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Watershed based agricultural land use management for the future inter-regional sustainable development: A compatible strategy to improve water quality and regional economic gap

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Abstract: This paper addresses the sustainable regeneration issue of rural area where has already been collapsing as a Japanese case study. A geographical model is developed to estimate the future cultivation abandonment state of agricultural land and the suitable agricultural subsidy policy for the sustainable rice farming is proposed. Introducing a comprehensive model coupled with economic, environmental and agricultural policy factors, we examine the impact of agricultural subsidy policy on the watershed from the economic and the water quality related environmental aspects. The agricultural subsidy policy as an interregional management is economically verified and the additional subject regarding the water pollution prevention and the economic growth is clarified.

Keywords: Agricultural subsidy policy, cultivation abandonment model, comprehensive watershed management, rural regeneration, and water quality.

1 Introduction

In Japan, there's a rising concern about rapidly collapsing rural community accompanied by the cultivation abandonment. Definitely the past irrigation developments such as the reclamation and the chemical fertilizer applications brought us a high elevation in agricultural production while reducing the labor hours drastically. In return for this, there has been a shift in population from the rural region to the urban region and we also accelerated the water pollution and regional economic gap due to the market principle. Furthermore, Japan has just run into the era of population decrease. These social circumstances would aggravate the cultivation use in agricultural farm, which might depress the economy and raise the vulnerability of the water pollution, the flood damage and the warming in the watershed without a suitable political measure. Therefore, it will be increasingly important to manage the rural resources as watershed common resources. However, in order to realize this kind of management, we above all have to show the further watershed utility given by involving in the common resources management.

In the previous research work of economic environmental policy, McCay and Acheson (1987) introduced the concept of a social common capital and provided us a hint to address this kind of social issue. Since Ramsey (1928) originally proposed the dynamic optimal model of sustainable development, Dasgupta and Heal (1974) developed the inter-temporal general equilibrium model with the accumulation and depletion process of the environmental resources. A lot of study related to the economic growth and environmental sustainability was presented (Ronald, W., 2001; López and Valdés, 2000; Torvik, 2001; Barbier, 2004; Andreas and Jacoby, 2005; Uzawa, 2005). However not much has been done to clarify the way of cross-regional management for sustainable water environment and economic growth in the watershed. Indeed, Kiyama (2007) limited to examine the optimal inter-regional trading for the rural economic rehabilitation and the improvement of watershed water quality on the static input-output basis. In this case, the study had not yet considered the farmers behavior related to the cultivation abandonment and the environmentally conscious farming in the dynamic process, but these considerations become foundation to develop a good relationship between the rural and the watershed for the economic and environmental sustainable management.

The first objective of this paper is therefore to develop the farmer behavioral model on the cultivation abandonment of paddy field. We discuss the condition of sustainable rice farming in the terms of the subsidy policy. Furthermore, integrating this model with the dynamic computable general equilibrium (CGE) model, the water pollutant emission model and another agricultural subsidy model describing the environmentally conscious rice farming state (2008a and 2008c), we review the applicability of agricultural subsidy policy to the watershed economic growth and water quality sustainability.

2 Rice cultivation abandonment model

It is necessary to develop the agricultural policy model related to the cultivation abandonment in order to assess the rural sustainability. We formulate a model based on disaggregate behavioral model (McFadden, 1981) and discuss the policy plan of the sustainable agricultural industry in the next chapter.

A rice cultivation abandonment model predicts the multi-stage of cultivation abandonment based on the GIS data of explaining variables such as population, the number of industrial employees and its composition ratio, the elevation, the land gradient, the proximity to station and the subsidy amount. This model has a structure of nested logit model as shown in Figure 1. The cultivation abandonment state is practically classified into three stages: the little sign stage, the mild stage and the severe stage. The symbol combination (rs, ms) indicates the corresponding stage by level. As for further details, we describe another reference (Kiyama, 2008b and 2008c).

After preparing the corresponding watershed polygon data with the explained variable and explaining variables of $\bar{x}$, the model parameters could be estimated via the maximum log likelihood procedure. First we would estimate parameters at the level 1 and then parameters at the level 2 as follows.

