wastage	1,000,000	30,000	50,000	150,000,000	5,000,000	9,000			
Rent for specific technology	0	0	0	0	0	6,000			
Value of production	7,000,000	902,000	600,000	341,448,000	50,000,000	50,000			

Table 4 Cost structure of active and inactive technologies in the forest conservation

Technology n		1	2	3	Total of
Technological status		active	active	inactive	active technologies
Agriculture		0	0	0	0
Forestry		1,000	2,000	10	3,000
Fisheries		0	0	0	0
Rest of industry		15,000	5,000	40	20,000
Consumer services		0	0	0	0
Labor		8,000	4,000	35	12,000
Capital wastage		6,000	3,000	20	9,000
Rent for specific technology		6,000	0	-5	6,000
Total cost		36,000	14,000	N/A	50,000
Conserved area	(ha)	360	140	1	500
Initial price of forest conservation	(10,000JPY/ha)	100	100	100	100
Marginal cost by technology	(10,000JPY/ha)	83.3	100	105	N/A

Note: For inactive technology, this study accounts for the costs per one hectare forest conservation.

3.2.2 Forest conservation, biodiversity, and ES

The forest conservation sector conserves the degraded forest area, by which the biodiversity of bird species and ES increase. Consider also the carbon dioxide absorption by forests as one of ES. The analysis needs not only the price of forest conservation, biodiversity, and ES, but also the coefficients of incremental relationships between the conserved forest area and bird diversity and between the conserved forest area and ES; k_h in Eq. (8) and k_{es} in Eq. (9).

The initial price of forest conservation is assumed as one million (JPY/ha), according to the fact that the Kyoto prefecture estimates a standard price for reforestation of Japanese cypress and cedar (afforestation of 2500 to 3000 trees per one hectare) as 958,000 (JPY/ha) in 2014.

Suppose the economy has a forest area of 14000 ha, half of which is artificial forest (the remaining half is natural forest). Initially, the degraded forest amounts to 64.2 % of the artificial forest. In this case, the initial healthy forest area of 9504 ha provides the biodiversity of 400 bird species. The number of species is calculated from the SPARs model, Eq. (1), in which ln$c$ = 5.923 and z = 0.03 in HICs. The result of the model identification is described in the section 4.1. In this case, the coefficient k_h of Eq. (8) is calculated as 1.26 (species/kha).

The other coefficient k_{es} is assumed as 4.11 (kt-CO_2/kha). By the way, the Ministry of Agriculture, Forestry and Fisheries, Japan (2000) estimates annual carbon dioxide absorption by forests as 97533 (kt-CO_2) and national forest area as 25080 (kha). Therefore, the value of k_{es} used in this study is approximately close to a value of 3.89 (kt-CO_2/kha) calculated by use of these estimates.

The initial price of biodiversity conservation p_h is set as 50 million (JPY/species) from the assumption that annual willingness to pay (WTP) for one species conservation is 50 (JPY) per one person. It is suggested that WTP for animal species is 0 (JPY) in ordinary species, 72 (JPY) in rare species (the Ministry of the Environment Japan, 2014).

The initial price of carbon dioxide absorption by forests p_{es} is set as 10 million (JPY/kt-CO_2). Due to lack of the survey information about WTP for carbon dioxide absorption by forests, the price is assumed based on the 2012 June-2014 October prices of the carbon dioxide emissions trading in Tokyo, Japan; 5000-12000 (JPY/t-CO_2) or 5-12 million (JPY/kt-CO_2).

