AN ECONOMIC EVALUATION OF THE MULTIFUNCTIONAL ROLES OF AGRICULTURE AND RURAL AREAS IN JAPAN

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ABSTRACT

How to maintain the multifunctional roles of hilly and mountainous areas is now becoming an important policy issue in Japan. The functions evaluated here are: flood prevention, conserving water resources, preventing soil erosion, and landslides, organic waste disposal, air purification, climate mitigation, and preserving amenities for recreation and relaxation. Since appropriate substitutive goods were found for each function, a replacement cost method could be employed for the evaluation. The results of evaluating the economic value of the multifunctional roles of agriculture and rural areas are as follows: each year, they are worth US$68.8 billion (6,878.8 billion yen) for the whole of Japan, or US$30.3 billion (3,031.9 billion yen) for hilly and mountainous areas alone.

INTRODUCTION

Agriculture and rural areas play a variety of roles. These include flood prevention, the conservation of water resources, landslide prevention, and the preservation of recreational amenities. At the OECD Committee for Agriculture at a ministerial level, held in Paris in March 1998, a communiqué focusing on the multiple functions of agriculture was announced. These functions are now attracting international attention.

Although governments will need further discussion on a number of issues regarding how to maintain these multiple functions, it is clear that they should be incorporated into the administrative framework.

In general, multifunctional roles are created by external economies of agriculture and rural areas. In other words, these multifunctional roles have the characteristics of by-products from agricultural production. Moreover, these functions have the characteristic of a public good, i.e. they are used by everyone without excluding any person who does not pay. Therefore, the beneficiaries of these functions pay little attention to the farmers who provide them.

Since multifunctional roles are formed by external economies and have the characteristics of public goods, if the supply of these functions depends on the market mechanism, efficient resource allocation will be hindered due to “market failure”. As a result, these functions will not be supplied as and when they are needed.

Policy intervention is therefore required in order to maintain these multifunctional roles. However, as these functions are not traded in the market place, they do not have a market price. Consequently, it is always pointed out to those who would like to implement such a policy, that it lacks any theoretical justification. Moreover, if the general public who benefit from these multifunctional roles do not fully understand them and do not appreciate their value, they will not approve of any policy intervention. It has therefore become necessary to evaluate the benefits of the multifunctional roles of agriculture and rural areas in monetary terms, and to

Keywords: external economy, Japan, multifunctionality, replacement cost method
present these monetary benefits as one of the important reasons for maintaining such functions.

Three methods are often used when evaluating multifunctional roles. One is the replacement cost method (RCM), the second is the hedonic pricing method (HPM), and the third is the contingent valuation method (CVM).

In RCM, goods and services traded on the market are substituted for the functions to be valued. The functions are then evaluated according to the market prices of these goods and services. This method has two advantages. Firstly, it is possible to evaluate each function separately, and secondly, the evaluation is easy to understand, since goods and services are used instead of functions.

In 1972, the Forestry Agency of Japan first introduced this method in order to evaluate the multifunctional roles of forestry. Since then, this method has been applied mainly to the multifunctional roles of paddy fields. According to the initial calculation of the Forestry Agency, the multifunctional roles of forestry in 2000 were worth approximately US$740 billion (74 trillion yen). A similar evaluation, carried out by the Mitsubishi Research Institute in 1995, estimated the multifunctional roles of paddy fields and upland fields to be worth approximately US$67 billion (6.7 trillion yen).

In HPM, it is assumed that differences in amenities in residential areas are reflected in land prices and wages. According to the evaluation based on HPM by Nishizawa, Yoshida, and Kato (1991), paddy fields in Japan offered amenities worth approximately US$120 billion (12 trillion yen).

CVM has been widely used in recent years. In this method, questionnaires are sent to the general public who benefit from the environment, asking people directly how much they would be willing to pay for the improvements of the environment which agriculture brings. According to the preliminary calculation using CVM by Yoshida, Kinoshita, and Goda (1997), the value of the multifunctional roles of agriculture and rural areas in Japan estimated by this method were worth US$41 billion (4.1 trillion yen). Yoshida (1999) estimated the multifunctional roles of upland fields according to this method to be worth US$35 billion (3.5 trillion yen).