We define a probability as $P_{is}(rs|ms = 2)$ when a sample number is chooses either rs=1 or rs=2 at the level 1 (ms=2).

$$P_{is}(rs|ms) = \frac{exp\{\sum_{ks'=0}^{K1} \beta_{ks'}\, \bar{x}(rs|ms)_{is,ks'}\}}{\sum_{rs'=1}^{2} exp\{\sum_{ls'=0}^{K1} \beta_{ls'}\, \bar{x}(rs'|ms)_{is,ls'}\}}, \tag{1}$$

where ks': ks'th explaining variable number, $K1$: the number of explaining variables. Parameters $\beta_{ks'}$ can be solved as the log-likelihood maximization problem of the level 1 as follows.

$$\max_{\beta} \sum_{is=1}^{Ns} \sum_{ms=1}^{Ms=2} \sum_{rs=1}^{Rm=2} \delta(rs, ms)_{is}\, lnP_{is}(rs|ms), \tag{2}$$

where Ns: the number of samples and δ value becomes 1 when the assumed combination (rs, ms) is the same as the observed combination, and otherwise δ becomes 0.

Let us next consider the level 2. When a sample number is chooses either ms=1 or ms=2, the corresponding probability $P_{is}(ms)$ can be written as follows.

$$P_i(ms) = \frac{exp\left[\lambda_2 \sum_{ks'=0}^{K2} \theta_{ms,ks'}\, \bar{x}(ms)_{is,ks'} + \lambda_2 A_1\right]}{\sum_{ms'=1}^{2} exp\left[\lambda_2 \sum_{ls'=0}^{K2} \theta_{ms',ls'}\, \bar{x}(ms')_{is,ls'} + \lambda_2 A_2\right]}, \tag{3}$$

$$A_1 = ln\left\{\sum_{rs'=1}^{2} exp\left(\sum_{ks'=0}^{K1} \beta_{rs',ms,ks'}\right) \bar{x}(rs'|ms)_{is,ks'}\right\},$$

$$A_2 = ln\left\{\sum_{rs'=1}^{2} exp\left(\sum_{ks'=0}^{K1} \beta_{rs',ms',ks'}\right) \bar{x}(rs'|ms')_{is,ks'}\right\}.$$

where λ_2 indicates the logit parameter which relates the level 2 to the level 1, $K2$: the number of explaining variable at the level 2. We can also write the log-likelihood maximization problem to estimate parameters of the level 2, $\theta_{ms,ls'}$ and λ_2, as follows.

$$\max_{\beta} \sum_{is=1}^{Ns} \sum_{ms=1}^{Ms=2} \delta(rs = 1, ms)_{is} \, lnP_{is}(ms). \tag{4}$$

After estimating model parameters, $\beta_j, \theta_{2,j}$ and λ_2, the cultivation abandonment stage of GIS polygon can be determined from the combination (rs, ms) having the maximum probability of $P_{is}(rs, ms) = P_{is}(rs|ms)P_{is}(ms)$.

3 Subsidy plan and Agricultural sustainability

We assume no subsidy plan as the baseline and the finite time period between 2000 and 2030. Other two plans are introduced to investigate the effect of subsidy policy: the current subsidy plan and the other subsidy plan which maintains the 2030 cultivation abandonment ratio below a level in 2000 with the minimum payment cost. The latter plan would be called as the optimal subsidy plan later. The current subsidy is given as the flat rate subsidy payment, whose amount is 8,000 yen/10a for the gentle slope land (gradient of 1/100 - 1/20) and 21,000 yen/10a for the steep slope land (gradient greater than 1/20). Compared with the baseline plan, we discuss the current subsidy plan in the light of the farming sustainability.

3.1 A case study of Japanese watershed

The target watershed is the Katsura river basin having 1361km^2 catchment area and 1.74 million inhabitants in 2000 and consisting of nine municipalities in Kyoto Prefecture, the middle area in Japan. National Institute of Population and Social Security Research in Japan (2004) shows that the watershed population turns to decreasing after 2005 and the decreasing rate amounts to 8.3% in 2030. The population at the upstream of agricultural promotion area will rapidly decrease to be 18.8% in 2030. The acreage of target paddy field amounts to 5378 ha and 9579 GIS polygons with 100m on a side are identified for the analysis. The distribution of the agricultural worker in 2000 and the elevation are shown in Figures 2a and 2b.

