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Assessment of Water Environment Improvement Projects with Computable General Equilibrium Model using Geographic Information Systems

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Abstract

Recently, the physical evaluation of water environment improvement measures has been performed spatially in detail by the technological advance and the expanded database of Geographic Information System (GIS). Since it is possible to clarify the factor that affected water environment, if we perform the economic evaluation of water environment improvement measures, we can cope with the measures by extracting the target area and agent. Therefore, in this study, we built the basin economic assessment model based on the computable general equilibrium (CGE) model by adopting the GIS database, in order to evaluate economically the water environment improvement measures. The basin economic assessment model uses the input-output table that is made in six regions of the Nagara river basin and classifies the agriculture sectors in detail from the input-output table of Gifu prefecture that is classified into 184 sectors. Furthermore, we developed the integrated model of combining the basin economic assessment model with the basin environmental assessment model that is able to evaluate physically the basin environmental condition. We tried to assess some water environment improvement projects in the Nagara river basin by applying this integrated model. As the result, it evaluated spatially in detail that the agents in the down-stream region enjoyed the effect brought by the water environment improvement measures those are implemented in the

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upper-stream region. Since we qualitatively and quantitatively obtained the appropriate result through the simulation at the actual river basin, the applicability of this integrated model was checked.

Key Words: computable general equilibrium model, geographic information system, water environment, strategic environment assessment, economic evaluation

1. Introduction

Recently, the physical evaluation of water environment improvement measures has been performed spatially in detail by the technological advance and the expanded database of Geographic Information System (GIS). Since it is possible to clarify the factor that affected water environment, if we perform the economic evaluation of water environment improvement measures, we can cope with the measures by extracting the target area and agent. Therefore, in this study, we build the basin economic assessment model based on the computable general equilibrium (CGE) model by adopting the GIS database, in order to evaluate economically the water environment improvement measures. The basin economic assessment model uses the input-output table that is made in several regions of an actual river basin and classifies the agriculture sectors in detail from the input-output table of a prefecture. Furthermore, we develop the integrated model of combining the basin economic assessment model with the basin environmental assessment model that is able to evaluate physically the basin environmental condition. Figure 1 shows the outline of this integrated assessment model. We try to assess some water environment improvement projects in the Nagara river basin by applying this integrated model. We check the applicability of this integrated model through the simulation at the actual river basin.

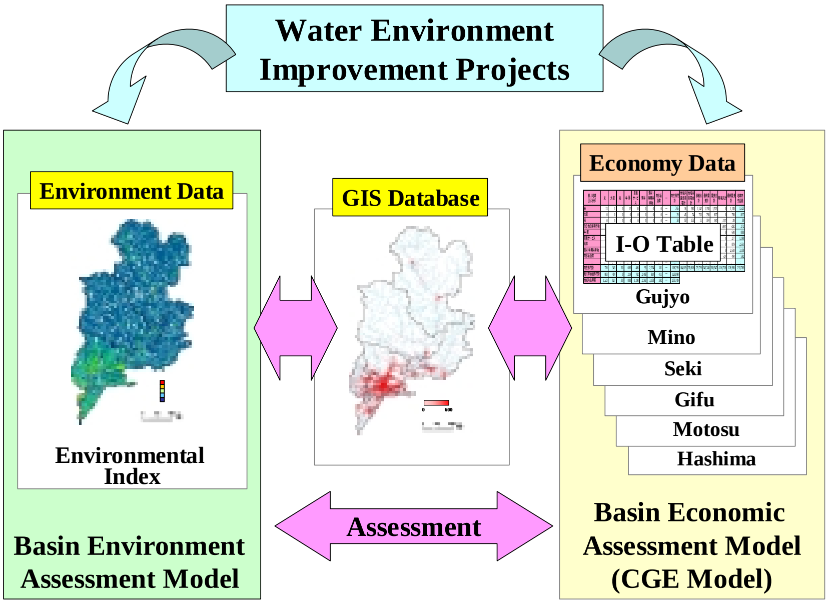


Figure 1 Outline of the Integrated Model for Assessing the Water Environment Improvement Projects

Some researches have evaluated the water environmental improvement measures with combined with physical model and economic model. For typical example, a series of research by Higano (Higano and Sawada (1996), Higano and Yoneta (1998), Mizunoya, Morioka and Higano (2001) and so on) has evaluated the water quality improvement measures of lake Kasumigaura. Jorgenson and Wilcoxen (1990) and Bergman (1991) applied the CGE model for the environmental policy evaluation. A special edition on the CGE approach compiled in the review of urban and regional development studies, in 2003.

2. Basin Environmental Assessment Model

The new index was proposed to evaluate the environmental condition in the watershed by Shinoda, et al. (2004). Since this index was defined as the statistical variance of the amount of mass flow in the runoff process, it included effects of the continuity on the mass flow/circulation system and the various human activities. As the results of the investigating the definition of the index, it has been found that spatial scales of non-point source such as cultivated lands and the runoff length where the natural purification was fully exhibited became important to the environmental assessment. Shinoda, et al. (2004). built the basin environmental assessment model as follows,

$$\Psi = \sum_{m}^{M} \left(\sum_{i}^{I} \beta_i A_i \big|_m \right) \exp\left(-\sum_{n|_m}^{N|_m} k_n x_n \right). \tag{1}$$

Where Ψ: the amount of mass arrived at the end point of watershed, x_n: the runoff length from mesh $n|_m$ to the end point of watershed (km), k: the mass transfer coefficient (1/km), m: mesh number in GIS database, M: the total number of meshes in GIS database, A_i: information of human activities, such as population, displacement from industry, produce of agriculture and the number of a cow and pigs for land use, β_i: the amount of mass discharge per unit A_i, I: the total number of information of human activities.

The environment of the Nagara river basin has been evaluated with this basin environment model. Figure 2(1) shows the land use distribution that is an input data of the model. Figure 2(2) shows the distribution of the amount of total nitrogen transfer that was estimated by the model. Figure 2(3) shows the environmental index in the Nagara river basin.

3. Basin Economic Assessment Model (Computable General Equilibrium Model)

3.1 Assumption

It assumes as follows as:

(a) Target area is Nagara river basin that is classified into six regions those economies consist of a household, firms, and government, representatively.

(b) Industry is classified into 35 sectors.

(c) The sectors of ‘Inland fisheries’ and ‘Hotel and other lodgings’ are impacted by water environment.

(d) Every agent does not select location.

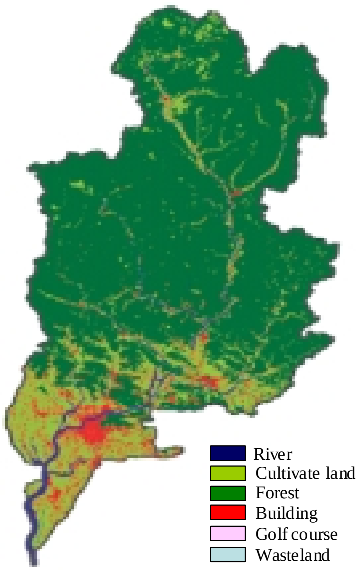


Figure 2(1) Land Use

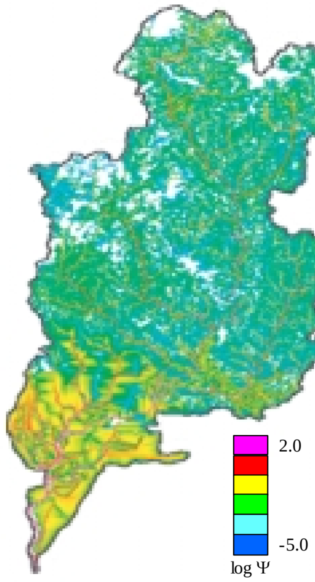


Figure 2(2) The Amount of Total Nitrogen Transfer

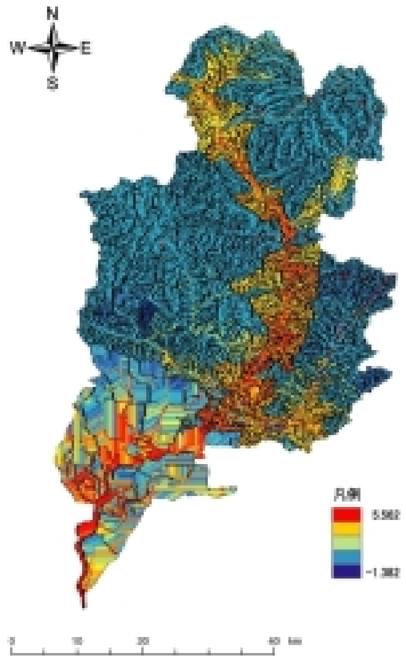


Figure 2(3) The Environmental Index

(e) The behavior of agent is same in a region.
(f) The profit of industry is equally distributed to every household.
(g) Every market of goods and services is closed.

