How Can We Evaluate the Sustainability of Agriculture? An Evaluation by NAMEA and the Ecological Footprint

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Abstract

The objectives of this study are as follows. (1) Using a case study of Hokkaido Prefecture in Japan, National Accounting Matrix including Environmental Accounting (NAMEA) is applied to agriculture to understand the status of its economy, its multifunctionality, and its environmental loads on a common framework. (2) Agriculture sustainability is then inclusively measured by the ecological footprint.

The NAMEA proposed in this study is based on the Japanese edition. It can measure environmental loads and also the multifunctionality of agriculture. It also attaches an ecological footprint (EF) to measure sustainability.

1. Introduction

Agriculture and forestry (commonly referred to as agriculture) provide multifunctionality as well as food and energy crops. On the other hand, agriculture actually generates environmental loads. When considering agriculture sustainability, the following points must be considered: (1) economic

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growth evaluated in monetary terms; (2) the promotion of multifunctionality; and (3) the reduction of environmental load evaluated in physical terms. It is necessary to present them in a common framework.

To understand these three factors in a common framework, with some modifications, the National Accounting Matrix including Environmental Accounts (NAMEA) can be applied to agriculture. And ecological footprint (EF) contributes to the measurements of agriculture sustainability. Furthermore, as agriculture heavily depends on geographic and climatic conditions of a particular area, an agriculture analysis should be performed at regional levels.

The objectives of this study are as follows. (1) NAMEA is applied to agriculture to understand the status of its economy, its multifunctionality, and its environmental loads on a common framework using a case study of Hokkaido Prefecture in Japan. (2) Agriculture sustainability is then inclusively measured by EF.

2. Agricultural NAMEA of Hokkaido Prefecture

2. 1 Agricultural NAMEA

The NAMEA proposed in this study is based on the Japanese model (J-NAMEA) proposed by Ariyoshi and Moriguchi (2003). Its characteristics follow: (1) It calculates such stock indexes as the capital formation of economic indexes and also measures the volume of forests as environmental indexes. (2) It includes accounts of natural resources such as forests and water and also incorporates natural resource depletion. (3) It introduces land use accounts for agricultural lands, rivers, aquatic areas, and so on, which are closely related to environmental issues. In this study, J-NAMEA is revised to construct an agricultural NAMEA.

Agricultural NAMEA is revised in the following points in comparison with J- NAMEA: (1) It is broken down into regional economic levels from its original national economic levels. Since such regional factors as geography and climate are heavily related to agriculture production, it is important to consider them in the analysis. Therefore, J-NAMEA, which was designed to be applied to national levels, is arranged and applied to regional levels. (2) J-NAMEA is arranged to understand only agriculture. Although J-NAMEA covers entire industries, our study focuses on agriculture. Therefore J-NAMEA framework is arranged for agriculture only. (3) It introduces a measurement of agriculture multifunctionality. Agriculture produces multi-functionality as well as food and energy crops. Multifunctionality is a kind of environmental benefit that categorizes external economy in economics. J-NAMEA only measures external diseconomy such as environmental loads and wastes. Therefore, external economy measurements must be incorporated into agricultural NAMEA. (4) Finally, it attaches EF to measure agriculture sustainability, which is another purpose of this study. Although many methodologies have been developed to measure it, EF is applied to measure sustainability in this study because it can measure it in physical terms, which are estimated using figures calculated in NAMEA. It distinguishes sustainability from a carrying capacity aspect.

The composition of agricultural NAMEA is indicated in Figure 1. NAMEA consists of two parts: a national accounting matrix (NAM) and environmental accounting (EA). Economic indexes are described with NAM, and environmental loads and agriculture multifunctionality are measured by physical terms and described with EA. Next, these indexes are converted to EF, which is then used to measure agriculture sustainability.

