Eco-efficiency Analysis of Organic Agriculture in Korea

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Abstract

Eco-efficiency which is calculated by dividing economic productivity by the environmental load was made by synthesizing eco and efficiency from ecology and economy, proposed by World Business Council for Sustainable Development in 2000. Eco-efficiency by connection of resource efficiency with resource intensity is used as an indicator for evaluating green growth for minimizing the impact on the environment and achieving economic development as well by means of efficient use of resources. This research analyzes eco-efficiency with the case of organic agriculture promoted as a key green growth policy. Thirty questionnaires for farmers producing organic rice in Hongseong-gun, Choongcheongnam-do were used for the analysis. Eco-efficiency was measured by means of the amount of used nitrogen with respect to the amount of income, and was represented that organic agriculture was 32.0 higher than conventional agriculture. The analytical result of technical efficiency, using the (Data Envelopment Analysis (DEA) model showed that it is 0.765 which has a possibility of 21% in management improvement, and higher eco-efficiency was with higher technical efficiency. The analytical results showed that an organic agriculture contributes to green growth more than conventional agriculture. In addition, higher technical efficiency groups exhibited higher eco-efficiency indices.

Introduction

The agricultural sector is promoting diversified green growth policies to grow the environment-friendly life industry together with the *Low Carbon Green Growth* policy of the Korean government. Green growth in the agricultural sector is defined as growth which is environmentally sound and economically profitable, considering environmental capacity of the agricultural ecosystem. Such green growth can be accomplished by conversion to the sustainable or organic agricultural system, e.g., environment-friendly agriculture and spreading low carbon agriculture.

There are some indicators for evaluating outcomes of green growth among which the eco-efficiency indicator is used in this paper. Eco-efficiency indicator is defined as a ratio of economic outcomes to the environmental pressure which is a key factor to be used as an index for evaluating green growth. Examples of applying eco-efficiency to the agricultural sector include research first attempted by Chang-Gil Kim and Hak-Kyun Jeong (2009) for analyzing eco-efficiency of geothermal heat pumps. This study is different from previous studies in that eco-efficiency for organic agriculture is analyzed for evaluating the outcomes of green growth then to compare it with technical efficiency.

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Methodology of Eco-efficiency Analysis

Eco-efficiency was made by synthesizing eco and efficiency from ecology and economy, proposed by World Business Council for Sustainable Development (WBCSD, 2000) and formally selected in the Earth Summit held in Rio de Janeiro, Brazil, in 1992. Eco-efficiency by connection of resource efficiency with resource intensity is used as an indicator for evaluating green growth for minimizing the impact on the environment and achieving economic development as well by means of efficient use of resources. Eco-efficiency is calculated by dividing the value in the industrial sector (economic productivity) by influence on the environment (environmental load) and defined as in the following equation 1.

(1) $$EE_r = \frac{y_r}{x_r}$$

where EE represents eco-efficiency and r is a sector (r = 1, 2, ..., k). x denotes an input variable (environmental influence) and y as an output variable (economic value).

The method of measuring eco-efficiency uses the input indicator of environmental load for the input variable and the economic productivity index for the output variable. For the environmental influence, physical indicators are used, but monetary indicators, e.g., sales, productivity and the like, are used for the economic indicators <Table 1>.

Table 1. Evaluation of Eco-efficiency using Input and Output

Category	Output indicator (y)	Input indicator (x)
Type	. Sales (or sale price) . Production . Productivity . Annual profit	. Unit element (energy, resource, water, land, waste, etc.) . General element (general environmental influence)
Evaluation category	. Production process (gate to gate) . Upper process (cradle to gate) . Entire process (cradle to grave)	

Generally, eco-efficiency is represented as a ratio of economic outcomes to an environmental load of a product. In this case, if the environmental load is not reduced but economic outcomes are improved, the eco-efficiency of the relevant product increases to cause problems in exactly evaluating the environmental outcomes. The Factor-X shown in equation 2 was proposed to solve such problems.

(2) $$FX = \frac{EE_r^t}{EE_r^0}$$

where EE_r^t represents eco-efficiency of comparison time (t) and EE_r^0 is eco-efficiency of reference time (0)

For measuring efficiency with respect to multi-input and multi-output, DEA method developed by Charnes, Cooper, and Rhodes(1978) was employed for calculating aggregate input in which a weight is given to a plurality of input elements and aggregate output in which a weight is given to a plurality of outputs

Eco-efficiency Analysis of Organic Agriculture

Analytical Data

For analyzing eco-efficiency of organic agriculture, questionnaire data (surveyed during 2010. 8. 20 ~ 9. 30) was used from 32 farmers producing organic rice with duck farming in Hongdong-myun, Hongseong-gun, Choongnam, which is an area well known for organic agriculture in Korea. The data showed that the farmers' average age who were in the analysis was 56.3 years; their school years were 12.1 years which are the period for at least high school education; years of practicing environment-friendly agriculture were 9.7 years; they were trained for organic agriculture 3.8 times per year; and the area for organic rice farming was 16,556 ㎡.