3.2 Model estimation

Considering the 2000 census data before performing the current subsidy policy "the direct payment system in hilly and mountainous areas", the cultivation abandonment model was first estimated with a rational t-value (Table 1). Unlike the multi-logit model, the nested model proficiently predicts three stages with the hitting ratio: 54.6% for the little sign stage, 44.7% for the mild stage and 42.5% for the severe stage.

According to this estimated model, the following causal relation is described. When the agricultural worker density and population are smaller and land elevation becomes higher, the obvious cultivation abandonment of either mild stage or severe stage is recognized. Furthermore, the condition of running into the severe cultivation abandonment stage could be explained as a steeper slope land, a longer distance to nearest station, a lesser number of agricultural and manufacturing business workers.

We next estimate one more subsidy parameter $\theta_{2,4}$ with the following assumption,

- The subsidy payment explicitly changes the cultivation abandonment stage to the little sign stage (cultivation abandonment ratio under 0.5%) or maintains the improved stage at least.
- Terrain condition such as elevation and slope angle and the proximity of station are invariable.
- The explaining parameters already estimated by the 2000 census are constant.

Since we can get the data regarding the watershed cultivation abandonment ratio in 2005, the subsidy parameter $\theta_{2,4}$ is estimated as -0.145 to accord with the rate of cultivation abandonment ratio for five years, -0.59%.

3.3 Current subsidy policy issue

Utilizing the estimated model, we predicted the long term behavior of the cultivation abandonment ratio by the subsidy plan (Figure 3). The cultivation abandonment used here denotes the arithmetic mean value of all GIS polygons. When we consider no subsidy plan, the cultivation abandonment ratio goes on increase to 8.4% in 2030. The current subsidy plan drastically can improve the cultivation abandonment ratio in the initial time period but gradually worsen the cultivation state and its ratio reaches 5.4% in 2030. As a result, the current subsidy plan can only remains the cultivation abandonment ratio below a level in 2000 for the first ten years.

The corresponding long term behavior of the composition ratio by cultivation abandonment stage is shown in Figure 4. In the current subsidy policy case, the composition ratio of the little sign stage is monotonously decreasing in the second half of the time period. The mild stage and the severe stage make up 70% in 2030. Especially, the severe stage raises its proportion at a constant rate. Most of severe stage is recognized as the hilly and mountainous area with the branch shape in the map (Figure 5a). From these discussions, the current policy yet remains a problem of unsustainable rice farming from a long-term standpoint.

3.4 Subsidy plan for sustainable rice farming

We should seek a suitable subsidy policy in solving the issue clarified by the current subsidy policy analysis. As a result, the optimal subsidy problem to realize the sustainable rice farming for three decades could be analytically solved as the following constant rate type subsidy plan.

$$sub(k) = 0.8 + 0.0574k, \qquad \text{for gentle slope,}$$

$$sub(k) = \begin{cases} 2.1 & , k < 22 \\ 2.1 + 0.0574(k - 23), & k \geq 23 \end{cases}, \quad \text{for steep slope,} \tag{5}$$

where k: the number of time, $sub(k)$: the amount subsidy payment per acreage (unit: yen/10a), and we assume the following conditions.

- The sustainability of cultivation is defined as the cultivation abandonment ratio in 2030 below a level in 2000.
- The constant rate type of subsidy payment is assumed for the gentle slope farm. In this regard, the amount of subsidy payment for the steep slope farm is consistently doesn't dip from the amount for the gentle slope.

It is found from Figure 3 that the optimal subsidy plan brings the cultivation abandonment ratio back into the 2000 level since 2023. Unlike the current subsidy policy, the optimal subsidy policy restricts the monotonous increase of the severe stage and chiefly improves the severe cultivation abandonment stage since 2010 (Figure 4). However, the mild stage remains nearly unaffected by the subsidy plan.