3.3 Welfare

To examine general equilibrium effect of biodiversity and ES, this study compares the welfare by scenario. Thus, consider the Hicksian equivalent variations (EV) with respect to the household consumption and biodiversity. The corresponding EV can be defined as EV_{CH} for the top-level composite goods for consumptions CH which have the substitute relationship between CSA (the composite of all consumption and service goods) and dH (the increment of biodiversity) in Fig. 4. The EV can be written as follows.

$$EV_{CH} = \left(p_{CSA}^{(t=0)} C\hat{S}A^{(t=1)} + p_h^{(t=0)} d\hat{H}^{(t=1)}\right) - \left(p_{CSA}^{(t=0)} CSA^{(t=0)} + p_h^{(t=0)} dH^{(t=0)}\right) \tag{30}$$

where $$\left(d\hat{H}^{(t=1)} \quad dC\hat{S}A^{(t=1)}\right) = k_{EV}\left(\left(\alpha_h / p_h^{(t=0)}\right)^{\sigma CH} \quad \left(\alpha_{CSA} / p_{CSA}^{(t=0)}\right)^{\sigma CH}\right), \tag{31}$$

and $$k_{EV} = p_{CH}^{(t=0)}\left(\alpha_{CSA}{}^{\sigma CH}\, p_{CSA}^{(t=0)1-\sigma CH} + \alpha_h{}^{\sigma CH}\, p_h^{(t=0)1-\sigma CH}\right)^{-1} CH^{(t=1)} \tag{32}$$

4. Results

4.1 SPARs model

The result of OLS regression for SPARs of Eq. (5) is shown in Table 5. From the t-statistics, explaining variables except for the variable $\gamma_5 D_{is}$ are significant because their p-values of 0.000 are less than 0.05. Since t-value of the variable $\gamma_5 D_{is}$ is 1.739, the corresponding coefficient is not significantly different from 0 (its p-value is 0.084, which is larger than 0.05). The adjusted R^2 is 0.734, which indicates that the identified model describes the bird SRARs well (see also Fig. 8). As a result, the SPARs are significantly influenced by not only geographical conditions either the country is island or continent but also GDP per capita.

The identified model indicates as follows. The number of species conserved by forest conservation is significantly different between HICs and LICs. The c-value is larger in HICs than in LICs because γ_2 has a positive value. In addition, a slope between species numbers and forest areas, i.e. the z-value is smaller in HICs than in LICs because γ_3 has a negative value. Thus it is suggested that HICs has a larger number of bird species even in small forests area. However, HICs need to a more forest area when one species is conserved. Furthermore, since the coefficient ln γ_4 has a negative value, continental countries (CCs) is richer in bird species when island countries (ICs) and CCs have the same forest area.

Table 5 SPARs regression result

Variables	Coefficients		Std. errors	*t*-statistics	VIF
(Constant)	ln $\square_0$	4.559	0.123	37.188 ***	
ln *A*	$\square_1$	0.212	0.014	15.015 ***	2.153
D_{hi}	ln $\square_2$	1.364	0.161	8.495 ***	5.757
D_{hi} ln *A*	$\square_3$	-0.182	0.021	-8.730 ***	5.942
D_{is}	ln $\square_4$	-0.327	0.078	-4.173 ***	1.463
Adjusted R square			0.734		
Durbin-Watson			2.070		
F-statistic			110.627 ***		

Notes: *** denotes significant with 1% level. This table excludes the variable *Dis*ln*A*, whose coefficient is not significantly different from 0 because its *p*-value is 0.084 (*t*-value = 1.739) and is larger than 0.05.