Agricultural NAMEA can systematically indicate the status of the economy, environmental loads, multifunctionality, and finally distinguishes agri-

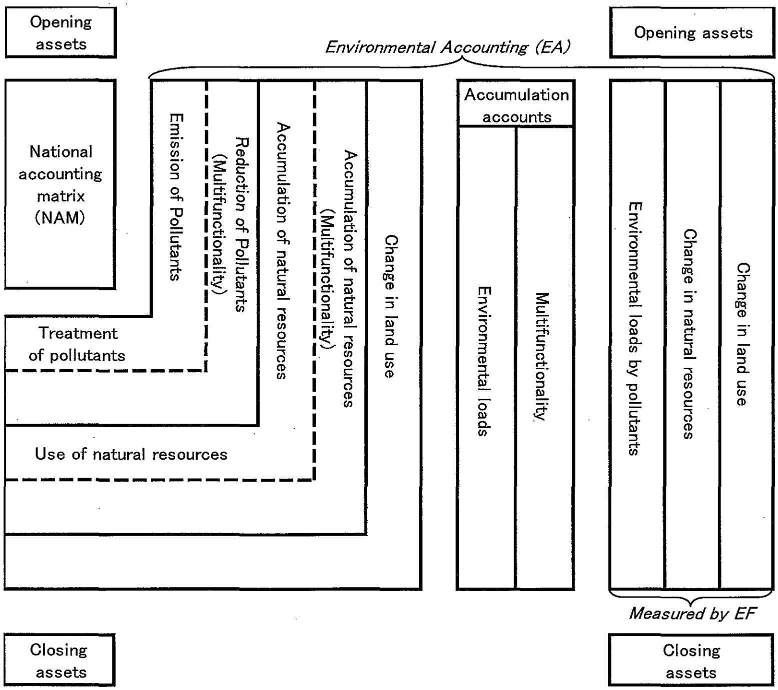

Figure 1 Components of agricultural NAMEA

culture sustainability. The calculation process is shown in Figure 2. First, economic indexes of agricultural production are described in NAM. The amount of environmental loads and wastes is mentioned in EA, on the right hand of NAM. Multifunctionality measurements are also mentioned here. Environmental loads and wastes are divided into two parts due to recycled/treated or accumulated to natural resources. The amount of recycled waste is indicated below NAM; recycled wastes are used for production again. The recycling process forms a clockwise circle in NAMEA: NAM, EA (right and under NAM), and NAM again.

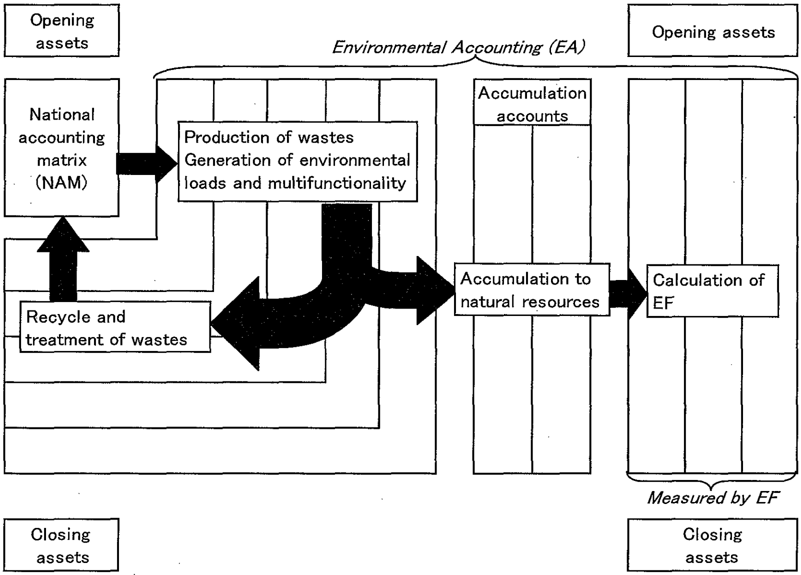

Figure 2 Calculation process of NAMEA

The amount of un-recycled waste and environmental loads accumulated in natural recourses is indicated in accumulation accounts in the center of EA. Multifunctionality is also mentioned in the accounts. Accumulation accounts show how agricultural production burdens environmental loads on natural resources and how much it produces multifunctionality. Environmental loads and multifunctionality are converted to single terms, an area unit by EF in the right side of EA. Both negative impacts (environmental loads) and positive impacts (multifunctionality) on natural resources are calculated by the same term. Finally, net EF can be estimated, as defined in the following equation, and used to distinguish sustainability:

$$\text{net EF} = \text{EL} - \text{M} \qquad (1)$$

where EL is environmental load and M is multifunctionality measured by

EF respectively.

