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A Study on the Management Efficiency of “Seolhyang” strawberries Farms Used SBM-DEA Model with Undesirable Output

Yu-Cong Sun, Shi-Yong Piao, Shuang-Yu Hu, Sung-Chan Kim, Jong-In Lee*
Department of Agricultural & Resource Economics, Kangwon National University

SBM-DEA 모델을 이용한 설향 딸기농가의 경영효율성에 관한 연구

손우총, 박세영, 호쌍우, 김성찬, 이종인*
강원대학교 농업자원경제학과

Abstract Ninety-nine strawberry farmers were assessed. A slacks-based and data envelopment analysis measure (SBM-DEA) of efficiency with an undesirable output was used to analyze the technical efficiency of farmers by taking carbon dioxide (CO2) as the undesirable output. Only 14 (14.14%) were technically efficient under a constant return to scale (CRS) and scale efficiency, while 30 (30.3%) households were technically efficient under variable return to scale (VRS). On average, the estimated technical efficiency scores of 'Seolhyang' strawberry farmers in the study area under the technical efficiency of the CRS (TECRS) assumption, technical efficiency of the VRS (TEVRS) assumption, and scale efficiency (SE) assumption were approximately 0.35, 0.53, and 0.60, respectively. The Tobit regression model was used to identify the factors influencing the technical efficiency of 'Seolhyang' strawberries. CO2 emissions, heating or not, and the land area negatively affected the technical efficiency, while the organic fertilizer ratio positively affected the technical efficiency. The effects of strawberry planting experience on the technical efficiency were not statistically significant. Therefore, agricultural policies should include measures to reducing the use of pesticides and fuels that emit high emissions and improve the use of organic fertilizers for sustainable strawberry development.

요 약 본 연구에서는 농촌진흥청에서 조사한 ‘표준소득자료집’의 99명의 설향 딸기농가 조사사료를 이용하여 분석하였다. 이러한 자료로 SBM-DEA 모델을 활용하여 이산화탄소 배출량을 고려한 설향 딸기농가의 경영효율성 분석을 실시하였다. 분석결과 99명 농가 중 14명(14.14%) 농가의 기술효율성은 불변규모수익(CRS)일 경우, 효율적인 것으로 나타났다. 반면, 가변규모수익(VRS)의 경우, 99명 농가 중 30명(30.3%) 농가의 순수기술효율성은 효율적인 것으로 나타났다. TE_{VRS} 가설, TE_{CRS} 가설, SE 가설을 통해 분석한 결과, 설향 딸기농가의 평균기술효율성은 0.53, 0.35, 0.60으로 나타났다. 그리고 Tobit모형을 통해 순수기술효율성에 영향을 미치는 요인을 분석하였다. 분석 결과 이산화탄소 배출, 난방여부, 재배면적 등 요인이 순수기술효율성에 부정적인 영향을 미치는 것으로 나타났다. 반면, 유기 비료의 비율은 높을수록 순수기술효율성이 높아지는 것으로 나타났다. 이는 유기비료를 많이 사용할수록 순수기술효율성에 긍정적인 영향을 미치는 것을 의미한다. 또한, 딸기농가의 재배경력은 순수기술효율성에 통계적으로 영향을 미치지 않는 것으로 나타났다. 따라서, 살충제 및 농약비용을 줄여야 하며, 지속가능한 딸기 생산을 위해 유기비료를 사용해야한다. 또한, 이산화탄소 배출 감소에 관한 농업정책을 설립할 필요가 있다.

Keywords : “Seolhyang” Strawberries, SBM-DEA With Undesirable Output, Tobit Model, Management Efficiency, Technical Efficiency

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*Corresponding Author : Jong-In Lee(Kangwon Univ.)
email: leejongin@kangwon.ac.kr
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1. Introduction

South Korean strawberries have high sugar content, high quality, and competitive price. Because of these advantages, South Korean strawberries are even exported abroad by chartered plane, capturing the taste of people all over the world. According to the Korea Agro-Fisheries & Food Trade Corporation (KATI) statistics show that the export volume of South Korea's strawberries has increased year by year. In 2020, the total export volume of South Korea's strawberries is 53.79 million US dollars, nearly double that of 2015 (33.03 million US dollars). The most important reason for the popularity of South Korean strawberries is taste. South Korea has four distinct seasons and higher sugar content than strawberries produced in other countries.

As of 2005, more than 90% of South Korean strawberries are Japanese varieties. To solve this problem, various regional agricultural technical institutes, including the Rural Development Office, have made a lot of efforts for the development and popularization of domestic strawberry varieties [1]. Starting with “Seolhyang”, the popularity of domestically grown snowberry for enabling cultivation has continued to expand which boosted farmers' incomes. Most of the strawberries grown in Korea are “Seolhyang” strawberries. Between 2006 and 2015, Seolhyang strawberries went from taking up 7.9% of the market to 81.3%, while Japanese varieties dropped from 78% to 7.4% during that same time.