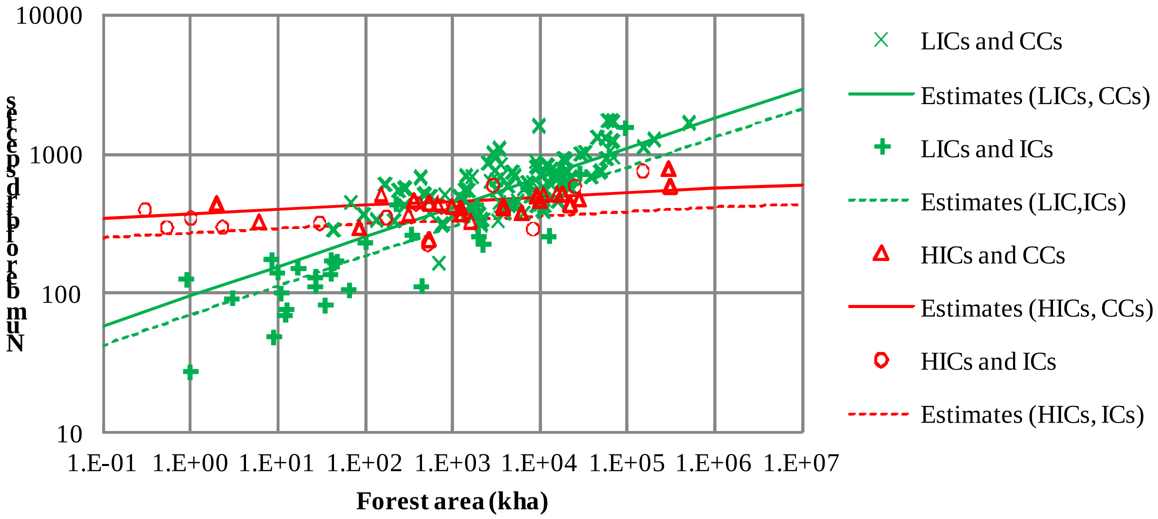

Fig. 8 Comparison of observed values and regression estimates

4.2 Stability of TD-BU calculation

This study confirmed that the iterative calculation scheme (Böhringer and Rutherford, 2006) works well to obtain the general equilibrium state. Fig 9 shows the example of search process to obtain new equilibrium state for the forest conservation in case 3. The elasticity of the inverse demand function was assumed as 0.5. Fig. 9(a) shows that the search path starts from initial equilibrium point E_0, and the zigzags but gradually disappears the variation toward the new equilibrium point E_1. Fig. 9(b) shows that we need to repeat the iterative TD-BU calculation ten times when the tolerance for numerical convergence is 0.0001.

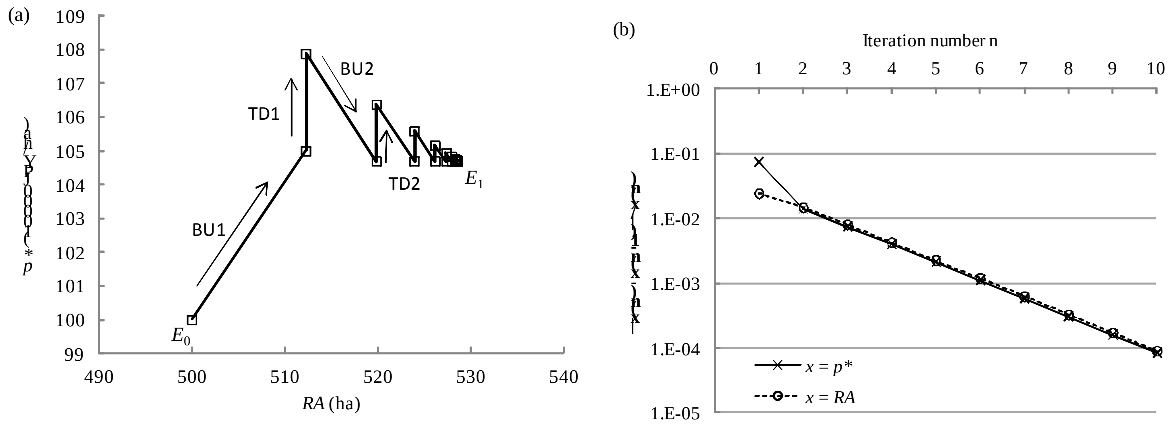

Fig.9 Numerical behavior during TD-BU calculation in case 3: (a) Search path for new equilibrium point; (b) Variability rate of variables solved from TD-BU model

4.3 Scenario comparison

4.3.1 Welfare

A maximum EV is observed in case 3; the payments of biodiversity of ES are added to the payment of the forest conservation and the productivity is improved in proportion to the increase of conservation area (EV_{CH} in Table 6). EV of case 3 exceeds the one of BAU. However, EV becomes smaller in case 1 and case 2 than in BAU. Case 1 shows the largest reduction in EV. Then, the case 2 shows a sign of recovery of EV.