In the case of no subsidy policy shown in Figure 5c, the severe stage in 2030 is distributed to the hilly and mountainous area and around the large scale paddy field cultivation. Compared with Figures 4a and 4b, it is shown that the optimal subsidy policy appreciably improves the severe cultivation abandonment stage at the hilly and mountainous area to the little sign stage. Therefore, the optimal subsidy plan is useful in the sustainable rice cultivation.

4 Sustainable agricultural and watershed development

We limited to confirm that the optimal agricultural subsidy policy could promote the sustainable rice farming in terms of geographical analysis. However, we should raise anew question of this policy ability to encourage the economic growth and reduce the corresponding environmental burden in the scale of rural and watershed. This is because the subsidy is basically paid by contributions from the watershed inhabitants and firms as the income tax and the production tax. At the same time, there is the evidence that the agricultural industry gives a considerably great pressure on the water quality according to the analysis of the embodied COD emission intensity (Kiyama, 2007). Therefore, the comprehensive assessment is very important to clarify a good relationship between the rural and the watershed for the sustainable development.

4.1 Methodology

We outline the comprehensive model coupled with the economic model, the environmental emission model and the agricultural policy model as shown in Figure 6 (Kiyama, 2008a and 2008c). For the economic analysis, the dynamic CGE model is utilized to solve the optimal growth path with the following maximizing problems.

- Watershed utility maximization for a finite time period (No.1 in Figure5)
- Firm profit maximization for the composite goods consisting of the domestic goods the and imported goods (No.2 in Figure5)
- Firm profit maximization for the production output consisting of the domestic goods and the exported goods (No.3 in Figure5)
- Firm profit maximization for the production factors input (No.4-1 in Figure5)
- Firm profit maximization for the input of intermediate goods and production factors (4-2 in Figure5)

The input-output based COD emission model is introduced to assess the impact of water pollution. Collecting the sectoral direct COD discharge and the value of production and import, we can calculate the embodied COD emission intensity from the input-output relation, and then the watershed COD emission amount is quantified. The corresponding formulation was originally proposed by Nansai et al. (2002) to estimate the national CO_2 emission. Kiyama (2007) applied this model concept to the regional COD emission problem.

Finally, two agricultural policy models are coupled with the economic model and the environmental model. These two models predict the cultivation abandonment state of paddy field and the environmentally conscious rice farming state (Kiyama, 2008a). By the way, these predicted quantities must be transformed to the exogenous variable and parameter of the economic and environmental model. Practically, the labor is determined depending on the cultivation abandonment ratio and the composition ratio of rice cultivation method: the conventional cultivation, the organic cultivation and the cultivation by low input at least 50% less of chemical fertilizer and pesticide. The intermediate input coefficient is also transformed from the composition ratio of rice cultivation method. Kiyama (2008a and 2008c) detailed these transformation procedures, the determination of model parameter and the initialization of model variables.

For this study the target watershed input-output tables were arranged with four sectors from the 2000 Kyoto prefecture input-output tables consisting of 92 industrial sectors. The four sector consists of the agriculture, forestry and fisheries industry (sector1), the manufacturing industry (sector 2), the construction, electricity, gas and heat supply, water supply and waste management (sector3) and other service industry such as commerce, finance, transport, medical and social security etc. (sector 4). We examine the watershed economic development by the agricultural subsidy policy, i.e., no subsidy, the current subsidy and the optimal subsidy described above. The corresponding optimization calculation was carried out every five years for three decades.

4.2 Agricultural subsidy effect on watershed economic growth

Figure 7 shows the watershed optimal growth path, the total consumption and total capital stock relation per capita. It is found that the agricultural optimal subsidy policy successfully generates the biggest watershed economic growth.

Figure 8 shows the long term behavior of the value of production by the agricultural subsidy policy. It is found that either subsidy policy gains a more value of production compared to the base line, i.e., no subsidy policy. Compared with no subsidy policy, the rate value of production in 2025 becomes 2.3 % for the current subsidy policy and 5.1% for the optimal subsidy policy.

It is suggested that the assumed subsidy policy promotes a higher added value production and a lesser cultivation abandonment. Indeed the cost of agricultural optimal subsidy payment amounts to 4,268 million yen which is nominal compared to the watershed value of production in 2000, 12,272,527 million yen. It is clearly suggested that the agricultural subsidy policy accelerates not only agricultural economic growth but also other sectors economic growth.