Figure 3 shows the outline of the basin economic assessment model.

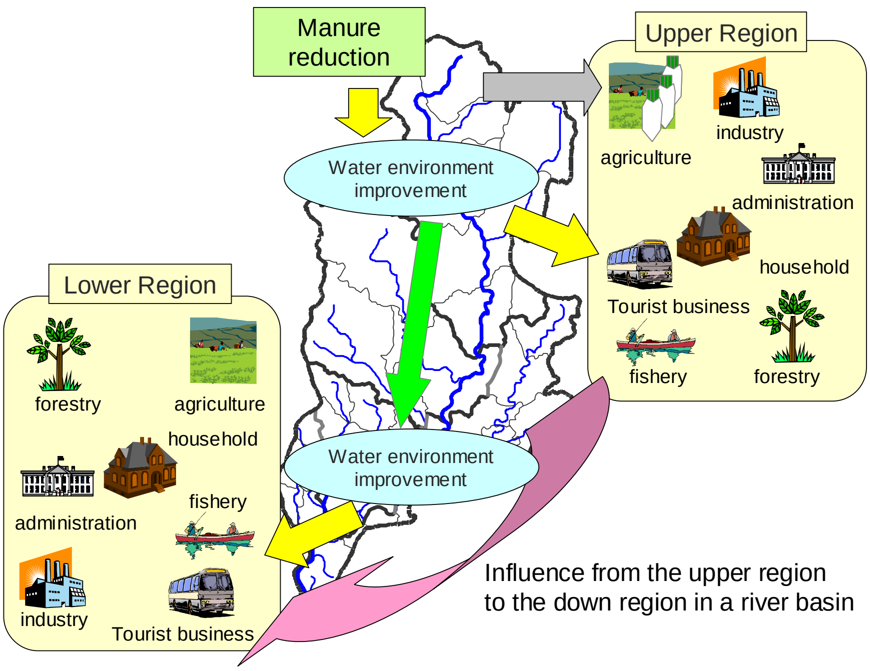


Figure 3 Outline of Basin Economic Assessment Model

3.2 Industries' behavior

Industries produce commodities/services by inputting factors and intermediate goods. Its behavior model is built by the nested structure (in Figure 4), that is, at first, industries determine on input volume of the composite factor and each intermediate goods, and next they decide on input volume of each factor.

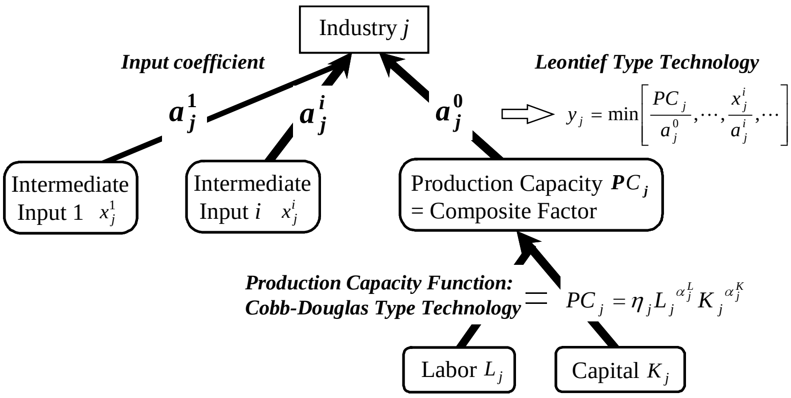


Figure 4 Outline of Industries' Behavior

At first step, the industries' behaviors inputting the composite factor and intermediate goods are formulated as minimization of production costs under Leontief type technology constraint.

$$C_j = \min_{PC_j, x_j^i} \quad c_j \cdot PC_j + \sum_i p_i x_j^i \tag{2a}$$

$$\text{s.t.} \quad y_j = \min\left[\frac{PC_j}{a_j^0}, \cdots \frac{x_j^i}{a_j^i}, \cdots\right] \tag{2b}$$

Where, PC_j : production capacity (input volume of composite factor), x_j^i : intermediate goods input volume from industry i to industry j, y_j : output volume, c_j : unit cost of composite factor, p_i : the price of commodity i, a_j^0 : production capacity rate [production capacity for the unit output], $a_j^i\ (i \neq 0)$: input coefficient in Leontief Matrix and C_j : product cost.

Solving the programming in (2), we obtain production capacity PC_j and intermediate goods input volume x_j^i, respectively.

$$PC_j = a_j^0 y_j \tag{3a}$$

$$x_j^i = a_j^i y_j \tag{3b}$$

Substitution of the (3) into the (2) gives the product cost C_j in industry j,

$$C_j = \left[a_j^0 c_j + \sum_i a_j^i p_i\right] y_j \quad . \tag{4}$$

At second step, industries decide on input volume of each factor. The behavior is formulated as minimization of the cost for input factors under Cobb-Douglass type technology constraint.

$$c_j = \min_{L_j, K_j} \quad p_L L_j + p_K K_j \tag{5a}$$

$$\text{s.t.} \quad PC_j = \eta_j L_j^{\alpha_j^L} K_j^{\alpha_j^K} = 1 \tag{5b}$$

Where, L_j, K_j: labor and capital input volume, respectively, p_L, p_K: labor wage and capital rent, respectively and $\eta_j, \alpha_{L_j}, \alpha_{K_j}$: parameters [$\alpha_{L_j} + \alpha_{K_j} = 1$].

The solution of cost minimization programming for input factors in (5) yields to the input volume of each factor demand function D_{L_j}, D_{K_j} for unit PC_j.

$$\text{Labor input:} \quad D_{L_j} = \frac{1}{\eta_j}\left[\frac{\alpha_j^L p_K}{\alpha_j^K p_L}\right]^{\alpha_j^K} \tag{6a}$$

$$\text{Capital input:} \quad D_{K_j} = \frac{1}{\eta_j}\left[\frac{\alpha_j^K p_L}{\alpha_j^L p_K}\right]^{\alpha_j^L} \tag{6b}$$

Substituting (6) into the (5), we obtain the unit cost of composite input factor c_j,

$$c_j = \frac{1}{\eta_j}\left[\left(\frac{\alpha_j^L}{\alpha_j^K}\right)^{\alpha_j^K} + \left(\frac{\alpha_j^K}{\alpha_j^L}\right)^{\alpha_j^L}\right] p_L^{\alpha_j^L} p_K^{\alpha_j^K} . \tag{7}$$

3.3 Price vector of products

The price [p_j] of commodity j is led through the zero profit condition in industry j.

The substituting (7) into (4) yields to the product costs of industry j,

$$C_j = \left[a_j^0 c_j\left(p_L, p_K\right) + \sum_i a_j^i p_i \right] y_j . \tag{8}$$

We can have the profit of industry j from (8) as below,

$$\pi_j = p_j y_j - \left[a_j^0 c_j\left(p_L, p_K\right) + \sum_i a_j^i p_i \right] y_j . \tag{9}$$

Where, π_j: profit of industry j.

The (9) is linear type for y_j, so the market equilibrium solutions exist under the zero profit condition. Its condition gives the commodity price p_j,

$$p_j = a_j^0 c_j\left(p_L, p_K\right) + \sum_i a_j^i p_i . \tag{10}$$

By arranging (10), we obtain a price vector of commodity,

$$\mathbf{p}' = \mathbf{c}' \cdot \left[\mathbf{I} - \mathbf{A}\right]^{-1} . \tag{11}$$

Where, $\mathbf{p}$: price vector of commodity, $\mathbf{c}$: product vector of composite factor unit cost by production capacity rate, $\mathbf{I}$: unit matrix, $\mathbf{A}$: input coefficient matrix and ’: transposed matrix.