4.3.2 Forest conservation

In BAU, the total area of conserved forest increases slightly from the initial 500 ha to 501.47 ha (*RA* in Table 6), which corresponds to 0.295 % increase in the forest production (Z_{RA} in Table 7).

Table 6 Equivalent variations and technological forest conservation

Variables		Unit	BAU	Case 1	Case 2	Case 3
EV_{CH}		JPY	692947	690801	692099	693355
		%		(-0.310)	(-0.122)	(0.059)
$RA = \mathrm{T}ra_n$		ha	501.47	528.58	528.59	528.60
		%		(5.406)	(5.407)	(5.409)
ra_n	$n = 1$	ha	389.47	360.00	360.00	360.00
	$n = 2$	ha	112.00	140.00	140.00	140.00
	$n = 3$	ha	0.00	28.58	28.59	28.60
zz_n-ra_n productivity: $\exp(Tdh_n + \mathrm{T}Tdes_n)$	$n = 1$	N/A	1.000	1.000	0.900	0.806
			[0.00]	[0.00]	[10.01]	[19.43]
	$n = 2$	N/A	1.000	1.000	0.960	0.919
			[0.00]	[0.00]	[4.02]	[8.06]
	$n = 3$	N/A	1.000	1.000	0.992	0.983
			[0.00]	[0.00]	[0.83]	[1.70]

Note: Numeric in parenthesis () denotes the increment rate from BAU value. Numeric in parenthesis [ ] denotes the improvement rate from productivity in BAU.

Table 7 Change of activity and price variables

		Unit	BAU	Case 1	Case 2	Case 3
Activity variables	dH	%	0.2950	5.7165	5.7181	5.7199
	dES	%	0.2950	5.7165	5.7181	5.7199
	Z_{AG}	%	0.2799	0.2787	0.2801	0.2816
	Z_{FO}	%	0.2485	0.3180	0.3190	0.3203
	Z_{FI}	%	0.2275	0.2268	0.2283	0.2299
	Z_{CS}	%	0.2148	0.2132	0.2148	0.2165
	Z_{ROI}	%	0.4363	0.4355	0.4360	0.4365
	Z_{RA}	%	0.2950	5.7165	5.7181	5.7199
Price variables	p^*	%	-0.2941	4.7049	4.7033	4.7016
	$p_{z,RA}$	%	-0.2941	-5.4074	-5.4089	-5.4104
	p_h	%	-0.0035	-0.0293	-0.0293	-0.0294
	p_{es}	%	-0.0035	-0.0293	-0.0293	-0.0294
	$p_{z,AG}$	%	-0.2364	-0.2362	-0.2378	-0.2396
	$p_{z,FO}$	%	-0.1324	-0.1321	-0.1338	-0.1357
	$p_{z,FI}$	%	-0.2166	-0.2162	-0.2177	-0.2194
	$p_{z,CS}$	%	-0.2353	-0.2336	-0.2351	-0.2368
	$p_{z,ROI}$	%	-0.4325	-0.4314	-0.4320	-0.4325

Note: p^* is defined as $p_{z,RA} + k_h p_{z,h} + k_{es} p_{z,es}$. However, p^* in BAU excludes the terms of p_h and p_{es}.

On the other hand, cases 1-3 show a significant increase of the conservation area, whose increase rates amount to 5.718-5.720 %. Additionally, the price of the forest conservation p^*

increases significantly in the cases 1-3, which is shown as a jump-up from -0.294 % in BAU to 4.705 % in case 1 (Table 7). However, the price of forest conservation $p_{z,\ RA}$ rather decreases as the conservation area increases (percent changes of the price are -0.294 % in BAU and -5.407 % in case 1). The facts indicate that adding the payments of the biodiversity and ES to the payment of forest conservation enhances to increase environmental-friendly goods as the conserved forests, biodiversity, and ES.