We some more discuss the economic growth relation between the agricultural sector and the watershed. Even at no subsidy policy, the watershed economic growth of 40.6% is expected for twenty five years. On the other hand, the resultant agricultural economic growth rate becomes 28.2% for no subsidy policy, 34.4% for the current subsidy, and 46.5% for the optimal subsidy. As the past free market process indicates, the no subsidy policy widens the economic gap between the agricultural sector and the watershed and results in the further cultivation abandonment. The analytical result of economic growth rate certainly denotes this social and economic behavior. When we would realize the sustainable agricultural development, the same level of economic growth between agricultural industry and watershed should be expected at least. Therefore the optimal subsidy plan will be better suited in terms of cross-regional economic growth.

4.3 Agricultural subsidy plan and COD emission

We discuss how the agricultural subsidy policy acts on the watershed COD emission. Figure 9 shows the long term behavior of the total amount of the watershed COD emission. We should note that the agricultural subsidy policy doesn't always work well on the COD emission reduction. Indeed the current subsidy plan effectively gives a lesser impact of water pollutant compared to no subsidy plan. Although the optimal subsidy plan is more environmentally friendly in the water quality compared to no subsidy plan, the optimal subsidy plan allows a greater environmental burden compared to the current subsidy plan. It should be noted that the agricultural policy-making which only watches the agricultural economy and watershed economy may raise fears of the additional water pollution.

Figure 10 shows the COD emission behavior of the agricultural industry (sector 1). Either subsidy policy attains the COD emission below the level of no subsidy policy in the every time period. However, we observed that the optimal subsidy policy gave a smaller reduction rate of COD emission after all due to the production expansion in the market principle. Therefore, we should have to progress the further discussion the framework of the environmentally friendly economic development.

5 Conclusion

This paper investigated the agricultural sustainable development from different two aspects such as the geographical farming condition and the market principle. The impact of the agricultural policy on watershed development is also discussed to assess the possibility of watershed common management for the rural regeneration.

According to the geographical analysis, the causal factor of rice cultivation abandonment is successfully classified by the degree of cultivation abandonment progression. Furthermore, the necessity of a constant rate subsidy plan is shown for the sustainable rice farming. The proposed optimal subsidy plan has the ability to improve the severe stage of cultivation abandonment at the hilly and mountainous area which is the front-line of collapsing agricultural commune.

In another examination of the optimal economic growth problem, either agricultural subsidy has advantage to develop the additional value of production in not only the agricultural sector but also the watershed. This suggests that the optimal subsidy plan exactly gives a good relation on the economic development between the agricultural industry and the watershed. Therefore, any agricultural subsidy policy seems to work as the inter-regional common management from these discussions. However, the resultant increasing COD emission remains a contentious matter for the sustainability of environment and economy.

As a result, the optimal agricultural subsidy policy can realize the continuous farming for a long time period but unfortunately backs up the further environmental burden on the watershed. And also the current subsidy system meets the difficulty of the continuous farming but reduces the watershed COD burden. As additional strategy to address this issue, the COD emission control policy should be discussed for future task.