3.4 Household behavior

(1) Outline of model

Household gains income by providing the input factors that consist of labor and capital, and determines the consuming volume of commodities/services so as to maximize his utility under the budget constraint. Hence the consuming behavior of the household should be illustrated in a nested structure, as shown in figure 3. This structure has been proposed by Shoven and Whalley (1992).

(2) Formulation of consuming behavior

At first stage, the household determines consumption levels of present goods H and savings C_F, and, at second stage, ones of composite goods, leisure time, and, at third stage, ones of each commodity.

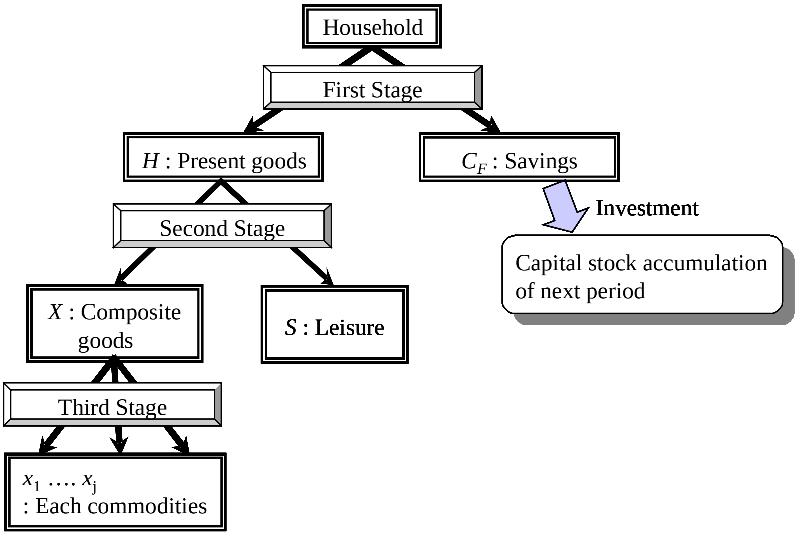


Figure 5 Outline of Household Nested Consuming Behavior

From the first stages to third one, household behaviors are formulated by general utility maximize programming as below,

$$V^l = \max_{x_j^l} \; U^l\left(x_j^l\right) \tag{12a}$$

$$\text{s.t.} \; \sum_j p_j^l x_j^l = M^l \tag{12b}$$

Where, superscript l : number of stage, superscript j : commodity or service, U^l : direct utility function, x_j^l : consuming volume of commodity/service j, p_j^l : price of commodity/service j, M^l : income, V^l : utility level.

Corresponding this utility maximization program to the nested consuming behavior shown in figure 3, the specified forms of household behavior as table 1 is obtained. The utility functions of the first, second and fourth stage, are adopted the CES type, and at the third state, it is done the Cobb-Douglas type. And the optimal solutions of those mathematical programming are also expressed in Table 1.

The endowment of time is given like this.

$$\Omega = L_S + S \tag{13}$$

Where, Ω : endowment of time, L_S : labor providing time, S : leisure time.

Substituting the optimal solutions solved in (11) into its objective function, we obtain utility level V^l. As mentioned above, time consumption is also determined by the framework of utility maximization problem.

Table 1 Formulation of household consuming behavior

	Utility maximizing program	Consuming volume of commodities
First stage ($l=1$)	$V_c^l = \max_{H,C_F}\left\{\left(\beta_H^{\frac{1}{\sigma_1}} H^{\nu_1} + \beta_C^{\frac{1}{\sigma_1}} C_F^{\nu_1}\right)^{\frac{1}{\nu_1}}\right\}$ s.t. $p_H H + p_F C_F$ $= \{p_L \Omega + p_K K_S\}(\equiv M^1)$	Present goods: $H = \frac{\beta_H M^1}{p_H^{\sigma_1} \Delta_1}$ Savings: $C_F = \frac{\beta_F M^1}{p_F^{\sigma_1} \Delta_1}$ Where, $\Delta_1 = \beta_H p_H^{(1-\sigma_1)} + \beta_C p_C^{(1-\sigma_1)}$
	p_H : present goods price, p_F : saving price, Ω : endowment of time, K : endowment of capital, M^1 : full income, β_H, β_C : Distribution parameter, σ_l : elasticity of substitution, $\nu_l := (\sigma_l - 1)/\sigma_l$, V : utility level.	
Second stage ($l=2$)	$H = \max_{X,S}\left[\gamma_X^{\frac{1}{\sigma_2}} X^{\nu_2} + \gamma_S^{\frac{1}{\sigma_2}} S^{\nu_2}\right]^{\frac{1}{\nu_2}}$ s.t. $p_X X + p_L S = M^2$	Composite goods: $X = \frac{\gamma_X M^2}{p_X^{\sigma_2} \Delta_2}$ Leisure: $S = \frac{\gamma_S M^2}{p_L^{\sigma_2} \Delta_2}$ Where, $\Delta_2 = \gamma_X p_X^{(1-\sigma_2)} + \gamma_S p_L^{(1-\sigma_2)}$
	p_X : Composite goods price, $M^2 := M^1 - p_F^* C_F^*$, γ_X, γ_S :Distribution parameters, H : Utility level gotten from consuming volume of present goods.	
Third stage ($l=3$)	$X = \max_{x_j, T_F} \prod_j x_j^{\varsigma_j}$ (j : 35 sector) s.t. $\sum_j p_j x_j = M^3$	Each commodity j : $x_j = \frac{\varsigma_j}{p_j} M^3$

$$V^l = V^l\left(p_j^l,\ M^l\right) \tag{14}$$

The commodity/service price at the l th stage is led through transforming the result of (13) and the budget constraint equation at the same stage as below.

$$p_i^l = p_j^l\left(p_j^{l-1}\right) \tag{15}$$

We show the results of solved V^l and p^l in table 2. Here, we want to emphasis that the nested utility maximizing behaviors become to be consistent by leading the relation among prices of each stage as (15).

Table 2 Specified utility level of household and commodity price

	Utility level	Commodity price
First stage ($l=1$)	$V = M^1 \cdot (\Delta_1)^{\frac{1}{\sigma_1 - 1}}$	Present goods: $p_H = (\Delta_2)^{\frac{1}{1-\sigma_2}}$
Second stage ($l=2$)	$H = M^2 \cdot (\Delta_2)^{\frac{1}{\sigma_2 - 1}}$	Composite goods: $p_X = \prod_j \left(\frac{p_j}{\varsigma_j}\right)^{\varsigma_j}$
Third stage ($l=3$)	$X = M^3 \cdot \prod_j \left(\frac{\varsigma_j}{p_j}\right)^{\varsigma_j}$	

3.5 Administration (Government) behavior

As a governmental behavior model, government service is offered by government consumption. When the expenditure rate to the goods of this government consumption is set constant, the consumption of governmental goods is as follows.

$$x_j^G = \frac{\zeta_j}{p_j}. \tag{16}$$

Where, x_j^G : volume of government consumption, ς_j : expenditure share of government consumption,

3.6 Treatment of export and import of region

This model treats endogenously the amount of import that is in proportion to the amount of regional endogenous demand. The amount of export is fixed. The regional endogenous demand consists of the intermediate demand and the final demand. The amount of import is calculated by multiplying the amount of regional endogenous demand by the import coefficient.

$$\mathbf{M} = \overline{\mathbf{m}}\,[\mathbf{A}\,\mathbf{y} + \mathbf{x}] \tag{17}$$

Where, $\mathbf{M}$: vector of the amount of import, $\overline{\mathbf{m}}$: diagonal matrix of import coefficient, $\mathbf{y}$: vector of amount of import production, $\mathbf{A}$: matrix of intermediate input coefficient, $\mathbf{x}$: vector of endogenous final demand, Regional final demand consists of household consumption x_j and government consumption x_j^G. Table 1 and government consumption are called by household consumption from a formula (17).

