Developing an indicator for environment improvement potential in the agricultural sector

Takashi HAYASHI*

（Policy Research Institute, Ministry of Agriculture, Forestry and Fisheries, Japan）

Yoshifumi TAKAHASHI

(Hokusei Gakuen University, Japan)

Mitasu YAMAMOTO

(Otaru University of Commerce, Japan)

Contributed paper for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18, 2006

*Corresponding author. E-mail: th8841@affrc.go.jp

1. Introduction

Agriculture and forestry[1] produce various environmental benefits such as CO_2 absorption and water storage as well as food and energy crops. This means agriculture has the potential to improve the environment. By measuring such potential, we can understand agriculture's affect on the environment. However, it is also true that agriculture produces not only environmental benefits but also environmental loads. Therefore, both environmental benefits and loads must be considered to accurately measure the agricultural potential for improving the environment.

Furthermore, as potential cannot be calculated by a single environmental factor, it is necessary to consider various environmental factors in the measurements. Therefore, a new comprehensive indicator is required for understanding the potential to improve the environment. To develop the indicator, the National Accounting Matrix including Environmental Accounts (NAMEA) is applied to manage information concerning economies and environments, and the Ecological Footprint (EF) can also be adapted to integrate individual environmental factors.

In this paper, a new indicator is introduced that measures the agricultural sector's comprehensive potential for improving the environment. A trial estimation of the indicator is done by using a case study from Hokkaido, Japan.

---

[1]Hereafter, agricultural sector includes forestry.

2. Environmental Improvement Potential and Agricultural NAMEA

Agriculture produces environmental benefits that contribute to improving the environment. However, whether the environment has actually been improved in specific areas depends on such factors as climate, geographical conditions, and environmental loads from other sectors. Improvement cannot only be explained by the agricultural sector. Therefore, this paper focuses not on actual environment changes due to agriculture but on agricultural “potential” for improving the environment.

We define environmental improvement potential (EIP) as the capacity of agriculture to improve the environment. If EIP is positive, agriculture has the potential to improve the environment; if negative, agriculture has the potential to worsen the environment.

To measure EIP, the following two points are important. First, the measurement must be comprehensive. Since many factors influence the environment, we must consider various environmental factors when EIP is measured. Second, both environmental loads and benefits should be taken into account because agriculture produces not only environmental benefits but also environmental loads, and both affect EIP.

A basic framework, which measures agriculture EIP considering these factors, has been developed to manage various statistical data used for EIP measurements. The framework is based on the Japanese NAMEA model (J-NAMEA) proposed by Ariyoshi and Moriguchi (2003).[2] In this study, J-NAMEA was revised to construct a new framework called agricultural NAMEA (A-NAMEA). In comparison with J-NAMEA, the A-NAMEA proposed in this paper has been revised as follows: (1) J-NAMEA is configured to focus on agriculture. Although J-NAMEA covers transactions between one nation and the rest of world and also covers all sectors within the nation, agricultural NAMEA is modified to only cover transactions between agriculture and other sectors. (2) It introduces a measurement of environmental benefits caused by agriculture. Previous NAMEAs including J-NAMEA only measured negative externality such as environmental loads and did not measure such positive externality as environmental benefits. Therefore, measurements of positive externality are newly incorporated into A-NAMEA. (3) Finally, it attaches Ecological Footprint (EF) to convert various environmental loads and benefits, which are managed in A-NAMEA in different physical terms, to common units (areal terms).

As J-NAMEA, agricultural NAMEA also consists on two parts: NAM and EA (Fig. 1). Economic indexes are described with NAM, and both environmental loads and benefits are described with EA. Part of EA is used to convert environmental loads and

[2]NAMEA was originally developed by Statistics Netherlands. See Haan and Keuning (1996).

benefits to EF, which is then used to integrate various environmental factors in common areal terms. First, economic indexes of agricultural production are described in NAM. The amount of environmental loads and wastes is mentioned in EA on the right side of NAM. Measurements of environmental benefits are also mentioned here. Environmental loads and wastes are divided into two parts due to recycled/used or accumulated to natural resources. The amount of recycled or used waste is indicated below NAM, which wastes are used for production again. The recycling process forms a clockwise circle in NAMEA: NAM, EA (right side and under NAM), and NAM again.