Moreover, we can see from ra_n in Table 6 that cases 1-3 regulate the production by the conventional technology (denoted by n = 1, 2) and a costly new technology (n = 3) penetrates for the forest conservation. The penetration of the new technology increases slightly in association with the improvement of productivity from the comparison of $\exp(\alpha dh_n + \beta des_n)$ by scenario in Table 6. As a result, it is found that building the economy which enhances the forest conservation with technological progresses raises the welfare measured by EV.

4.3.3 Biodiversity and ES

From the comparison of dH and dES in Table 7, case 3 has the maximum increase of bird diversity and ES. Then, it can be said that the increments of biodiversity and ES are highly expected by adding payments of biodiversity and ES to the payment for the forest conservation. However, change rates of the increments of biodiversity and ES, dH and dES, are the same by scenario because those increments are given as a linear function of areas of the forest conservation Z_{RA}. The prices of biodiversity and ES, p_h and p_{es}, decrease in response to the increase of the biodiversity and ES supplies. However, the decreasing rates are considerably small among production prices of all industries.

4.3.4 Spillover on other industrial outputs

Case 1 in Table 7 shows that sectors of the agriculture, fisheries, consumer services, and the rest of industry decrease their outputs (Z_{AG}, Z_{FI}, Z_{CS}, and Z_{ROI}). This case corresponds to the case that the prices of the biodiversity and ES are added as surcharges to the price of the forest conservation and the forest conservation sector produces the composite goods with a constant productivity. Then, reduction rates of the corresponding prices are small.

However, the results of case 2 and case 3 indicate that the improvement of productivity in the forest conservation sector leads to the enhancement of all sectoral outputs and a further reduction in production prices (Table 7).

4.3.5 Labor and capital

In BAU, the labor share increases in the agriculture, forestry, fisheries, and consumer services, and decreases in the rest of industry and forest conservation sector (Table 8).

On the other hand, in the forest conservation sector, a decrease of the labor share is caused by the concentration of capital accumulation to a lower cost technology denoted by $n = 1$ (ra_1 in Table 9). The capital of the lowest cost technology $n = 1$ increases from 60.00 to 64.91 and the capital of higher cost technology $n = 2$ decreases from 30.00 to 24.00. As a result, the sum of capital of two technologies decreases. In fact, Table 4 shows that the labor cost share of technologies $n = 1$ and $n = 2$ are calculated as 0.22 and 0.29, respectively, which means that a lower cost technology has a lower labor cost. These are the reason why both the labor and capital decreases in the forest conservation sector regardless of the enlargement of forest conservation area.

On the other hand, the case 1 shows that the demand increase of composite goods produced by the forest conservation sector boosts the increase of production factors (the capital and labor) needed for the forest conservation. As a result, the case 1 maximizes the labor and the labor share in the forest conservation sector. Meanwhile, other sectors except for the forestry generally lead to a reduction in the labor and capital inputs.

Table 8 Sectoral composition of labor

Scenario		Initial	BAU	Case 1	Case 2	Case 3
Time period		t = 0	t = 1	t = 1	t = 1	t = 1
Sector	AG	30000.0	30084.0	30083.6	30084.1	30084.5
		(3.3912)	(3.4007)	(3.4006)	(3.4007)	(3.4007)
	FO	5700.0	5712.2	5716.2	5716.2	5716.3
		(0.6443)	(0.6457)	(0.6461)	(0.6462)	(0.6462)
	FI	3000.0	3003.9	3003.9	3003.9	3004.0
		(0.3391)	(0.3396)	(0.3396)	(0.3396)	(0.3396)
	ROI	618333.0	618027.3	618015.7	618021.1	618025.6
		(69.8955)	(69.8610)	(69.8597)	(69.8603)	(69.8608)
	CS	227500.0	227707.1	227703.6	227707.3	227711.4
		(25.7163)	(25.7397)	(25.7393)	(25.7397)	(25.7402)
	RA	120.0	118.5	130.0	120.3	111.1
		(0.0136)	(0.0134)	(0.0147)	(0.0136)	(0.0126)
All sector		884653.0	884653.0	884652.9	884652.9	884652.9
Residual error rate (%)		3.9E-14	-9.8E-10	-7.3E-06	-1.4E-05	-1.3E-05

Notes: Numeric in parenthesis ( ) denotes the component ratio in percentage %. Residual error rate is a division of residual error in the labor balance equation by the labor endowment. Absolute values of the residual errors rate satisfy the tolerance (1.0E-4) needed to obtain numerical solutions.