2. 2 Survey Area

The survey area of this study is Hokkaido Prefecture located in northern Japan. Agriculture is one of the main industries in Hokkaido. The major types include arable crops, dairy farming in entire Hokkaido, and rice especially in central area. Dairy farming is conducted on a large scale in Hokkaido compared with other dairy farming regions in Japan. Therefore, water pollution in rivers and underground water supplies caused by livestock excrement is a serious problem in some parts of Hokkaido. Finally, forest area comprises a large part of Hokkaido's total land area.

3. Sustainability measurements

EF was originally developed by Wackernagel and Rees (1996). Rees (1996) defines EF as the "corresponding area of productive land and aquatic ecosystems required to produce the resources used, and to assimilate the wastes produced, by a defined population at a specified material standard of living, wherever on Earth that land may be located." When EF is compared with a given available area, we can judge whether such activities excess sustainable levels. If EF is smaller than a given area, human activities are sustainable. On the other hand, if EF is larger than a given area, they are not.

When judging agriculture sustainability, multifunctionality due to such activities should be heeded. In this study, EF measures not only environmental loads caused by agriculture but also multifunctionality provided by agriculture. Therefore, both positive and negative environment aspects are considered in EF.

Generally, EF is a tool for measuring sustainability from the viewpoints of environmental load and carrying capacity of a specific area to show whether present activities exceed carrying capacity. When adapting EF to measure environmental benefits such as multifunctionality, some of its concepts must be changed. Originally, sustainable development was judged by the following formula:

$$EF < CC \qquad (2)$$

where CC is carrying capacity that shows the absolute limitation of natural resources. By introducing environmental benefits, formula (2) must be changed to:

$$\text{net } EF < CC \qquad (3)$$

Under this formula, the EF of environmental loads is measured by positive figures, and EF of multifunctionality is measured by negative figures and deducted from that of environmental loads. Environmental loads affect increasing EF and environmental benefits inversely affect decreasing EF. This calculation shows the EF of net environmental loads (net EF). A comparison of net EF with carrying capacity shows whether activities are sustainable considering both environmental loads and multifunctionality.

This evaluation however, disturbs EF's sustainability judgments of present activities. The original EF can not only measure present status of environmental loads but also show the natural resources required to maintain our present activities by converting various environmental loads to area unit. Sustainability is judged by comparing EF and carrying capacity.

But, the net EF introduced in this study cannot show the required natural resources because multifunctionality is deducted from environmental load. This is caused by supposing that multifunctionality negatively affects environmental loads. This may detract from EF's advantages which can show the required natural resources.

However, it is thought that measuring both environmental loads and multifunctionality with single tool is important. Agriculture generates many positive effects to many people and wild-life living around rural area. On the other hand, agricultural production has been producing negative effect such as environmental load. These two aspects are thought differently because a tool for integrating these two aspects has not existed. By developing the tool, we can understand whether agriculture actually affects good or bad to environment. The priority of this study is to develop the tool. EF is the best tool for achieving our purpose by arranging it.

4. Estimation of Agricultural NAMEA

In this section, NAMEA estimation methodologies are explained. In agricultural NAMEA, economic status is measured in monetary terms, and environmental loads and multifunctionality are measured in physical terms. Since we are measuring the sustainability of agriculture production, only manmade forests are incorporated into the estimation; measurements of natural forests are excluded because they are not managed for commercial use.

Environmental load items considered in measurements include global warning, oxidization, water pollution, waste generation, consumption of forest and water resources, and land use. The multifunctionality items considered in the estimation are absorption of greenhouse and oxidized gases, accumulation of forest resources, and water storage. Regarding air pollution, CO_2 and N_2O for global warning factors, NO_x, SO_2, and NH_3 for oxidization, and SPM (Suspended Particulate Matter) for air pollution are considered in the measurement. Water pollution items are T-N, T-P, and BOD/COD. Plastic, rice straw, excrement, and livestock corpses are considered as waste items. Regarding natural resource use, energy (petroleum), forests, and water resources are measured. Land use measurements focus on the area of agricultural and forest lands.