Although several methods have been applied at a national level to quantify the value of the multifunctional roles of agriculture and rural areas, particularly in hilly and mountainous areas, there is now strong political pressure in Japan to place more importance on them. These methods have also been applied at a municipal level.

In view of the advantages of RCM, this method was applied by the author to evaluate multifunctional roles. In this study, based on the evaluation by the Mitsubishi Research Institute, the multifunctional roles of agriculture and rural areas were reevaluated using the latest scientific data currently available, and the multifunctional roles of hilly and mountainous areas were evaluated for the first time.

Table 1 shows a summary of the results. The value placed on each multifunctional role will be discussed below, together with the definitions used and the method of calculation.

**VALUATION AND METHOD OF CALCULATION**

**Function of Flood Prevention**

**The Concept**

Paddy fields surrounded by ridges temporarily store water at times of heavy rain, and discharge it gradually into downstream rivers and surrounding areas. In this way, they prevent or mitigate the damage which might otherwise be caused by floods. Upland fields, on the other hand, store rainwater temporarily in porous soil formed by cultivation, preventing sudden run-off and helping to prevent flooding. This role played by agricultural land is called the water retention function.

**Preconditions**

**Paddy Fields**

Evaluation of the water retention capacity of paddy fields (except for those in low-lying flatlands) and the temporary water retention capacity of paddy fields in low-lying flatlands (near buildings which benefit from the drainage they provide) is based on the cost of constructing a dam which would fulfill the same function of water control.

**Upland Fields**

The value of the temporary water retention capacity of porous soils is based similarly on the replacement cost which would be incurred by a dam.

**Method of Calculation**

Paddy Fields: Valuation = (Effective water retention
<table>
<thead>
<tr>
<th>Role of Agriculture and Rural Areas</th>
<th>Valuation for Whole of Japan</th>
<th>Valuation for Hilly and Mountainous Areas</th>
<th>Abstract of Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood prevention</td>
<td>28.789</td>
<td>11.496</td>
<td>Water retention capacity of paddy fields and upland fields (paddy field: 5.2 billion m³, upland fields: 0.8 billion m³) is evaluated based on depreciation costs and annual maintenance costs of a dam controlling the water supply.</td>
</tr>
<tr>
<td>Conservation of water resources</td>
<td>12.887</td>
<td>6.023</td>
<td>Water capability (638 m³/S) contributing to the stabilization of water flow and the reuse of irrigation water in paddy fields by returning it to rivers is evaluated based on depreciation costs and annual maintenance costs of an irrigation dam. Also, the volume of groundwater supplied from paddy fields and upland fields (3.7 billion m³) is evaluated by the difference in price between groundwater and tap water.</td>
</tr>
<tr>
<td>Soil erosion prevention</td>
<td>2.851</td>
<td>1.745</td>
<td>The estimated volume of eroded soil (53 million mt) prevented by cultivation of farmland is given monetary value, based on the construction costs of a dam to arrest sediments.</td>
</tr>
<tr>
<td>Landslide prevention</td>
<td>1.428</td>
<td>0.839</td>
<td>The estimated number of landslides (1,700 cases) prevented by cultivation of paddy fields is evaluated based on average losses incurred.</td>
</tr>
<tr>
<td>Organic waste disposal</td>
<td>0.064</td>
<td>0.026</td>
<td>The value of organic wastes applied to farmland (municipal waste: 60,000 mt, human waste: 860,000 kg, sewage sludge: 230,000 mt) is based on the final disposal costs.</td>
</tr>
<tr>
<td>Air purification</td>
<td>0.099</td>
<td>0.042</td>
<td>The estimated volume of exhaust fumes (SO₂: 49,000 mt, NO₂: 69,000 mt) absorbed by paddy fields and upland fields is evaluated based on depreciation costs and annual maintenance costs of desulfurization and denitrification equipment.</td>
</tr>
<tr>
<td>Climatic mitigation</td>
<td>0.105</td>
<td>0.02</td>
<td>Capability of paddy fields to reduce temperatures in summertime (1.3°C on average) is evaluated based on cost otherwise required for air conditioning.</td>
</tr>
<tr>
<td>Recreation and relaxation</td>
<td>22.565</td>
<td>10.128</td>
<td>Functions of recreation and relaxation provided by agriculture and rural areas are evaluated by travelling costs for tourists and homecoming people to rural areas.</td>
</tr>
<tr>
<td>Total</td>
<td>68.788</td>
<td>30.319</td>
<td></td>
</tr>
</tbody>
</table>