The amount of unrecycled waste and environmental loads accumulated to the environment is indicated in the accumulation accounts in the middle of EA. Environmental benefits are also mentioned in the accounts. Accumulation accounts show how agricultural production burdens the environmental loads of natural resources and produces environmental benefits. Finally, environmental loads and benefits are converted to areal terms by EF on the right side of EA. By conversion to areal terms, we can measure various environmental loads in common units. A-NAMEA can systematically indicate the status of agricultural economy, environmental loads, and benefits.

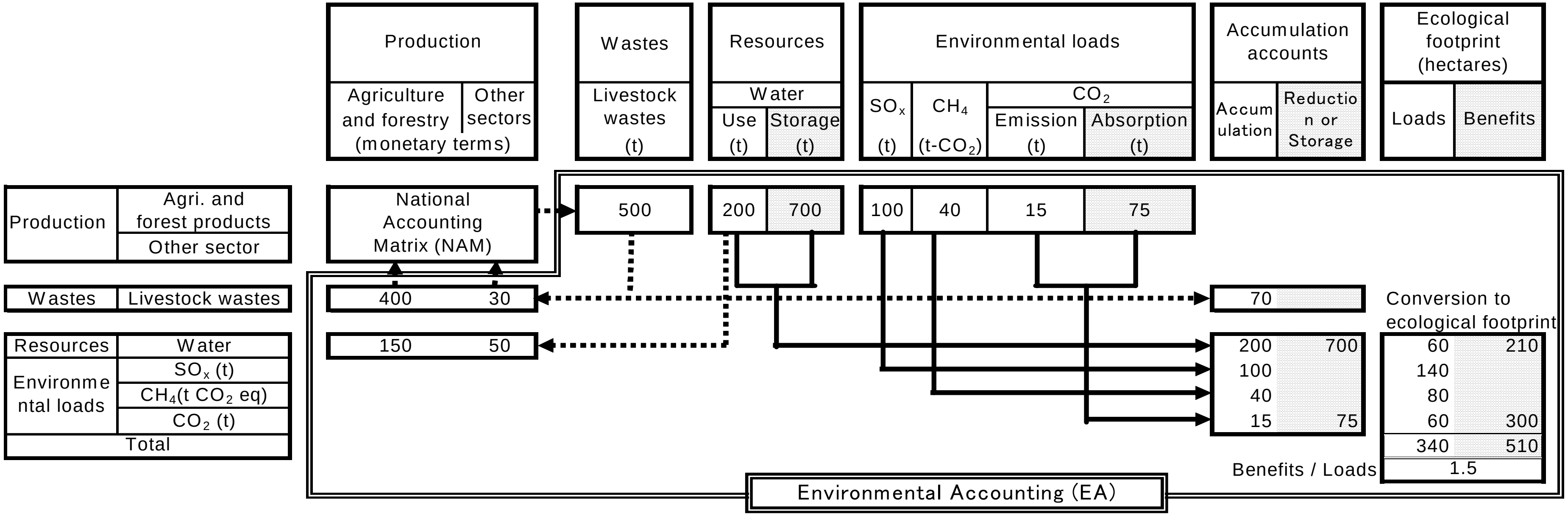


Fig. 1 Structure and numerical examples of A-NAMEA

3. An EIP indicator

Data in the A-NAMEA are used to measure the agri-environmental relationship. Traditional indicators for agri-environment are applied to a single environmental load or such issues as global warning, acidification, etc. Although admittedly measuring eco-efficiency by issues is important, it is also necessary to develop comprehensive environment indicators that enable people to easily understand whether agriculture can improve the environment. In this section, we introduce EIP as an agri-environmental indicator and explain EIP measurement.