Table 9 Sectoral composition of capital

Scenario		Initial	BAU	Case 1	Case 2	Case 3
Time period		t = 0	t = 1	t = 1	t = 1	t = 1
Sector	AG	10000.0	10028.0	10027.9	10028.0	10028.2
		(0.6407)	(0.6384)	(0.6384)	(0.6384)	(0.6384)
	FO	300.0	302.7	302.9	302.9	302.9
		(0.0192)	(0.0193)	(0.0193)	(0.0193)	(0.0193)
	FI	500.0	504.1	504.1	504.1	504.1
		(0.0320)	(0.0321)	(0.0321)	(0.0321)	(0.0321)
	ROI	1500000.0	1509558.9	1509552.0	1509558.5	1509564.5
		(96.0990)	(96.0969)	(96.0964)	(96.0968)	(96.0972)
	CS	50000.0	50389.4	50389.4	50390.0	50390.8
		(3.2033)	(3.2077)	(3.2077)	(3.2078)	(3.2078)
	RA	90.0	88.9	95.7	88.5	81.5
		(0.0058)	(0.0057)	(0.0061)	(0.0056)	(0.0052)
	ra_1	60.00	64.91	60.00	53.99	48.34
		[66.67]	[73.01]	[62.69]	[61.04]	[59.28]
	ra_2	30.00	24.00	30.00	28.79	27.58
		[33.33]	[26.99]	[31.34]	[32.55]	[33.82]
	ra_3	0.00	0.00	5.72	5.67	5.62
		[0.00]	[0.00]	[5.97]	[6.41]	[6.90]
All sector		1560890.0	1570872.0	1570872.0	1570872.0	1570872.0
Residual error rate (%)		0	3.8E-12	7.3E-12	7.7E-12	7.3E-12

Notes: Numeric in parenthesis ( ), [ ] denotes the component ratio in percentage %. Residual error rate is a division of residual error of the capital balance equation by the capital endowment.

However, case 2 and case 3 show that, the capital and labor, and their share of the forest conservation sector reduces in response to technological progress in the forest conservation sector. Meanwhile the capital and labor of other sectors increase again. Additionally, both improving productivity and regulating outputs with the conventional technology enhance to penetrate the costly technology denoted as n = 3, which is obvious from the fact that capital share of the technology n = 3 is 5.97 % in the case 1, 6.41 % in case 2, and 6.90 % in case 3 (Table 9).

5. Discussion

This study has two major findings in terms of perceiving the bird biodiversity and ES as the composite goods produced by forest land conservation. First, the world bird SPARs can be classified into two SPARs by introducing GDP per capita of the non-OECD high income countries. The SPARs influence on the production function as well as price of the composite goods produced by the forest conservation sector. Second, adding payments for the biodiversity and ES to the payment of the forest conservation may not always lead to improvement of the economy welfare. As a measure of the welfare improvement, we need to promote technological progress to conserve forest area with the view of the biodiversity and ES.

Determining SPARs is a necessary step to examine the impact of enhancing biodiversity conservation on the economy. Generally, the species number is described as a power function of the species habitat area and z-value has a wide range (0.11-0.66) depending on geographic conditions (e.g. Preston, 1962; Rosenzweig, 1995; Gaston and Blackburn, 2000). This study confirmed this law and indicated that the bird SPARs is a function of not only the geographic conditions but also the economic condition either countries are HICs or LICs.

In fact, this study estimated z-value as 0.212 in LICs, and 0.03 in HICs. Compared with the z-value of the previous studies, we can confirm that the z-value of LICs falls in the range of previous estimates. Indeed, although HICs has a smaller z-value the HICs data are generally plotted within the distribution range clarified by Preston (1960). And from the t-statistics of this regression analysis, we believe that the z-values of both HICs and LICs are reasonable. Additionally, the geographic condition either a country is island or continent and the national income level show up in the c-value. The c-value is then estimated as 68.9 in the island LICs, 95.5 in the continental LICs, 269.3 in the island HICs, and 373.5 in the continental HICs in ascending order.