Unit: Billion US$
capacity of paddy fields (except those in low-lying and flat land areas) * (depreciation cost of dam storing an equivalent volume of water + annual maintenance cost of the dam per unit of water stored) + (effective water retention capacity of paddy fields in low flatland areas, where buildings exist which benefit from this function) * (depreciation costs of a dam per unit of water stored + annual maintenance cost of the dam per unit of water stored)

Upland fields: Valuation = Effective water retention capacity of fields * (depreciation cost of a dam with the same function per unit of water stored + annual maintenance cost of the dam per unit of water stored).

Equation Used in the Calculation

Paddy fields: 4,404 million m$^3$ * (US$4.73 + 0.05) + 7.70 million m$^3$ * (4.73 + 0.05) = US$21.05 billion + 3.68 billion = 24.73 billion
(Hilly and mountainous areas: 1,836 million m$^3$ * (US$4.73 + 0.05) + 1.83 million m$^3$ * (4.73 + 0.05) = US$8.73 billion + 0.875 billion = US$9.61 billion)

Upland fields: 849 million m$^3$ * (US$4.73 + 0.05) = US$4.05 billion
(Hilly and mountainous areas: 394 million m$^3$ * (US$4.73 + 0.05) = US$1.88 billion)

**Function of Conserving Water Resources**

**The Concept**

Water drawn from rivers to irrigate paddy fields penetrates into the soil, and eventually drains away and returns to the rivers. Some of this water contributes to the stabilization of flow regimes, while some of the rest penetrates deep into the ground and becomes part of the groundwater reserves. The soil of paddy fields and similar areas also absorbs rainwater at times when they are not being irrigated. This reusable water in the soil and subsoil is evaluated as the function of conserving the water resources of fields used for paddy and crop fields.

**Preconditions**

- At least 75% of the water absorbed by paddy fields is returned eventually to rivers.
- Water returned to rivers is evaluated on the basis of the replacement cost of a dam with the same function.
- Taking into account the price of irrigation water, the function of groundwater conservation is evaluated, based on the difference in price between groundwater and tap water.
- For paddy fields in low lying flatlands, the effect of stabilizing a river flow is disregarded, since it is assumed that none of the water they receive returns to rivers.
- The volume of groundwater used for agriculture is deduced from the volume of groundwater conserved, since this is regarded as an internal economy.

**Method of Calculation**

Valuation = Recycling of water resources via paddy fields * (depreciation costs of irrigation dam per unit of water) + annual maintenance costs of dam per unit of water + volume of external groundwater utilized * (supply of groundwater from paddy field irrigation + supply groundwater conserved originating in rainwater on paddy fields) * difference in groundwater prices + volume of external groundwater utilized * rate of conservation of groundwater from rainwater on fields * difference in groundwater prices.