We define EIP as the ratio of environmental loads and benefits, both of which are integrated in the areal term by EF in A-NAMEA:

$$EF^{r} = EB/EL, \qquad (1)$$

where EB is environmental benefits and EL is environmental loads in area terms. In general, as EL>0, EF^r satisfies $EF^r>0$. In the case of EFr>1, environmental benefits exceed environmental loads; therefore, agriculture has potential left for environmental improvement, which means EIP is positive (Fig. 2). On the other hand, when $0<EF^r<1$, as environmental benefits are smaller than environmental loads, agriculture has no potential left for improvement but instead potential to worsen the environment, which means EIP is negative. The closer EF^r is to 0, the smaller it is. Finally, when EF^r equals 1, environmental benefit equals environmental load. So, agriculture stands neutral to the environment, and EIP equals 0.

To understand EIP's dynamic change in a specific accounting period, we define CEF to consider the difference of EF^r at the opening (time point: t-1) and closing (time point: t) of the period:

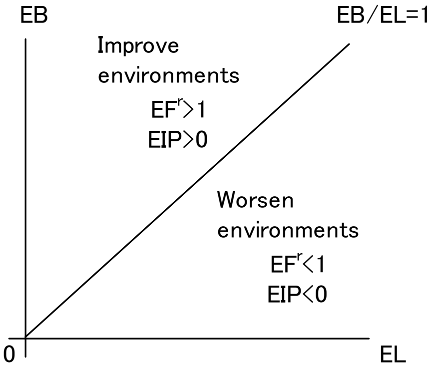


Fig. 2 Condition of EF^r and EIP

$$CEF = \exp\left(EF^{r}{}_{t} - EF^{r}{}_{t-1}\right). \qquad (2)$$

If CEF>1, EIP increases during the period, and if CEF<1, it declines. If CEF=1, EIP does not change. CEF only distinguishes the direction of EIP change without reflecting EIP's volume. Therefore, we must consider both EF^r and CEF. The area is divided into six segments by EF^r and CEF, as shown in Fig. 3. The status of EIP in each area is as follows.

(Area I) EIP increased and EIP itself is positive during the period. Agriculture has potential to improve the environment and increases it.

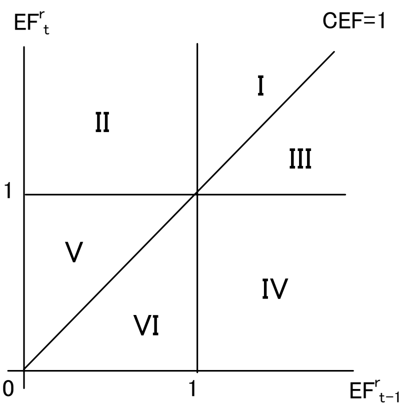


Fig. 3 Condition EF^r and CEF

(Area II) EIP increased during the period and EIP is negative at the opening and became positive during the period. Agriculture changed to have potential to improve the environment.

(Area III) Although EIP decreased, EIP still remained positive during the period. Therefore, agriculture has the potential to improve the environment but its potential is declining.

(Area VI) EIP decreased and EIP was positive at the opening and became negative during the period. Agriculture changed and lost potential for improving the environment.

(Area V) Although EIP increased, EIP is still negative during the period. Agriculture does not yet have the potential to improve the environment, but the potential is being promoted.

(Area VI) EIP decreased and was negative during the period. Agriculture has potential to worsen the environment.

4. Trial estimation of A-NAMEA

4.1. A-NAMEA for regional analysis

In this section, the first trial estimation of A-NAMEA is explained, and an estimation is also made using a case study of Hokkaido, Japan.

Issues of environmental load considered in measurements include global warning, oxidization, water pollution, waste generation, consumption of forest and water resources, and land use. Environmental benefit issues considered in the estimation are absorption of greenhouse and acidified gases, accumulation of forest resources, and water storage. These items form counterparts to environmental load items, showing both the positive and negative aspects of agriculture on agriculture. Regarding air pollution, CO_2 and N_2O for global warning factors and NO_X, SO_2, and NH_3 for acidification are considered in the measurement. Water pollution items are nitrogen and phosphorus. Plastic, rice straw, and livestock waste are considered waste items. Regarding natural resource uses, energy (petroleum), forest, and water resources are measured. Land use measurements focus on the area of agricultural and forest lands.