The reduction of environmental loads and the accumulation of forests and water resources are considered. Reduction or absorption of CO_2, NO_x, and SO_2 are also measured as multifunctionality items. These items form counterparts to environmental loads items, showing both the positive and negative aspects of agriculture.

EF is estimated using EA calculations. Gas emission EF (CO_2, N_2O, CH_4, NO_x, and SO_2) and water pollutants EF (T-N, T-P, and BOD/COD) are measured by crop and forest areas required to absorb gas or water pollutants generated by activities. Forest resource use EF is calculated by the volume of forest area being cut. On the other hand, EF multifunctionality is mainly calculated as the land area required to produce multifunctionality substitutes that provide equivalent functions. The absorption of oxidized gas (CO_2, NO_x, and SO_2), in other words, phytoremediation function, is calculated by the cropping area volume. The accumulation of forest resources is calculated by the forest area itself. The EF of water resource storage is calculated by paddy field area, arable area, and forest area.

When measuring EF, similar multifunctions may cause double counting. For example, the treatment of wastes produces CO_2, NO_x, and so on. The EF of these pollutants is measured as items of CO_2 and NO_x itself. Therefore, the EF of waste items is not calculated in the waste category, and these figures are referred to as the EF of CO_2 and NO_x. Finally, the years estimated are 1995 and 2000.

5. Results

Since EF originally measures environmental loads, in this study positive EF figures indicate the environmental load volume, and negative EF figures show the multifunctionality volume. Environmental load EF, which is deducted from multifunctionality (net EF), shows the balance of environmental loads and multifunctionality. By comparing net EF with carrying capacity, the sustain-ability of activities is determined. A negative net EF shows that multifunction-ality is larger than environmental loads, and so activities are sustainable. This relation is explained in formula (3). On the other hand, if net EF > CC, present activities are not sustainable, even considering the multifunctionality from those activities.

The estimation results are as follows. In 1995, net EF was -895,000 hectare, and in 2000 it was -1,208,000 hectare (See Table 1). As each net EF is negative, multifunctionality exceeded environmental loads in both years. In 1995 and 2000, Hokkaido's agricultural activities were on the track to sustainable development in view of carrying capacity. Changes in EF between 1995 and 2000 decreased environmental loads from 4,654,000 hectare to 4,329,000 hectare, and multifunctionality also decreased from 5,549,000 hectare to 5,537,000 hectare. However, the environmental load decrease is much larger than in multifunctionality. These results mean that agricultural activities are approaching sustainable development, and they may have already achieved such sustainable development.

Table 1 Results of EF estimates (hectare)

EF estimates	1995	2000	Increase
EF of loads (a)	4,654,231	4,328,601	−325,630
EF of multifunctionality (b)	5,548,760	5,536,752	−12,008
net EF (=a−b)	−894,529	−1,208,151	−313,622

Table 2 A breakdown of EF (hectare)

Items	1995			2000		
	EF of loads	EF of mul.func	net EF	EF of loads	EF of mul.func	net EF
$CO_2/N_2O/CH_4$ (1)	973,006	-1,516,476	-543,470	787,282	-1,522,448	-735,166
NO_x/SO_2 (1)	648,885	-1,191,000	-542,115	526,629	-1,176,000	-649,371
NH_3	****		****	****		****
SPM	****		****	****		****
T-N/T-P/BOD/COD (1)	191,056		191,056	176,386		176,386
Plastic (2)	(1,840)		(1,840)	(2,758)		(2,758)
Excrement (3)	(191,056)		(191,056)	(176,386)		(176,386)
Rice straw (2)	(2,261)		(2,261)	(1,759)		(1,759)
Corpses	****		****	****		****
Forest resources (2)	(86,104)	-(32,926)	(53,178)	(62,071)	-(31,926)	(30,145)
Water resources	****	-2,841,284	-2,841,284	****	-2,838,304	-2,838,304
Use of agricultural land	1,324,808		1,324,808	1,315,856		1,315,856
Use of forest land	1,516,476		1,516,476	1,522,448		1,522,448
Change in agricultural land (4)	-(602)		-(602)	(2,904)		(2,904)
Change in forest land (4)	(1,297)		(1,297)	(90)		(90)
Total	4,654,231	-5,548,760	-894,529	4,328,601	-5,536,752	-1,208,151

Note:
(1) Items are integrated to avoid double counting. Figures in parentheses are not calculated in total EF to avoid double counting.
(2) EF of plastic, rice straw and forest resources are calculated in column $CO_2/N_2O/CH_4$.
(3) Excrement is calculated in column T-N/T-P/BOD/COD.
(4) EF of land use change is calculated in use of land.
(5) **** : Not estimated because of data availability.