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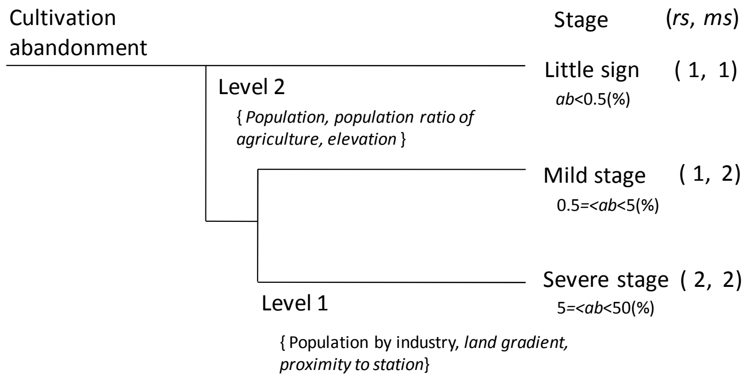
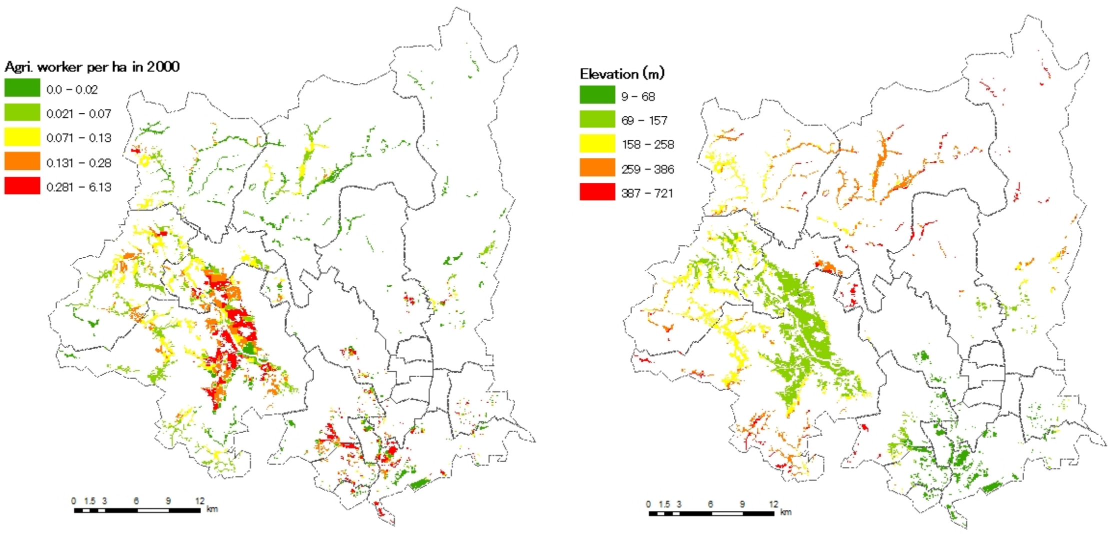