3.7 Market equilibrium conditions

This model has the commodity market and the production factor market in each region. The commodity market is expressed as equilibrium condition what deducted the amount of import from the total amount of intermediate commodity demand, the amount of regional final demand, and the amount of export becomes equal to the amount of commodity production. Since the amount of import is endogenous, the equilibrium condition of commodity market is given as follows.

$$\text{Commodity market: } \mathbf{y} = [\mathbf{A}\,\mathbf{y} + \mathbf{x}] + \mathbf{E} - \overline{\mathbf{m}}\,[\mathbf{A}\,\mathbf{y} + \mathbf{x}] \tag{18}$$

Where, $\mathbf{E}$: vector of the amount of export.

The (18) can arrange the following formula by the vector of the amount of production. This is the equilibrium condition of commodity market.

$$\text{Commodity market: } \mathbf{y} = [\,\mathbf{I} - (\mathbf{I} - \overline{\mathbf{m}})\mathbf{A}\,]^{-1}\,[(\mathbf{I} - \overline{\mathbf{m}})\mathbf{x} + \mathbf{E}\,] \tag{19}$$

The equilibrium conditions concerning market of production factor are directly represented by the following formulas that demand and supply of production factor is balance.

$$\text{Labor market: } \sum_j L_j = L_S \tag{20a}$$

$$\text{Capital market: } \sum_j K_j = K_S. \tag{20b}$$

Where, L_j, K_j: the demand of labor and capital at industry j, L_S, K_S: supply of labor and endowment of capital.

L_j, K_j are represented as follows as:

$$L_j = a_j^0 y_j D_{L_j} \tag{21a}$$

$$K_j = a_j^0 y_j D_{K_j} . \tag{21b}$$

The labor supply L_S is obtained by subtracting the leisure time from the endowment of time as follows as:

$$L_S = \Omega - S \tag{22}$$

3.8 Assessment of the impact to the market by environmental improvement measure

The industries' sector that is influenced by water environment, is impacted by environmental improvement measure. This model assumes that the production efficiency parameter, η is influenced by the change of the environmental index brought by the environmental improvement. In this study, we assume that the relation between the production efficiency parameter, η in the sector of 'Inland fisheries' and 'Hotel and other lodgings' and the environmental index is shown as the following formula.

$$\eta^A = \alpha \exp(Q^A) + 0.8\eta^B \tag{23}$$

Where, superscript A, B: with or without project (A: with, B: without), α: parameter, η: production efficiency parameter.

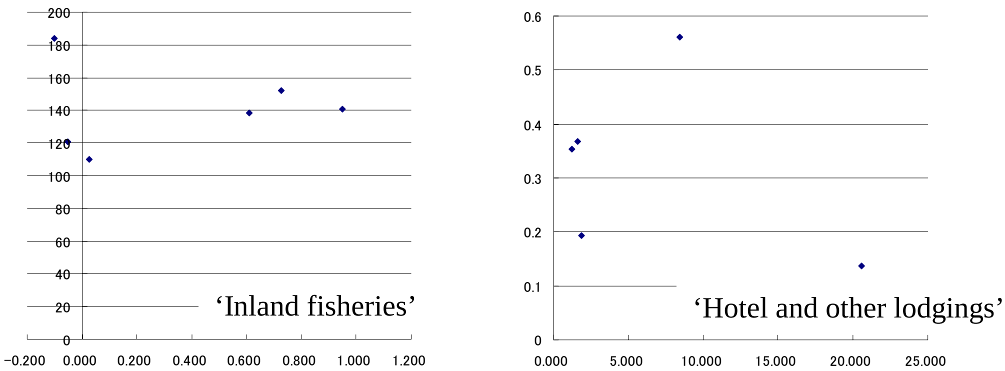


Figure 6 Relations between Production Efficiency Parameter, η and Environmental Index

3.9 Definition of market benefit

The impact to the market is assessed by the change of a household utility with the equivalent variation (EV). The EV is defined by using the utility level at the first-step consumption. Therefore, the EV is represented as follow as:

$$V\left(p_H^B, p_C^B, M^{1^B} + EV\right) = V\left(p_H^A, p_C^A, M^{1^A}\right) \tag{24}$$

Since V is represented the specific formula in Table 2, EV is finally represented as follows as:

$$EV = \frac{\left(\Delta_1^A\right)^{\frac{1}{\sigma_1 - 1}} M^{1^A} - \left(\Delta_1^B\right)^{\frac{1}{\sigma_1 - 1}} M^{1^B}}{\left(\Delta_1^B\right)^{\frac{1}{\sigma_1 - 1}}} \tag{25}$$

The mesh distribution of market benefit is obtained by multiplying the formula (25) by the number of households in each mesh as the following.

$$EV^m = N^m EV \tag{26}$$

Where, superscript m : mesh number, N^m : the number of households in a mesh.

3.10 Definition of environmental improvement benefit

Since this model needs to evaluate economically the environmental index estimated from the basin environment assessment model, we have to know the willingness to pay the environmental index. However, since we will investigate it next year, we assume the formula (27). The environmental improvement benefit is estimated by the formula (28) with the equivalent variation (EV).

$$V_e^m = -0.03\,Q^m \tag{27}$$

$$V_e^{mB}\left(Q^{mB}, M^B\right) = V_e^{mA}\left(Q^{mA}, M^A + B_e^A\right) \tag{28}$$

Where, V_e: the utility level concerning the environment, Q: the environmental index, B_e: environmental improvement benefit, 0.03: the tentative coefficient of expressing the preference to the environmental index. The household utility level is expressed with the sum of utility level of consumption and environment.

$$V^m = V_c^m + V_e^m \tag{29}$$

$$B^m = EV^m + B_e^m \tag{30}$$

4. Regional Input-Output Table

4.1 Concept of making the regional input-output table

In order to evaluate economically the environment in the Nagara river basin, we make the regional input-output tables in each region based on Non-Survey method (Ishikawa, 2001,2003). At first, we make the 35 sectors input-output table of Gifu Prefecture from the 184 sectors input-output table of Gifu Prefecture. Next, we make regional input-output table in each region where are Gujyo, Mino, Seki, Gifu, Motosu and Hashima (in Figure 7).

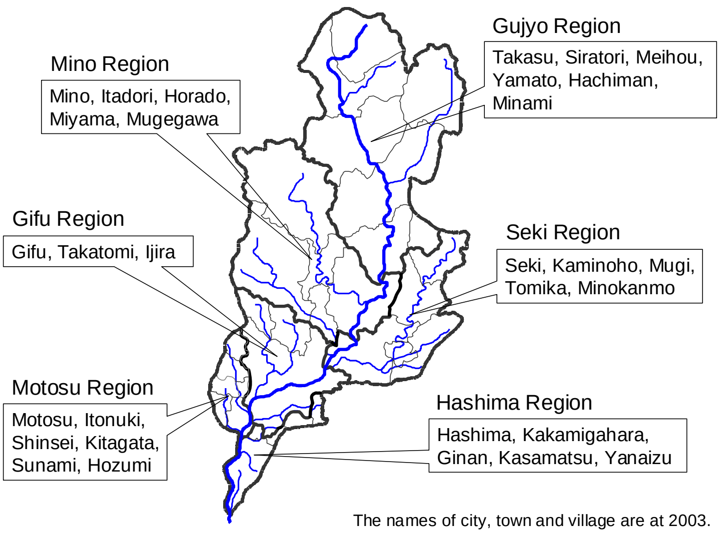


Figure 7 Regional Division of the Nagara River Basin

4.2 Division of Sector

Since it is necessary to economically evaluate the measure for the target sector, industry is reclassified as follows.

(1) Subdivision of the agriculture and forestry and fisheries section those receive the impact to the environmental improvement measures directly

(2) Extraction of the sector those are influenced by water environment.

(3) Integration of the sector those are not influenced so much by the environmental improvement measures.