For analyzing eco-efficiency of conventional agriculture, it is necessary to use questionnaire data from farmers of conventional agriculture as for organic agriculture. The data of Choongcheongnam-do for the volume of main inputs and output were drawn from the *Agricultural Production Cost Survey Report* provided by Statistics Korea.

Analytical Result

The basic data for analyzing eco-efficiency comprises the ratio of nitrogen contents in mixed organic fertilizer, top soil, livestock manures, and rice bran which are the input materials applied to organic farming. The nitrogen contents of input material were drawn from analytical data and experts' advices in the National Academy of Agricultural Science and Rural Development. In addition, the data of farm management such as yields and income in Choongnam province were employed the Statistics of Cost for Producing Farm Products by Statistics Korea.

The eco-efficiency index is an index of environmental pressure ratio with respect to the economic outcome, and the eco-efficiency of organic and conventional agriculture was calculated by means of 'total income/amount of used nitrogen'. The eco-efficiency index of organic agriculture was 83.4 which was 32.0 higher than the eco-efficiency index of conventional agriculture of 51.4. If the number for the level of environmental pressure is limited to the amount of used nitrogen, it is analyzed that organic agriculture contributes to green growth more than conventional agriculture <Table 2>.

Table 2. Comparison of eco-eff in organic and conventional agriculture

	Amount of used N (kg/10a)	Yield (kg/10a)	Sale Price (won/kg)	Total Income (1,000 won/10a)	Eco-efficiency Indicator
Organic(A)	13.4	582	1,918	1,117	83.4
Conventional(B)	20.6	734	1,442	1,058	51.4
A-B	-7.2	-151.7	476.0	58.7	32.0

Comparative Analysis of Technical Efficiency and Eco-Efficiency

Model and Data for Analyzing Technical Efficiency

For measuring the efficiency of farmers producing organic rice in Hongseong-gun area, DEA method was modified to use total income of farmers producing organic rice and the amount of organic rice/10a as a yield variable, the cost of organic fertilizer, the cost of organic agricultural materials, the cost of labor and the amount of used nitrogen as input variables. The analysis was carried out for 30 farmers producing organic rice in the Hongseong-gun area. In this case, the linear programming model for calculating technical efficiency of j'th farmer in the Hongseong-gun area is shown in equation 3. Here, λ_j is a weight applied to the j'th farmer to modify the farmer's yield or inputs to achieve piecewise linearization.

(3) $Min\theta_j$

$$s.t. y_{jm} \le \sum_{j=1}^{J} \lambda_j y_{jm}, m = 1,2,..., M$$

$$\sum_{j=1}^{J} \lambda_j x_{jn} \le \theta_j x_{jn}, n = 1,2,..., N \qquad \lambda_j \ge 0, j = 1,2,..., J$$

Analytical Result of Technical Efficiency

As a result of analyzing technical efficiency of 30 farmers producing organic rice, 9 farmers were technically efficient. The 9 farmers formed an efficiency frontier and the relative efficiency was determined for the rest 21 farmers. The average technical efficiency was 0.79 which means a possibility of 21% in management improvement.

It was shown that, as the level of technical efficiency is higher, the level of yield is higher with low level of input. The most efficient group (9 farmers) showed 1.17 times and 1.12 times the entire group in terms of total income and the volume of production, but showed that their level was lower than the average of all farmers in terms of all of the cost of organic fertilizer, the cost of organic agricultural materials, the cost of labor and the amount of used nitrogen. That is, it is analyzed that the higher technical level group is doing production of more economic income but less environmental burden.

Concluding Remarks

This research evaluated the performances of green growth for organic agriculture which is a main green growth policy, using eco-efficiency indicator which is a key factor for green growth. The analytical results showed that an organic agriculture contributes to green growth more than conventional agriculture. In addition, higher technical efficiency groups exhibited higher eco-efficiency indices. In this note, we need for expanding organic farming which contributes more to green growth and to train farmers of lower technical and eco-efficiency for nutrient management through advanced cultivation training.

Since eco-efficiency indicator has a characteristic of partial factor and evaluation was made only with the ratio of environmental load to economic outcomes, it cannot represent absolute increase in environmental pressure. However, it is expected that analysis of eco-efficiency will be more important as a means for diagnosing and evaluating the outcomes of green growth in the agricultural sector. For analyzing eco-efficiency, interdisciplinary research is necessary in the field of agricultural economics, crop science, soil science, agricultural ecology and the like, in parallel with further scientific and technical research.

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