Figure 1 Nested logit model structure for rice cultivation abandonment



(a) Agricultural worker (b) Elevation

Figure 2 Watershed paddy field map in 2000

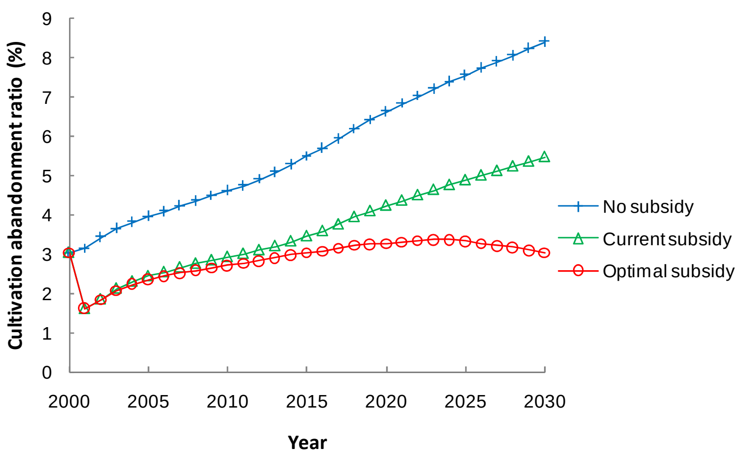


Figure 3 Long term behavior of cultivation abandonment ratio

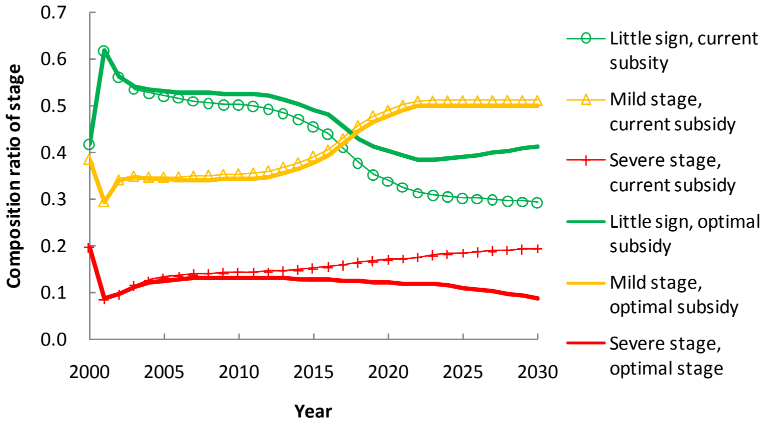
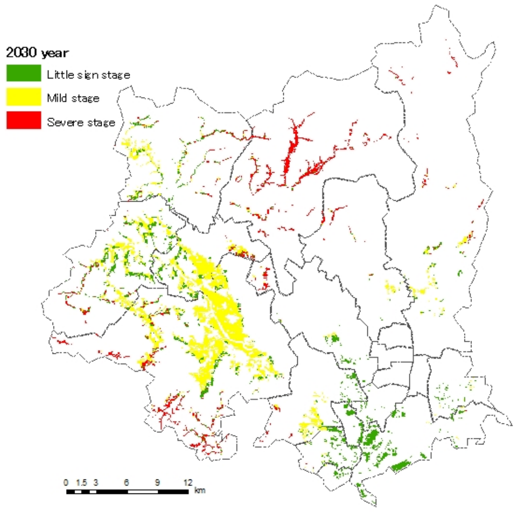
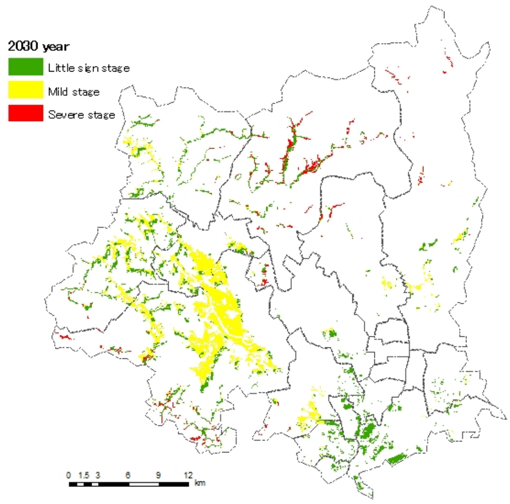