Table 3 Division of Sector

1	Rice	19	Pulp, paper and wooden products
2	Other grain	20	Chemical and allied products
3	Radish	21	Petroleum and coal products
4	Other vegetables	22	Ceramic,stone and clay products
5	Persimmon	23	Metal products
6	Other fruits	24	Machinery products
7	Other crops	25	Other industrial products
8	Stockbreeding of cow and pig	26	Construction
9	Other stockbreeding	27	Electric power, gass and heat supply
10	Sericulture	28	Water supply
11	Agricultural service	29	Waste disposal
12	Afforestation	30	Commerce
13	Wood and mushroom	31	Fainance, Insurance, Real estate
14	Sea fisheries	32	Transport
15	Inland fisheries	33	Service
16	Mining	34	Hotel and other lodgings
17	Food and beverages	35	Other
18	Textile products		

4.3 Regional Input-Output Table

Table 4 and Figure 8 show the comparison with the regional sharing in each sector those are read in each regional input-output table.

5. Assessing the Water Environment Improvement Project

5.1 Date Set

The data set of the Nagara river basin for assessing the water environment improvement projects is created as follows.

(1) Regional input-output table

The regional input-output tables in each region of the Nagara river basin are used.

(2) Mesh distribution data of the number of households

The mesh distribution data of the number of households that is shown in Figure 9, uses the minimum mesh size (500m) of census in 2000.

(3) Mesh distribution data of the environmental index

The mesh distribution data of environmental index in the Nagara river basin that is estimated by the basin environment assessment model are used (in Figure 2(3)). This data is 100m mesh data.

Table 4 The Comparison with Regional Sharing in Each Sector

	Region						Gifu Prefecture
	Gujyo	Mino	Seki	Gifu	Motosu	Hashima	
Rice	1,692	524	1,980	2,388	1,752	1,923	32,519
Other grain	232	0	385	187	400	0	16,255
Radish	928	46	901	593	30	152	2,698
Other vegetables	580	374	218	3,501	1,780	2,778	35,275
Persimmon	0	11	105	413	1,339	63	2,797
Other fruits	91	76	1,175	371	391	87	6,076
Other crops	269	268	529	1,402	2,737	804	13,848
Stockbreeding of cow and pig	985	132	1,462	902	147	988	13,831
Other stockbreeding	607	410	3,073	4,825	856	1,306	28,502
Sericulture	0	0	150	0	0	0	159
Agricultural service	1,198	349	1,198	1,406	1,054	673	20,845
Afforestation	2,561	1,087	465	616	75	0	18,090
Wood and mushroom	3,143	759	659	369	106	12	30,285
Sea fisheries	0	0	0	0	0	0	0
Inland fisheries	592	1,372	5	346	2	0	7,379
Mining	2,172	2,438	2,438	4,874	1,025	8,347	91,890
Food and beverages	3,805	3,673	15,300	53,856	16,700	62,256	357,527
Textile products	18,970	18,327	102,283	184,157	75,088	186,443	1,062,955
Pulp, paper and wooden products	0	16,828	7,295	18,234	9,582	4,522	278,498
Chemical and allied products	0	0	5,576	12,647	0	2,171	211,774
Petroleum and coal products	0	0	0	0	0	1,233	9,787
Ceramic,stone and clay products	5,164	6,150	18,664	7,431	31,487	24,835	544,912
Metal products	13,026	15,919	138,627	43,524	20,096	45,800	553,995
Machinery products	16,346	72,333	396,920	32,023	19,378	232,163	1,685,685
Other industrial products	5,995	27,064	52,046	63,174	12,301	65,687	556,861
Construction	26,755	40,192	143,453	286,908	64,779	209,859	1,567,629
Electric power, gass and heat supply	4,500	6,073	16,629	40,490	13,182	26,707	240,802
Water supply	602	836	2,431	5,658	1,724	3,830	33,037
Waste disposal	934	749	2,902	11,606	2,137	7,108	50,789
Commerce	13,154	6,888	50,617	428,538	29,517	164,755	1,087,588
Fainance, Insurance, Real estate	21,674	10,983	86,717	552,160	47,171	117,399	1,454,052
Transport	7,025	6,278	22,295	80,002	31,806	90,589	467,149
Service	71,554	44,229	172,867	788,959	105,527	313,617	2,892,534
Hotel and other lodgings	5,888	1,274	1,536	11,010	5	2,841	93,601
Other	1,952	2,403	10,523	22,298	4,150	13,315	113,583
Gross regional product	232,394	288,045	1,261,424	2,664,868	496,324	1,592,263	13,583,207

(million yen)

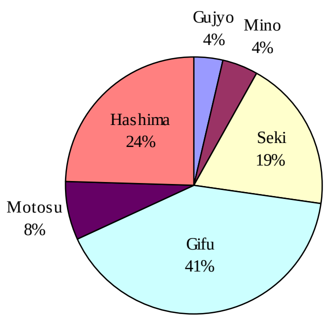


Figure 8(1) Gross Regional Product

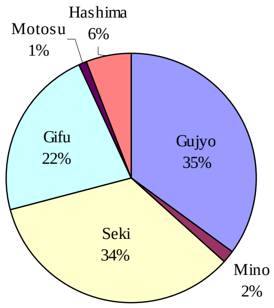


Figure 8(2) ‘Radish’

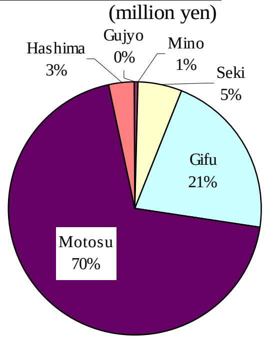


Figure 8(3) ‘Persimmon’

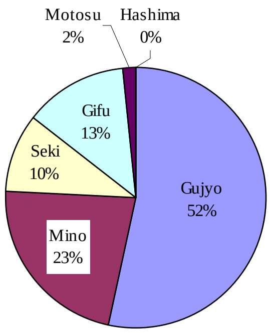


Figure 8(4) ‘Forestry’

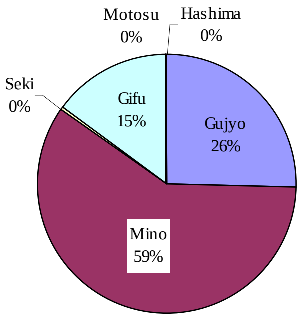


Figure 8(5) ‘Inland Fisheries’

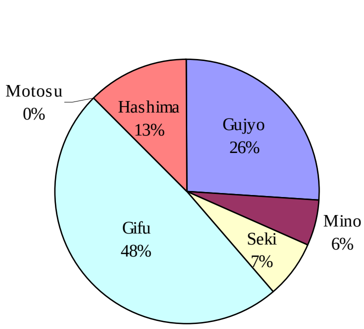


Figure 8(6) ‘Hotel and Other Lodges’

Since the mesh distribution of the number of households that used in the basin economic assessment model, is 500m mesh data, it is used by changing to 500m mesh data from 100m mesh data. The environmental index of the present environmental condition that is changed into 500m mesh data, is shown in Figure 10. This figure can combine between the environmental assessment and the economic assessment.

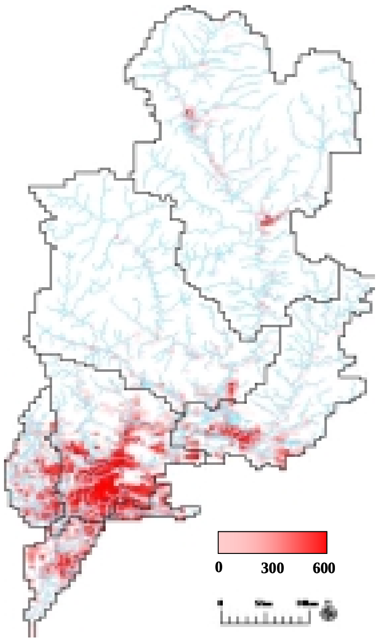


Figure.9 The Number of Households Distribution

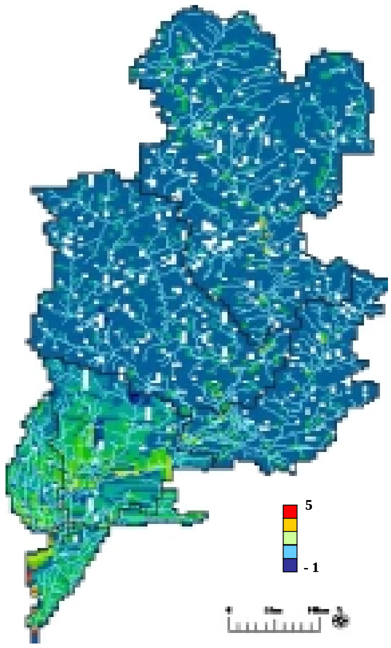


Figure 10 The Environmental Index Distribution (500m mesh)

Table 5 The number of meshes and households in each region

Region	Gujyo	Mino	Seki	Gifu	Motosu	Hashima
The number of meshes	2,935	2,078	1,021	971	317	336
The number of households	13,547	12,284	31,414	144,521	31,216	43,338

5.2 Setting the Environmental Improvement Projects

It is setting the following three environmental improvement measures, as the result that we analyzed the present environmental condition and regional economy.