EF for gas (CO_2, N_2O, CH_4, NO_X, and SO_2) and water pollutants (nitrogen and phosphorus) are measured by crop and forest areas required to absorb gas or water pollutants generated by activities. EF for forest resource use is calculated by volume of forest area cut. On the other hand, EF for environmental benefits is mainly calculated as land area required to produce substitutes of environmental benefits that provide similar functions. Absorption of acidified gas (CO_2, NO_X, and SO_2), which is phytoremediation, is calculated by crop area volume. Accumulation of forest resources is calculated by forest area. EF of water resource storage is calculated by paddy field and forest areas.

When measuring EF, similar functions 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. Therefore, the EF for 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, EF^r is calculated using total environmental loads and benefits for 1995 and 2000.

4.2. Results

Estimation results are shown in Table 1, and the estimated A-NAMEA for 2000 is shown in Fig. 5. Environmental loads converted to areal terms by ecological footprint were 8.6 and 6.7 million hectares in 1995 and 2000, respectively. On the other hand, environmental benefits were 13.5 million hectares in both 1995 and 2000. EF^r was 1.57 and 2.01 in 1995 and 2000, respectively.

Next, CEF was 1.55, which implies that EIP increased during the period. Fig. 4 shows

Table 1 Results of EF^r and CEF estimation

	1995	2000
Loads (EL) (hectares)	8,642,619	6,731,831
Benefits (EB) (hectares)	13,541,610	13,508,690
EF^r=EB/EL	1.57	2.01
CEF=exp(EF^r_{00}−EF^r_{95})	1.55	

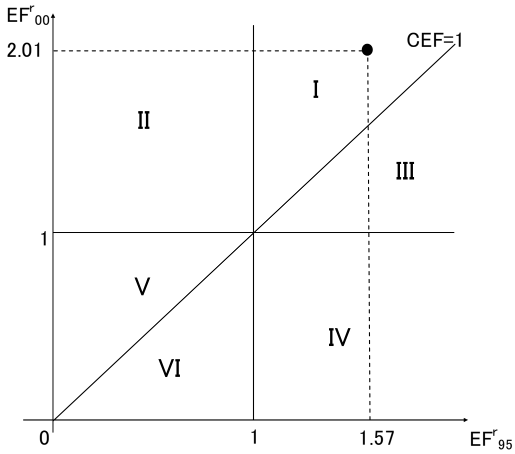
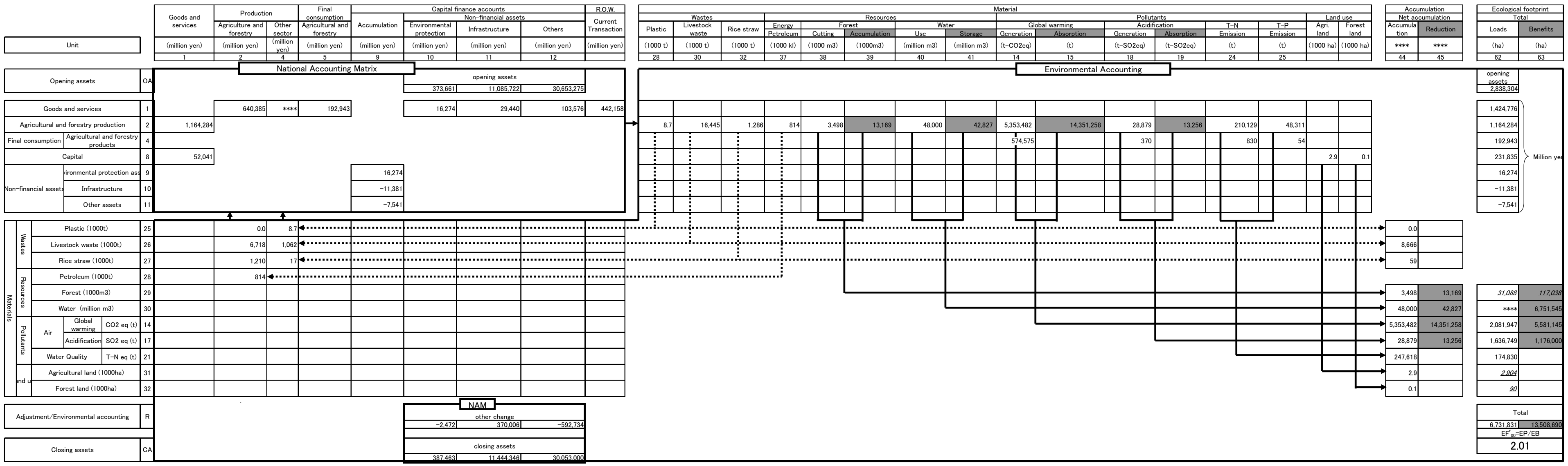