**Equation Used in the Calculation**

Contribution of Stabilization of River Flow (in the Case of Paddy Fields)

Conservation of water resources by paddy fields * (depreciation costs of a substitute irrigation dam per unit of water conserved + annual maintenance costs of the dam per unit of water = 638 m$^3$/s * (18.73 million/(m$^3$/s) + 0.18 million/(m$^3$/s)) = US$12.07 billion
(Hilly and mountainous areas: US$12.07 billion * 0.472 = US$5.69 billion)
Volume of groundwater conserved by paddy fields

Volume of external groundwater utilized
* (rate of groundwater originating in irrigation of paddy fields + rate of groundwater originating as rainwater on paddy fields) *
difference in groundwater prices = (15.77 billion m³ - 3.88 billion m³) * (0.196 + 0.052) * US$0.223/m³ = US$0.658 billion
(Hilly and mountainous areas: US$0.658 billion * 0.383 = US$0.252 billion)

Volume of groundwater recycled through fields

Volume of external groundwater utilized
* rate of groundwater supplied by rainwater on field * difference in groundwater prices = (15.77 billion m³ - 3.88 billion m³) * 0.06 * US$0.223/m³ = US$0.159 billion
(Hilly and mountainous areas: US$0.159 billion * 0.464 = US$0.074 billion)

FUNCTION OF PREVENTION OF SOIL EROSION

The Concept

In the process of crop cultivation, levees are repaired and organic materials are added to the soil. This leads to an increase in the bulk density of soil, while the ground surface is gradually smoothed and flattened. Both these effects reduce loss of soil by water and wind erosion. However, if cultivated fields are abandoned and left fallow, soil is likely to be lost. In a word, soil erosion can be prevented by the cultivation of farmland.

Preconditions

The volume of soil conserved (i.e. the difference in the volume of soil lost from cultivated farmland and the volume of soil lost from abandoned farmland) is estimated, and given a monetary value based on the cost which would be incurred by constructing a dam to filter and retain sediments.

Method of Calculation

Valuation = (Estimated volume of eroded soil if cultivation is abandoned - estimated volume of soil eroded if cultivation continues) * construction costs of a dam to retain sediments per unit of sediments stored.

Equation Used in the Calculation

All Japan: (14.77 mt/ha/year - 4.20 mt/ha/year) * 5.038 million ha * US$53.54/m³ = US$2.851 billion
Hilly and mountainous areas only: (21.60 mt/ha/year - 5.97 mt/ha/year) * 2.085 million ha * US$53.54/m³ = US$1.745 billion

Remarks

• The specific gravity of soil is assumed to be 1.0.
• The depreciation cost of a dam to retain sediments is not included in the valuation. However, a dam of this kind has a shorter service life than a dam to conserve water or for irrigation.

FUNCTION OF LANDSLIDE PREVENTION

The Concept

In the process of rice cultivation, paddy fields form shallow plates filled with water. Irrigation water constantly permeates into the soil, thereby maintaining a steady level of groundwater. However, if paddy fields are abandoned, the ground will crack, and the capacity to maintain a steady groundwater level will be reduced. As a result, the groundwater level may rise sharply at times of heavy rain, leading to landslides. Small-scale landslides on abandoned paddy fields tend to be overlooked, so that sequential large-scale landslides become more likely. Thus, landslides can be prevented through the continuous cultivation of paddy fields.

Preconditions

The estimated number of landslides that are prevented by continuous cultivation is valued, based on the estimated cost of losses incurred by landslides.

Method of Calculation
Valuation = (The estimated number of landslides if cultivated fields are abandoned - the estimated number of landslides in the case of continuous cultivation) * cost of losses per landslide

Equation Used in the Calculation

All Japan: (1,851 cases/year — 151 cases/year) * US$0.84 million/case = US$1.428 billion
Hilly and mountainous areas only: (1,092 cases/year — 93 cases/year) * US$0.84 million/case = US$0.839 billion

FUNCTION OF ORGANIC WASTE DISPOSAL

The Concept

Microorganisms in cultivated soil use organic materials as a food source, and eventually reduce them to their mineral form which can be directly used by plants. Organic wastes such as food residues and human wastes can thus be returned to fields as compost. This differs from disposing of wastes as landfill. Organic materials returned to the fields are recycled and used by crops as part of the global circulation of materials. Thus, cultivated farmland receives organic wastes, thereby reducing final disposal costs.