Measure [1]: 30% Fertilizer reduction of the radish cultivation in Gujyo region
Measure [2]: 30% Fertilizer reduction of the persimmon cultivation in Motosu region
Measure [3]: 10% Forestry management strengthening in Mino region

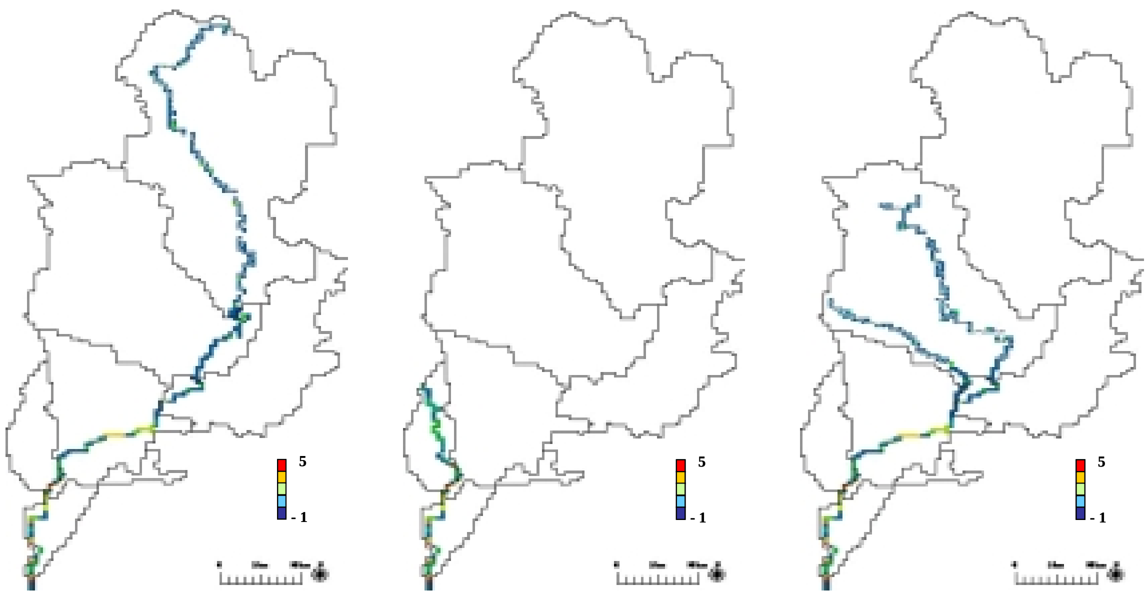
5.3 Assumption of The Water Environmental Improvement by Measure

If we simulate the environmental condition by using the basin environmental assessment model in the case that each measure carries out, the environmental improvement can be estimated. However, since required data is not full, it assumes the environmental index of improved water environmental condition by using the following formula (31).

$$Q_A^w = \ln\left(0.9\exp\left(Q_B^w\right)\right) \tag{31}$$

Where, superscript w: mesh number of improving the water environment, Q: environmental index.

The improved environmental indexes by each measure are assumed in Figure 11.



Measure[1] Measure[2] Measure[3]

Figure 11 Assumption of Environmental Improvement by each Measure

5.4 The results of Assessing the Water Environmental Improvement Projects

The results and considerations of assessing the environmental improvement measures are shown below.

(1) Measure [1]: 30% Fertilizer reduction of the radish cultivation in Gujyo region

The benefits/costs in each region by Measure [1] are shown in Table 6, and the changes of gross regional product are shown in Table 7 and Figure 12. The changes of the goods price, the amount of household's consumption and the amount of production are shown in Figure 13. Table 6 shows that the cost is 4,590,000 yen in the Gujyo region, but since the total benefit in 5 regions of down-stream is larger than it, the total benefit is 126,400,000 yen at the whole Nagara river basin. The benefit per household in the Gifu region is the largest. The reason why it is that the shares of 'Inland fisheries' and 'Hotel and other lodges' which enjoys a positive effect by environmental improvement, are higher in the Gifu region. Table 7 shows that since the negative effect to the radish cultivation sector which enforces a measure affects the whole region, the gross regional product decreases 0.080% in the Gujyo region where is a measure implementation region. On the other hand, the gross regional product increases a little bit in each region of down-stream. Therefore, the model can describe the ripple effect of the environmental improvement through the market. Figure 13 shows the ripple effect to the market economy by Measure [1] in the Gujyo region. The mesh distribution of the market benefit and environmental improvement benefit by the environmental improvement measure is shown in Figure 14(1), (2), respectively. Since the market benefit per household is constant in each region, it is necessary to take care about that the mesh distribution of benefit is equal to the mesh distribution of the number of household in Figure 14(1).

Table 6 Benefits by Measure [1]

Region	Gujyo	Mino	Seki	Gifu	Motosu	Hashima	Whole basin
Market benefit (10,000 yen)	-459	295	608	12,196	0	0	12,640
Enviroment improvement benefit	11	3	3	33	4	2	56
Total Benefit (10,000 yen)	-449	298	611	12,229	4	2	12,696
Benefit per a household (yen)	-319	242	130	831	1	0	371

Table 7 Change of gross regional product by Measure [1]

Gross regional product (million yen)	Gujyo	Mino	Seki	Gifu	Motosu	Hashima	Whole basin
without	1,941	285,635	1,253,822	2,650,189	492,654	1,580,019	6,264,259
with	1,940	285,662	1,253,825	2,650,283	492,654	1,580,019	6,264,381
The amount of change	-2	27	3	94	0	0	122
Rate of change	-0.080%	0.009%	0.000%	0.004%	0.000%	0.000%	0.002%

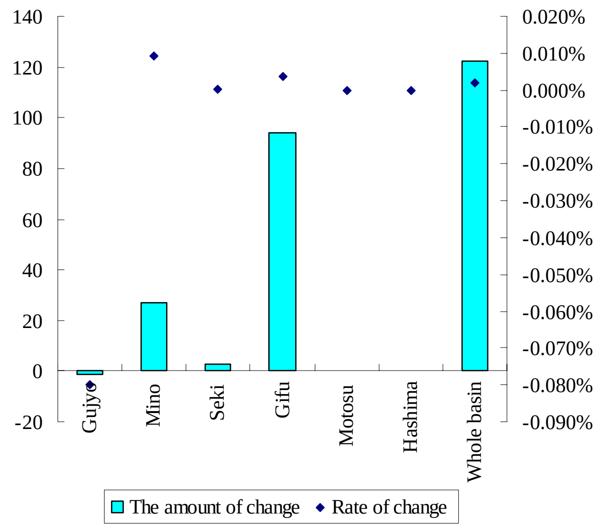


Figure 12 Amount and rate of change of gross regional product by Measure [1]