Table 2 shows a breakdown of EF. The largest environmental load is land use. According to the EF concept, land use is understood as an environmental load. This result is quite natural because agriculture is land-intensive. The second largest environmental load is greenhouse gas (GHG), such as $CO_2/N_2O/CH_4$. The main cause of GHG emissions is farm households rather than agricultural production itself. The results reveal that GHG emission from households increased during 1995-2000. The GHG emission EF greatly decreased from 973,000 hectare to 787,000 hectare during the period 1995-2000 because the area of manmade forests grew and forest volume per hectare increased, and as a result, GHG absorption volume increased. Namely, the capability of GHG absorption increased during the period.

The largest multifunctionality is in water resources. The water resource EF is equal to the sum of agricultural and forest lands because the present amount of water storage is caused by the existence of the present agricultural and forest lands. The second largest multifunctionality is GHG absorption, which heavily depends on forest resources.

The sustainability mentioned above reflects the carrying capacity viewpoint and does not consider economic growth. The NAM indexes in NAMEA illustrate that agriculture production decreased between 1995 and 2000 (See Table 3). Therefore, agriculture did not achieve sustainable "development." This will be an argument over whether sustainability requires economic growth. To argue this point here carries us too far from the objectives of this paper. At the least, we suggest that a minimum sustainability condition is net EF growth despite economic decline. By comparing EF with production, net EF grew 26%, although economic activities declined 9.2%. Therefore, agriculture in Hokkaido achieved "sustainable decline" during 1995-2000.

Table 3 Economic growth and net EF

	1995	2000	Growth rate
Production (million yen)	1,271,633	1,164,284	-9.2%
Production per farm (thousand yen)	8,918	9,695	8.0%
net EF (hectare)	-894,529	-1,208,151	26.0% (1)

Note:
(1) For easy understaning, growth rate of net EF is calculated by positive figures. Positive figures of growth rate means better status of sustainability.

However, as regards with production per farm, there was 8.0% growth during 1995-2000. This result shows that microeconomic sustainability has already achieved. From the viewpoint of farm, agriculture of Hokkaido is sustainable contemporary to the viewpoint of entire agriculture of Hokkaido.

This result is caused by decrease of number of farms. As number of farms had rapidly declined, production of agriculture in entire Hokkaido had also declined among the estimated period. On the other hand, farms which had been continuing agricultural production had relatively good financial status. Therefore, pre farm income increased among the period.

6. Conclusions

The objectives of this study were as follows. (1) NAMEA was applied to agriculture to understand the status of its economy, its multifunctionality, and its environmental loads on a common framework, using the case study of Hokkaido Prefecture in Japan. (2) Agriculture sustainability was then measured inclusively by ecological footprint.

Agricultural NAMEA is revised with the following points in comparison with J- NAMEA: (1) It is broken down into regional economic levels from its original national economic levels. (2) It only focuses on agriculture. (3) It introduces the measurement of agriculture multifunctionality. And, (4), it attaches an ecological footprint to measure agriculture sustainability. Agricultural NAMEA systematically shows the status of the economy, environmental loads, multifunctionality, and agriculture sustainability.

The estimation results for Hokkaido agriculture prove that in 1995 and 2000 agricultural activities in Hokkaido achieved sustainable development and became much more sustainable from a carrying capacity aspect. However, as agriculture economic activities decline, they did not achieve sustainable "development" but sustainable "decline" when economic aspects during the period 1995-2000 were considered. On the other hand, as regards with production per farm, there was 8.0% growth during 1995-2000. This result shows that microeconomic sustainability has already achieved.

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