Figure 4 Composition ratio of cultivation abandonment stage



(a) Current subsidy policy



(b) Optimal subsidy policy

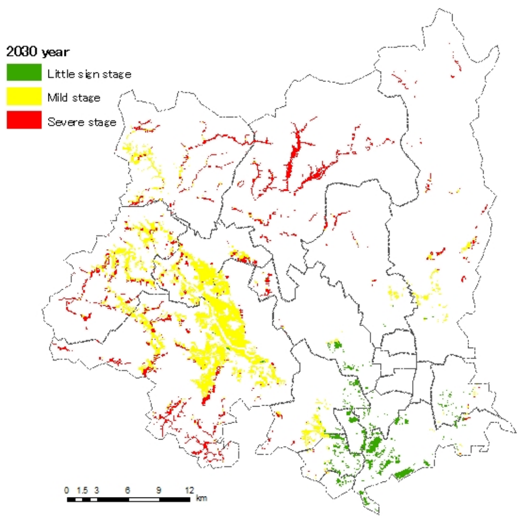


Figure 5 Cultivation abandonment stage in 2030 (C) No subsidy policy

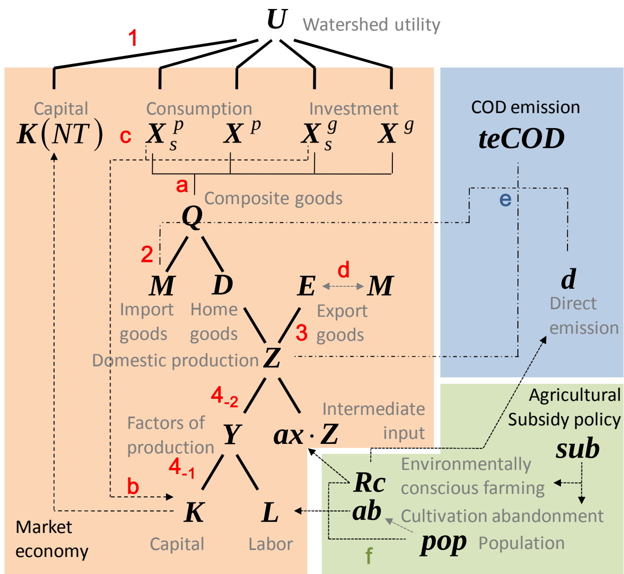


Figure 6 Configuration of a comprehensive model

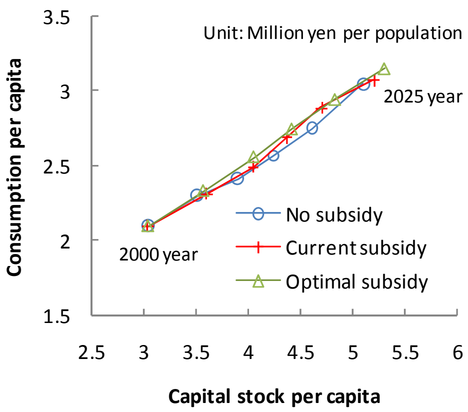


Figure 7 Optimal growth path

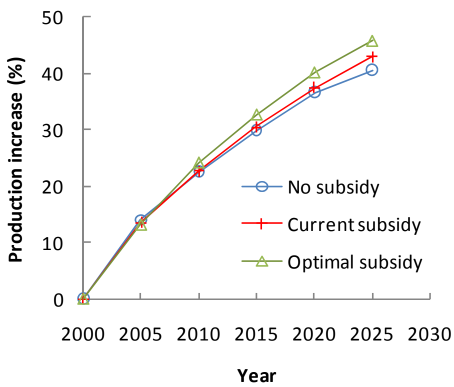


Figure 8 Value of production

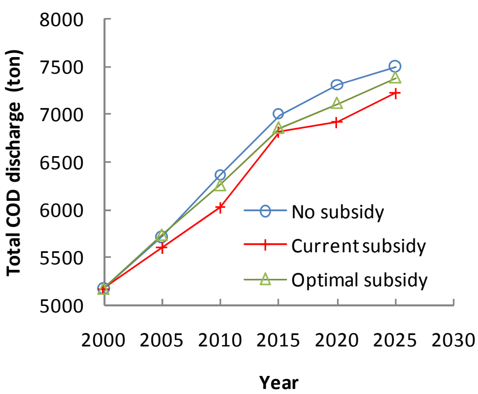


Figure 9 Watershed COD discharge

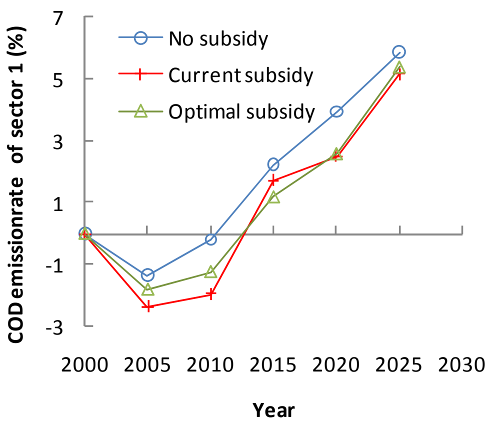


Figure 10 COD emission of agricultural sector

Table 1　Estimated parameters of cultivation abandonment model

Parameter		Explaing variable name	t-value	
$\beta_{2,2,0}$	-2.01412	Constant number, level 1	-31.184	***
$\beta_{2,2,1}$	0.10562	Land gradient (degree)	34.037	***
$\beta_{2,2,2}$	0.16679	Proximity to station (km)	28.763	***
$\beta_{2,2,3}$	-9.90988	Agricultural population	-26.198	***
$\beta_{2,2,4}$	-0.07288	Population of manufacturing industr	-4.656	***
$\beta_{2,2,5}$	0.01982	Population of service industry	2.778	**
$\theta_{2,0}$	-0.24937	Constant number, level 2	-5.316	***
$\theta_{2,1}$	-4.77037	Population ratio of agriculture	-31.169	***
$\theta_{2,2}$	0.00762	Elevation (m)	24.905	***
$\theta_{2,3}$	-0.00518	Population	-12.033	***
λ_2	0.50932	Logit parameter	10.067	***