Some processes produce some "bad" outputs as well as good ones that people need such as the wastewater and waste gas produced in the production process will have a negative impact on the production system, which is called undesired output. In today's environment protection era, it is obviously unreasonable to ignore the undesired output if we only pursue the desired output as much as possible. SBM-DEA with undesirable output was adopted and integrated with Life Cycle Analysis (LCA) results from 10 dairy cattle farms in Umbria (Italy) to estimate their environmental efficiency and emission reduction potential for marginal abatement costs knowledge that could allow assessing the economic impacts of different farms strategies aimed at reducing polluting emissions, as well as the introduction of incentive mechanisms by public decision-makers [2]. Kuang et al. took carbon emissions resulting from cultivated land use into the measurement framework of cultivated land use efficiency (CLUE), and SBM model with undesirable outputs, boxplot, kernel density estimation, and Tobit regression model are adopted for the analysis of 31 provinces in China from 2000 to 2017 and found that natural conditions, cultivated land resource endowments, agricultural production conditions, regional economic development, and regional science and technology development are important factors resulting in the disparity of China's CLUE [3]. Lena K et al. via SBM-DEA, approached the question of efficiency gains from both technical and environmental perspective along with a 2012 sample of 371 Chinese hog farms and separated the multiple effects of different determinants of technical and environmental efficiency using a Tobit model, founded that an efficient pig sector does not only require intensified, large-scale farms with high technical efficiency, but dedicated measures to solve the decreasing manure-land ratio [4]. In this study, CO_2 was regarded as undesired output. From the perspective of improving strawberry income, 99 strawberry farmers in Gyeongsang-nam do, Gyeongsang-bukdo, Gwangju gwangyeoksi, Jeollanam do, Jeolla-buk do, Chungcheong-namdo were selected as the objects to analyze the management efficiency of farmers by SBM-DEA model with undesirable output. Tobit Regression Model was used to identify the factors influencing the technical efficiency levels of ‘Seolhyang’ strawberry in Korea.

2. Materials and Methods

2.1 SBM-DEA Model with Undesirable Output

DEA is to use a mathematical programming model to compare the relative efficiency between decision-making units and evaluate decision-making units (DMUs). Since the model C^2R was established in 1978, new models have been constantly updated and applied in various fields [5]. Compared with other methods, DEA has the biggest advantage in that it does not need a pre-known production function and is not affected by the dimension of input and output data. According to the measurement method of efficiency, the DEA model can be divided into input-oriented, output-oriented, and addictive models. Input-oriented or output-oriented DEA model is chosen according to the purpose of the research. If both input reduction and output enhancement are desirable goals in a particular application, then a slacks-based measure [6] may provide the appropriate model structure to capture a decision-making unit (DMU)'s performance measure [7]. Tone, K. proposed and developed the SBM-DEA model [6], which solved the problem of slacks-based input and efficiency evaluation under the condition of undesired output. SBM-DEA model is a non-radial approach that is suitable for analyzing efficiency considering undesirable outputs, such as CO_2 emissions or greenhouse gas (GHG) [8].

There were n DMUs expressed as $DMU_j(j=1,2,\dots,n)$. X, Y and C are the input, expected output and undesirable output variables, respectively. Namely, $x \in R^m$, $y \in R^{s_1}$, $c \in R^{s_2}$. Matrix X, Y, C was defined as: $[X]=[x_1,\dots,x_n]^T \in R^{m\times n}$, $[Y]=[y_{1,}\dots,y_2]^T \in R^{s_1\times n}$ and $[C]=[c_{1,}\dots,c_2]^T \in R^{s_2\times n}$, X>0, Y>0, C>0.

The production possibility set P under constant returns to scale is defined below:

$$P=\{x,y,c \mid x \geq X\lambda, y \geq Y\lambda, c \geq C\lambda\} \quad (1)$$

Based on Tone's approach, the non-oriented SBM-DEA model with variable scale return could be specified as follows when considering undesirable output slack [9].

$$\rho^*=\min\frac{1-\frac{1}{m}\sum_{i=1}^{m}\frac{s_{i0}^-}{x_{i0}}}{1+\left(\frac{1}{s_1+s_2}\right)\left(\sum_{r=1}^{s_1}\frac{s_{r0}^y}{y_{r0}}+\sum_{r=1}^{s_2}\frac{s_{r0}^c}{c_{ro}}\right)} \quad (2)$$

S.T.

$$x_0=X\lambda+s_0^-$$

$$y_0=Y\lambda-s_0^y$$

$$c_0=C\lambda+s_0^c$$

$$s_0^-\geq 0,\ s_0^y\geq 0,\ s_0^c\geq 0,\ \lambda\geq 0,$$

Where, m, s_1 and s_2 are the numbers of input, expected output and undesirable output variables, respectively. s_0^-, s_0^y and s_0^c are the slack variables of inputs, expected outputs and undesirable output. λ is a non-negative weight vector for production possibility set construction linear programming. ρ^* indicates the resource and environmental efficiency, $0\leq\rho^*\leq 1$, is its value range with larger value representing higher efficiency. If and only if $\rho^*=1$ satisfies $s_0^-=0$, $s_0^y=0$ and $s_0^c=0$, the DMU is absolutely efficient, namely, comprehensive technical efficiency, technical efficiency and scale efficiency are all efficient. If $\rho^*<1$, or at least one of s_0^-, s_0^y and s_0^c not equals to 0, the DMU is not efficient, that is to say, technical efficiency or scale efficiency are not efficient.