From the facts, this study suggests that HICs need to conserve a more forest area to conserve one bird species because the slope of SPARs regression line is smaller in HICs (z = 0.03) than in LICs (z=0.212). Furthermore, because of relatively large c-values, HICs or continental countries have larger bird species even as a small forest land. These considerations will be significant in the policy design how many species should be conserved by country. The forest area needed for one species conservation acts on the production cost and household burden charge, which leads to the change of production structure in a whole industry and welfare of the economy. Therefore, policy making of the biodiversity conservation should be carefully made with considerations of the economic performance as well as geographic ecology.

From the point of view of the macroecology, the expansions of afforestation enhances the bird diversity and additional ES, which suggests that the relationships affect a wide range of economic, social, and cultural aspect in the human well-being.

Indeed, the forest conservation has a potential to enhance the added value by consideration of biodiversity and ES and to create a certain positive effects in the economy when the household utility is given as a function of the non-use goods of the biodiversity and ES. This study takes the thought one step further; a further forest conservation enhances the economic welfare in the original meaning of the sustainable development. Therefore, there is a room to consider the commercialization of the biodiversity and ES as additional goods of the conserved forest stock.

Thus, this study developed a CGE model and assumed an economy in the small continental HICs which encounter a hard situation that a more forest should be conserved for bird species. The household utility function defined by Carbone and Smith (2013) is applied to consider non-use goods of the species habitat and carbon dioxide absorption which is one of the ecosystem services provided by the forest.

Additionally, this study introduced the production function which defined heterogeneous goods of the forest conservation, biodiversity, and ES as a composite goods produced by the forest conservation sector. Furthermore, this study enabled to deal with changes the productivity and technological penetration by the production function. The CGE model with TD-BU description could be stably solved by the numerical scheme proposed by Böhringer and Rutherford (2006).

The purpose of this study was to investigate whether the welfare loss is caused by the commercialization of the biodiversity and ES and to find the condition how to prevent welfare loss if so. From the comparison of EV by scenario, this study had the result that the welfare would be worse and outputs of other industries and consumption demands would decline when the prices of the biodiversity and ES are included as the surcharges in the price of the forest conservation. Then to prevent the welfare from deteriorating, it is important that the forest conservation sector develops so that the technologies can improve the productivity of the composite goods consisting of the biodiversity, ES, and the conserved forest area.

This study also elucidates that consumption demand of the agriculture and food commodities can increase or decrease by the introduction of the biodiversity and ES into the market. Analytical results show that the trend of demand of these commodities is consistent with the trend of welfare. The welfare basically increases in accordance with the increase of existing consumption goods such as agricultural foods rather than the increase of the biodiversity and ES provided by the forest conservation.

The main reason is that the enhancement of the forest conservation with the biodiversity and ES accumulates more mobile production factors and the agricultural food sector loses the mobile production factors. As a result, the economy moves toward the equilibrium state that agricultural food sector produces a reduction in the outputs. What matters is that the economy sustains that the forest conservation sector develops with high productivity technologies to prevent the excess exploitation of the production factor from existing agricultural food industries. We believe that this economic system reform contribute to the development of natural conservation industries with the progress of agricultural food industry, the demand expansion of all industries goods, and the improvement of the regional welfare.

Remaining issues are how to combine more complicated ES for PES in the real economy and the applicability of the model to empirical studies. However, we believe that the model proposed by this study opens the door for economists to assess the trade-off and synergy effects of ES in the agricultural food supply as well as the welfare.

References

Arrhenius, O. (1921). Species and area. *Journal of Ecology*, 9, 95−99.