Preconditions

The volume of wastes (disposed of as organic fertilizer in fields) is valued on the basis of the disposal costs. In some cases, returning organic wastes to cultivated farmland is beneficial to the farmland. Therefore, the cost of purchasing organic fertilizers is reduced.

Method of Calculation

Valuation: Volume of wastes such as food residues disposed of by applying them to fields * waste disposal costs = (Volume of municipal waste returned to cultivated farmland * waste disposal costs + volume of human waste returned to cultivated farmland * waste disposal costs) + (volume of sludge returning to cultivated farmland * waste disposal costs)

Equation Used in the Calculation

Waste disposal costs, including food residues = 63,145 mt/year * US$51.85/mt + 861,765 kl/year * US$63.08/kl + 226,000 mt/year * US$27.85/mt = US$0.064 billion
(Hilly and mountainous areas only: US$0.064 billion * 0.41 = US$0.026 billion)

Remarks

Human wastes after disposal are utilized in various ways on cultivated farmland, not only as organic fertilizer. Therefore, the cost of purchasing organic fertilizer is not deducted.

FUNCTION OF AIR PURIFICATION

Concept

Vegetation growing on cultivated farmland purifies air by absorbing gases which are air pollutants, such as SO2 and NO2. The volume of these gases absorbed by crops is calculated and given a monetary value.

Preconditions

The volume of air pollutant gases absorbed by agricultural fields is calculated, and given a monetary value based on the replacement cost of flue gas desulfurization and denitrification.

Method of Calculation

Valuation = Estimated volume of air pollutant gases absorbed by fields * depreciation costs and maintenance costs of desulfurization equipment and denitrification equipment per metric ton treated.

Equation Used in the Calculation
All Japan: 49,388 mt * US$268/mt + 69,316 mt * US$1,244/mt = US$0.099 billion
Hilly and mountainous areas only: 20,900 mt * US$268/mt + 29,335 mt * US$1,244/mt = US$0.042 billion

FUNCTION OF CLIMATIC MITIGATION

The Concept

Due to the effect of evaporation from paddy fields covered in water, paddy fields can have a cooling effect on ambient air temperatures. In this way, paddy fields contribute to the climatic mitigation of surrounding areas, particularly in summertime.

Preconditions

The effect of a drop in temperature in the areas surrounding paddy fields is given a monetary value, based on the saving of air conditioning costs during the summer.

Method of Calculation

Valuation = Drop in temperature due to the latent heat effect of paddy fields * the number of households affected * the number of days in which air conditioning is used * electricity charges required for air conditioning * duration of air conditioning

Equation Used in the Calculation

Hokkaido: 82,974 households (hilly and mountainous areas: 27,908 households) * 0 day * US$0.0512/°C * 1.3°C * 6 hours = US$0 billion (hilly and mountainous areas: US$0 billion)
Tohoku: 678,998 households (hilly and mountainous areas: 196,572 households) * 23 days * US$0.0512/°C * 1.3°C * 6 hours = US$0.00624 billion (hilly and mountainous areas: US$0.00181 billion)
Hokuriku: 590,636 households (hilly and mountainous areas: 163,898 households) * 58 days * US$0.0512/°C * 1.3°C * 6 hours = US$0.01368 billion (hilly and mountainous areas: US$0.0038 billion).
Kanto: 819,151 households (hilly and mountainous areas: 106,030 households) * 52 days * US$0.0512/°C * 1.3°C * 6 hours = US$0.01701 billion (hilly and mountainous areas: US$0.0022 billion)
Tokai: 486,113 households (hilly and mountainous areas: 39,832 households) * 70 days * US$0.0512/°C * 1.3°C * 6 hours = US$0.01359 billion (hilly and mountainous areas: US$0.00111 billion)
Kinki: 538,223 households (hilly and mountainous areas: 76,228 households) * 75 days * US$0.0512/°C * 1.3°C * 6 hours = US$0.01612 billion (hilly and mountainous areas: US$0.00228 billion)
Chugoku: 288,480 households (hilly and mountainous areas: 92,509 households) * 68 days * US$0.0512/°C * 1.3°C * 6 hours = US$0.00783 billion (hilly and mountainous areas: US$0.00251 billion)
Shikoku: 375,714 households (hilly and mountainous areas: 73,583 households) * 76 days * US$0.0512/°C * 1.3°C * 6 hours = US$0.0114 billion (hilly and mountainous areas: US$0.00223 billion)
Kyushu: 573,483 households (hilly and mountainous areas: 112,987 households) * 82 days * US$0.0512/°C * 1.3°C * 6 hours = US$0.01878 billion (hilly and mountainous areas: US$0.0037 billion)
Okinawa: 0 household (hilly and mountainous areas: 0 household) * 153 days * US$0.0512/°C * 1.3°C * 6 hours = US$0 billion (hilly and mountainous areas: US$0 billion)