Fig. 4 EIP status in Hokkaido



Note:

****Not estimated due to data availability

XX Not used forEF^r calculation to prevent from double counting.

Figures for environmental benefits in physical term.

Fig. 5 A-NAMEA of Hokkaido in 2000

the status of agriculture in Hokkaido. As the point was in Area I, the agricultural sector had potential to improve the environment in both 1995 and 2000, and agriculture also increased its potential to improve the environment during the period.

5. Concluding remarks

In this paper, a new indicator was developed to measure EIP in the agricultural sector by using an NAMEA framework to which ecological footprint was applied. A trial estimation of the indicator was done using a case study of Hokkaido, Japan.

A-NAMEA is a useful tool for systematically arranging environmental and economic information. Various environmental factors measured in different physical terms are integrated by conversion to areal terms using EF. Then EIP indicators are estimated from information in A-NAMEA. The EIP indicator considers both environmental loads and benefits related to agriculture and also various environmental factors. The indicator shows agriculture's potential to comprehensively improve the environment.

The trial estimation of EIP using the Hokkaido case study shows agriculture in Hokkaido had the potential to improve the environment in both 1995 and 2000 and also that agriculture increased its potential to improve the environment during the period.

References

Ariyoshi, N. and Moriguchi, Y., 2003. The Development of Environmental Accounting Framework and Indicators for Measuring Sustainability in Japan, Proceedings of the Workshop on Sustainable Development held on 14-16, May 2003, at the OECD, Paris.
http://www.oecd.org/document/62/0,2340,en_2825_503546_2503806_1_1_1_1,00.html

Daly, H. E. and Cobb, J. B. Jr., 1989, For the Common Good, Beacon, Boston.

Haan, de M. and Kee, P., 2003, Accounting for Sustainable Development: The NAMEA-Based Approach, Statistics Netherlands,
http://www.cbs.nl/nl-nl/menu/themas/macro-economie-financiele-instellingen/nationale-rekeningen/publicaties/artikelen/accounting-for-sustainable-development-the-namea-based-approach.htm

Haan, de M. and Keuning, S.J., 1996, Taking the environment into account: The NAMEA approach, Review of Income and Wealth, 2, 131-48.

Hartridge, O. and Pearce. D., 2001, Is UK Agriculture Sustainable? Environmental Adjusted Economic Accounting for UK Agriculture, CSERGE-Economics University College London,
http://www.ucl.ac.uk/cserge/AGNNP.FINALFINAL.pdf

Ike, T., 1998. A Japanese NAMEA, Structural Change and Economic Dynamics, 10-1, 123-149.

Rees, W.E., 1996. Revisiting Carrying Capacity: Area-Based Indicators of Sustainability, Population and Environment, 17-3, 195-213.

Wackernagel, M. and Rees, W. E., 1996. Our Ecological Footprint: Reducing Human Impact on the Earth, New Society Publishers, British Columbia.

World Commission on Environment and Development, 1987. Our common future.

Yamamoto, M., 2006, Developing an environmental indicator including environmental benefits, Otaru University of Commerce Center for Business Creation Discussion Paper Series No.105.