Babiker, M.H., Reilly, J.M., Mayer, M., Eckaus, R.S., Wing, I.S., and Hyman, R.C. (2001). *The MIT emissions prediction and policy analysis (EPPA) model: Revisions, sensitivities, and comparisons of results* (Report No. 71). MIT Joint Program on the Science and Policy of Global Change.

Böhringer, C. and Rutherford, T.F. (2006), *Combining top-down and bottom-up in Energy Policy Analysis: A decomposition approach* (ZEW Discussion Paper No. 06−007). Mannheim: Center for European Economic Research. Retrieved 2006, from ftp://ftp.zew.de/pub/zew-docs/dp/dp06007.pdf

Carbone, J.C. and Smith, V.K. (2013). Valuing nature in a general equilibrium. *Journal of Environmental Economics and Management*, 66, 72−89.

Environmental Bureau of the Tokyo Metropolitan Government. *Survey results of emissions trading: the outcome of assessment of trading price* (in Japanese). Retrieved Sep 21, 2014, from http://www.kankyo.metro.tokyo.jp/climate/large_scale/cap_and_trade/trade.html#ka-kakusatei

Food and Agriculture Organization of the United Nations (FAO). *Forest area in 2012*. Retrieved Sep. 28, 2014, from http://faostat.fao.org/site/377/default.aspx#ancor

Gaston, K.J., and Blackburn, T.M. (2000). *Pattern and Process in Macroecology*. Blackwell Publishing.

Johansen, L. (1959). Substitution versus fixed production coefficient in the theory of economic growth: A synthesis. *Econometrica*, 27(2), 157−176.

Kyoto Prefecture, Japan. *The 2014 forest improvement project* (in Japanese). Retrieved Sep. 21, 2014, from http://www.pref.kyoto.jp/rinmu/13000018.html

Millennium Ecosystem Assessment (2005). *Ecosystems and human well-being: Synthesis*. Washington, DC: Island Press.

Ministry of Agriculture, Forestry and Fisheries Japan (2000). *Evaluation of multiple functions of agriculture and forest involved in the global environment and human life* (in Japanese). Retrieved Sep. 17, 2014, from http://www.maff.go.jp/j/nousin/noukan/nougyo_kinou/03_tousin.html

Ministory of the Environment Japan. *A study of comprehensive evaluation method for forestry ecosystem contributing to secondary forests initiative: Economic valuation of ecosystem services provided by the biodiversity* (in Japanese). Retrieved sep. 21, 2014, from http://www.env.go.jp/policy/kenkyu/suishin/kadai/syuryo_report/pdf/E0801-1.pdf

Porras, I., Barton, D.N., Miranda, M., and Chacón-Cascante, A. (2013). *Learning from 20 years of Payments for Ecosystem Services in Costa Rica*. International Institute for

Environment and Development, London.

Preston, F. W. (1960). Time and space and the variation of species. *Ecology*, 41(4), 612−627.

Preston, F. W. (1962). The canonical distribution of commonness and rarity: Part I. *Ecology*, 43(2), 185−215.

Ricketts, T. H., Daily, G. C., Ehrlich, P. R., and Michener, C. D. (2004). Economic value of tropical forest to coffee production. *PNAS*, 101(34), 12579−12582.

Rosenzweig, M.L. (1995). *Species diversity in space and time*. Cambridge, UK: Cambridge University Press.

Sandhu, H. S., Wratten, S. D., Cullen, R., and Case, B. (2008). The future of farming: The value of ecosystem services in conventional and organic arable land. An experimental approach. *Ecological Economics*, 64, 835−848.

Sandhu, H. S., Wratten, S. D., and Cullen, R. (2010). Organic agriculture and ecosystem services. *Environmental Science and Policy*, 13, 1−7.

The World Bank. *GDP per capita (current US$) in 2012*. Retrieved Oct. 1, 2014, from http://data.worldbank.org/indicator/NY.GDP.PCAP.CD

World Conservation Monitoring Centre (WCMC) (1994). *Biodiversity data sourcebook*. Cambridge, UK: World Convention Press. M.D. Retrieved Sep. 21, 2014, from https://archive.org/details/biodiversitydata94groo.