Total: 4,433,770 households = US$0.10446 billion (hilly and mountainous areas: 889,543 households = US$0.01965 billion)

Remarks

In this paper, only the climatic mitigation function of paddy fields is evaluated, although crop fields also have this function. It is assumed that each household will have air conditioners, regardless of any drop in temperature produced by adjacent farmland. For this reason, only a saving of the running cost of air conditioning is included, not the purchase cost.

FUNCTION OF PRESERVING
AMENITIES FOR RECREATION AND RELAXATION

The Concept

Paddy fields and upland fields not only constitute a beautiful rural landscape, but also create unique natural, cultural, and social environments. Many of those living in urban areas like to visit the countryside, seeking the landscape and natural amenities that cannot be found in cities, as well as for leisure and relaxation.

Preconditions

Assuming that the costs required when urban residents visit a rural area are equal to the benefits obtained from a visit to a rural area, the function of preserving rural amenities for recreation and relaxation are given a monetary value based on the costs of travel from urban to rural areas.

Method of Calculation

Valuation = (The number of tourists with the purpose of recreation * the proportion of tourists coming to a rural area * the correction coefficients of the number of tourists with the purpose of recreation * costs per visit per person) + (The number of homecoming people to rural areas * the proportion of homecoming people to rural areas * cost of homecoming).

Equation Used in the Calculation

A. Overnight visit: 186.55 million persons * 0.55 * 0.35 * US$430 = US$15.442 billion
B. One-day visit: (From four metropolitan areas) 71.3 million persons * 0.7 * 0.35 * US$44 = US$0.769 billion
   (From other local cities) 278.04 million persons * 0.7 * 0.35 * US$32 = US$2.18 billion
C. Cost of homecoming: 64.72 million persons * 0.30 * 1/2 * US$430 = US$4.174 billion


(Hilly and mountainous areas: (US$15.442 billion + US$2.949 billion) * 0.41 + US$4.174 billion * 0.62 = US$10.128 billion)

CONCLUSION

This paper has developed a monetary value for eight multifunctional roles of agriculture and rural areas, using the replacement cost method. The results are as follows: US$68.788 billion (6,878.8 billion yen) for the whole of Japan, and US$30.319 billion (3,031.9 billion yen) in hilly and mountainous areas only.

In this study, the replacement cost method was applied to estimate the monetary value of the multifunctional roles of agriculture, particularly in hilly and mountainous areas. How to maintain these roles in such areas is now an important policy issue in Japan. In order to obtain detailed information for the discussion of policy issues, the calculation was carried out in greater detail than the conventional replacement cost method.

In this calculation, the functions regarding the conservation of Japan’s land resources are evaluated in detail. However, the functions related to the preservation of amenities in rural areas, where traditional culture has its home and which provide a habitat where wild animals and plants can live, have not been discussed fully. In the future, it is important to evaluate these functions as well using appropriate substitutive goods. Moreover, it is necessary to apply CVM and a range of other experimental methods, in order to obtain an accurate estimate of the monetary value of Japan’s agriculture.

REFERENCES

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