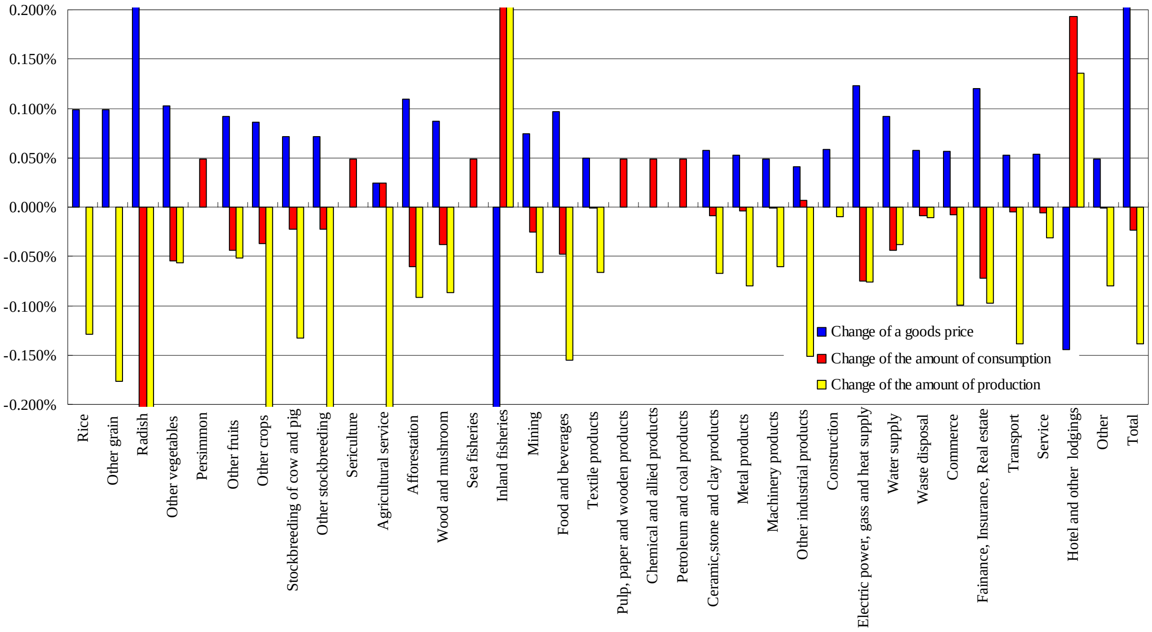


Figure 13 Change of price, consumption and production by Measure [1]

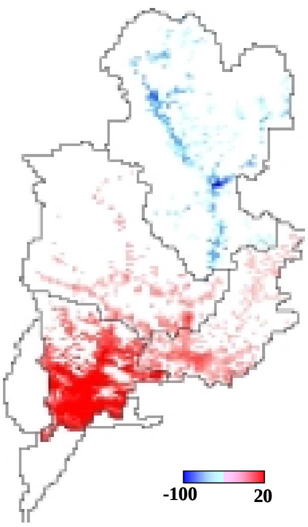


Figure 14(1) Distribution of market benefit by Measure[1]

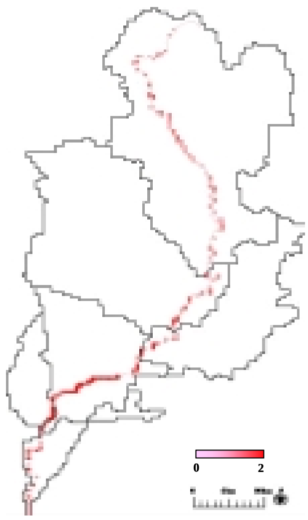


Figure 14(2) Distribution of environmental improvement benefit by Measure [1]

(2) Measure [2]: 30% Fertilizer reduction of the persimmon cultivation in Motosu region

The benefits/costs in each region by Measure [2] are shown in Table 8, and the changes of gross regional product are shown in Table 9 and Figure 15. The changes of the goods price, the amount of household's consumption and the amount of production are shown in Figure 16. Table 8 shows that the cost is 83,270,000 yen in the Motosu region, the total benefit is –71,070,000 yen at the whole Nagara river basin. Table 7 shows that the gross regional product decreases 0.118% in the Motosu region where is a measure implementation region, and the gross whole basin product also decreases 0.009%. Figure 16 shows the ripple effect to the market economy by Measure [2] in the Motosu region. The mesh distribution of the market benefit and environmental improvement benefit by the environmental improvement measure is shown in Figure 17(1), (2), respectively.

Table 8 Benefits by Measure [2]

Region	Gujyo	Mino	Seki	Gifu	Motosu	Hashima	Whole basin
Market benefit (10,000 yen)	0	0	0	1,220	-8,327	0	-7,107
Enviroment improvement benefit	0	0	0	1	20	2	23
Total Benefit (10,000 yen)	0	0	0	1,221	-8,307	2	-7,084
Benefit per a household (yen)	0	0	0	83	-2,566	0	-207

Table 9 Change of gross regional product by Measure [2]

Gross regional product (million yen)	Gujyo	Mino	Seki	Gifu	Motosu	Hashima	Whole basin
without	1,941	285,635	1,253,822	2,650,189	492,654	1,580,019	6,264,259
with	1,941	285,635	1,253,822	2,650,204	492,074	1,580,019	6,263,695
The amount of change	0	0	0	15	-579	0	-564
Rate of change	0.000%	0.000%	0.000%	0.001%	-0.118%	0.000%	-0.009%

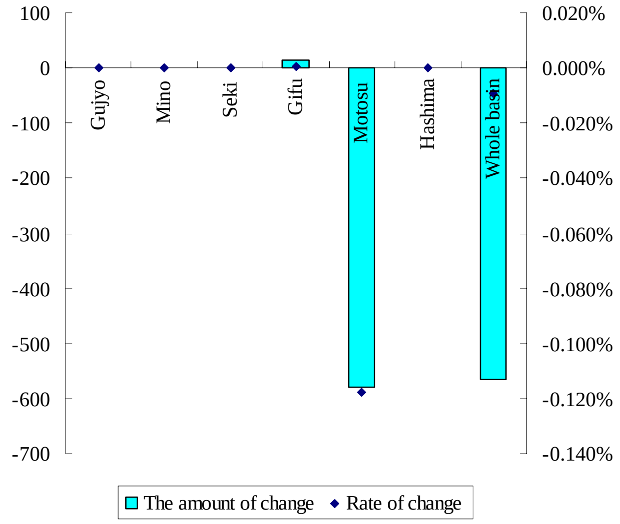


Figure 15 Amount and rate of change of gross regional product by Measure [2]

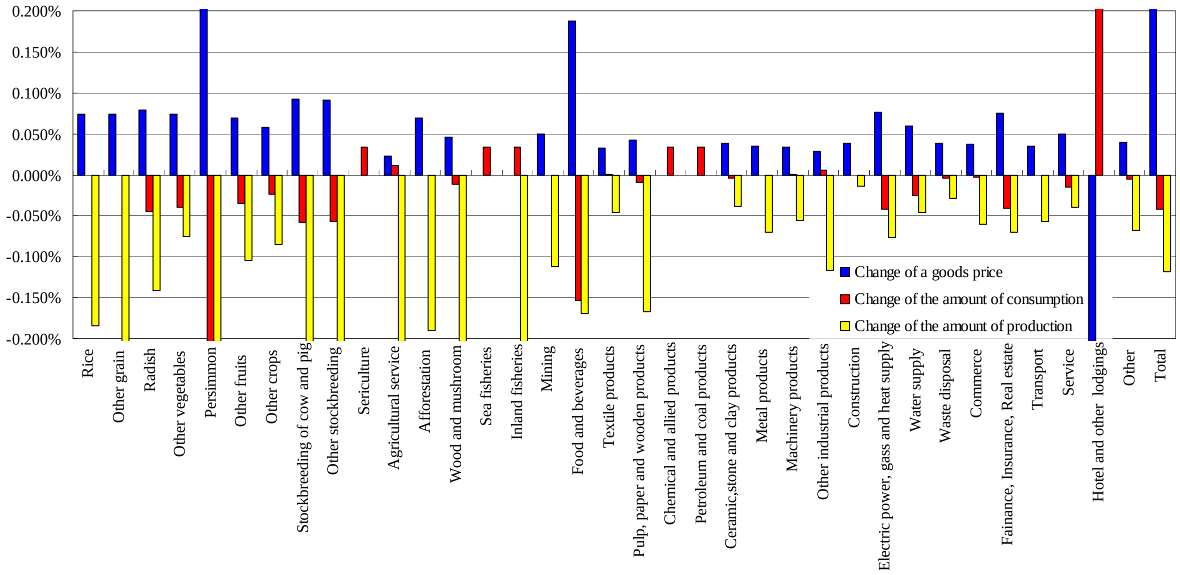


Figure 16 Change of price, consumption and production by Measure [2]

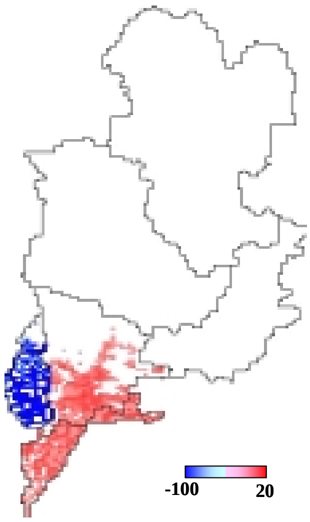


Figure 17(1) Distribution of market benefit by Measure[2]

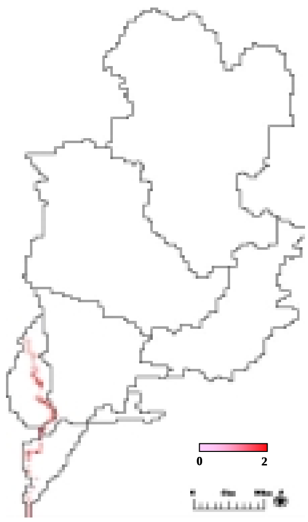


Figure 17(2) Distribution of environmental improvement benefit by Measure [2]

(3) Measure [3]: 10% Forestry management strengthening in Mino region

The benefits/costs in each region by Measure [3] are shown in Table 10, and the changes of gross regional product are shown in Table 11 and Figure 18. The changes of the goods price, the amount of household's consumption and the amount of production are shown in Figure 19. Table 10 shows that the cost is 42,930,000 yen in the Mino region, but since the total benefit in 4 regions of down-stream is larger than it, the total benefit is 35,300,000 yen at the whole Nagara river basin. Table 11 shows that the gross regional product decreases 0.060% in the Mino region where is a measure implementation region, and the gross whole basin product also decreases 0.002%.Figure 18 shows the ripple effect to the market economy by Measure [3] in the Mino region. The mesh distribution of the market benefit and environmental improvement benefit by the environmental improvement measure is shown in Figure 20(1), (2), respectively.

Table 10 Benefits by Measure [3]

Region	Gujyo	Mino	Seki	Gifu	Motosu	Hashima	Whole basin
Market benefit (10,000 yen)	0	-4,293	604	5,350	201	1,668	3,530
Enviroment improvement benefit	0	14	3	34	4	2	58
Total Benefit (10,000 yen)	0	-4,279	607	5,384	205	1,670	3,588
Benefit per a household (yen)	0	-3,484	129	366	63	188	105

Table 11 Change of gross regional product by Measure [3]

Gross regional product (million yen)	Gujyo	Mino	Seki	Gifu	Motosu	Hashima	Whole basin
without	1,941	285,635	1,253,822	2,650,189	492,654	1,580,019	6,264,259
with	1,941	285,464	1,253,825	2,650,228	492,654	1,580,027	6,264,139
The amount of change	0	-170	3	39	0	8	-120
Rate of change	0.000%	-0.060%	0.000%	0.001%	0.000%	0.001%	-0.002%

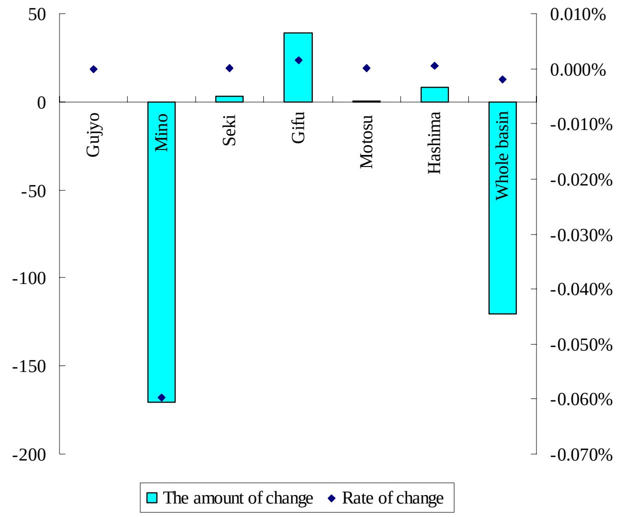


Figure 18 Amount and rate of change of gross regional product by Measure [3]

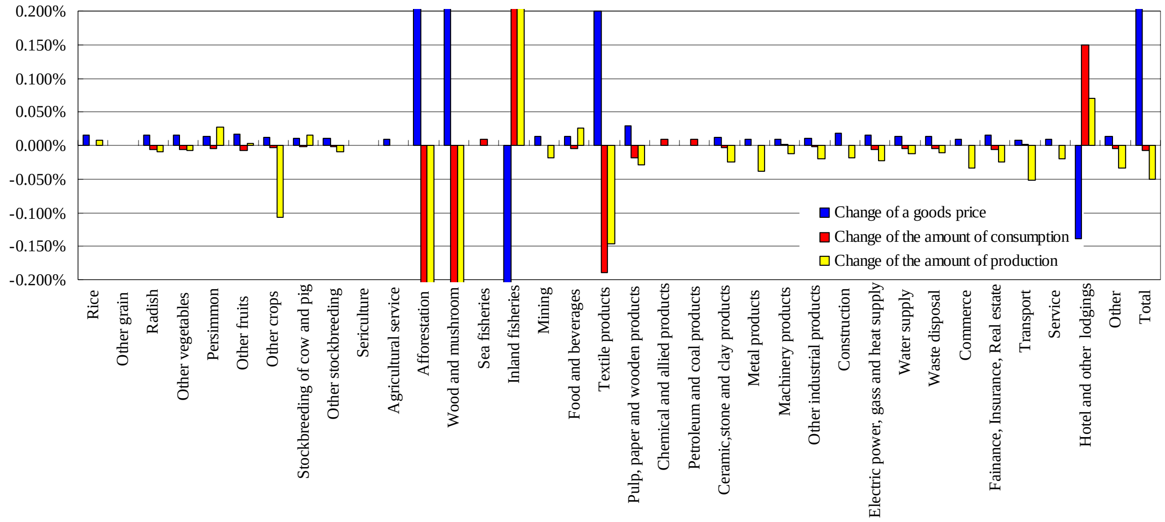


Figure 19 Change of price, consumption and production by Measure [3]

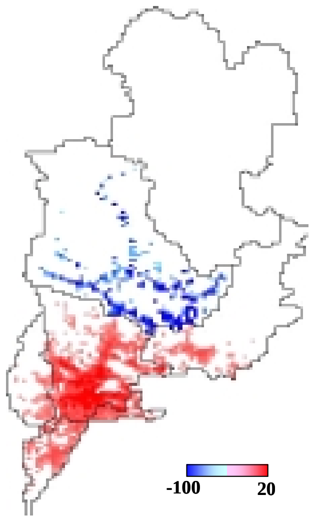


Figure 20(1) Distribution of market benefit by Measure[1]

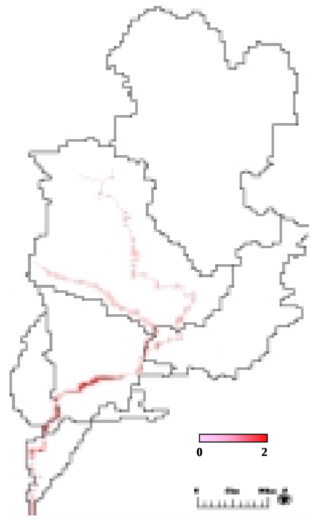


Figure 20(2) Distribution of environmental improvement benefit by Measure [1]

6. Conclusion

We developed the integrated model of combining the basin economic assessment model with the basin environmental assessment model. The basin environmental assessment model that has been built by Shinoda, et al. (2004), can evaluate physically the basin environmental condition. The basin economic assessment model was built based on the computable general equilibrium (CGE) model which has been built by Muto et al. (2003) and Takagi et al. (2002), by adopting the GIS database, in order to evaluate economically the water environment improvement measures. We tried to assess some water environment improvement projects in the Nagara river basin by applying this integrated model. We checked that the integrated model assessed the water environment improvement measure in consideration of the regional property in each region of the Nagara river basin.

Acknowledgement

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