2.2 Tobit Regression Model

The pure technical efficiency of 'Seolhyang' strawberry considered by the SBM-DEA model is not only affected by the input-output index but also affected by many external factors. Therefore, it is necessary to measure the influence of other factors on the pure technical efficiency of strawberries. In this paper, the Tobit model is used to analyze the influencing factors of strawberry pure technical efficiency. The Tobit model is used because it solves the model-building problem of limited or truncated dependent variables [10]. The pure technical efficiency of 'Seolhyang' strawberry is a discrete truncation value between 0 and 1 calculated by using the SBM-DEA model, and the Tobit model is expressed as follows:

$$Y_i = f(x) = \begin{cases} \alpha_i + \beta^T x_i + \epsilon_i, & Y_i > 0 \\ 0, & Y_i \leq 0 \end{cases} \quad (3)$$

Where, x_i is the independent variable vector, α is the intercept term vector, β is the correlation coefficient vector, Y_i is the dependent variable, and ϵ is the random error term.

Tobit model was specified in the study by the following function:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \mu_i \quad (4)$$
$$i = 1, 2, \ldots, n$$

Where,

Y_i is an efficiency measure representing pure technical efficiency of the i_{th} farm.

X_{1i} is planting experience of strawberry.

X_{2i} is emissions of CO_2 per square metre.

X_{3i} is heating as 1 if heating was used and 0 if heating wasn't used during planting.

X_{4i} is land size planting "Seolhyang" strawberries

X_{5i} is ration of organic fertilizer application.

β_0 is the intercept term.

$\beta_j (j = 1, 2, \ldots, 5)$ is represented coefficients associated with the co-responding independent variables.

Tobit regression parameters were estimated in Stata 16 software.

2.3 Data Sources and Indicator Selection

The cross-sectional data were obtained by Rural Development Administration (RDA) in South Korea. Data collection was done through interviews and calculated using literature statistics with 'Seolhyang' strawberry producers gathered from a total of 133 randomly selected 'Seolhyang' strawberry farm households in the 2018 production year. After sorting out the data, there are 100 producers with effective data, and the effective rate is 75.19%. Considering that the first stage of efficiency analysis by using the SBM-DEA model, eight inputs, one output, and one undesirable output were included. A suggested rule is that the number of DMUs is at least twice the number of inputs and outputs combined on the other hand state that the number of DMUs should be at least three times the number of inputs and outputs combined [11-12]. Thus, the number of DMUs of this research is efficient. The six 'Seolhyang' strawberry inputs were labor used (hour/m^2), seed cost (won/m^2), cost of pesticides (won/m^2), cost of fertilizer (won/m^2), cost of water, electricity, gas (won/m^2), and cost of other materials (won/m^2). The expected output was defined as the revenue of 'Seolhyang' strawberry (won/m^2). CO_2 emissions related to 'Seolhyang' strawberry cultivation were treated as undesirable outputs. Following the carbon emission coefficients of various sources from guidelines developed by the Intergovernmental Panel on Climate Change (IPCC) [13], Oak Ridge National Laboratory (ORNL), Institute of Resource, Ecosystem, and Environment of Agriculture of Nanjing University (IREEA), we estimated CO_2 total emissions using function as follows:

$$E = \sum E_i = \sum T_i \cdot a_i \quad (4)$$

Where, E is total carbon emission, E_i is carbon emissions from various carbon sources, T_i is the amount of each carbon source factor and a_i is carbon emission coefficient of each carbon source factor. Table 1 presents the data for CO_2 emissions coefficients, which are related to the value of pesticide and fertilizer from ORNL, a mulching film from IREEA, and diesel, kerosene, gasoline from IPCC.

2.4 Data Sources

The cross-sectional data were obtained from the agricultural income survey conducted in 2019 by RDA in South Korea. After disposal data, 99 strawberry farmers in Gyeongsang-nam do, Gyeongsang-bukdo, Gwangju gwangyeoksi, Jeollanam do, Jeolla-buk do, Chungcheong-namdo were selected as the objects of the study.

Table 1. Carbon emission coefficients of different emission sources.

Carbon sources	Carbon emission numerical value	Data source
Pesticide	4.9341 kg(C)/kg	ORNL
Fertilizer	0.8956 kg(C)/kg	ORNL
Mulching film	5.18 kg(C)/kg	IREEA
Diesel	0.5927 kg(C)/kg	IPCC
Kerosene	0.5714 kg(C)/kg	IPCC
Gasoline	0.5538 kg(C)/kg	IPCC

Note: ORNL, IREEA and IPCC refer to Oak Ridge National Laboratory, Institute of Resource, Ecosystem and Environment of Agriculture of Nanjing Agricultural University and Intergovernmental Panel on Climate Change, respectively.

3. Empirical Results and Analysis

3.1 Descriptive Statistics

The Descriptive statistics of variables used in the econometric analysis were interpreted in Table 2 and Table 3, includes two stages - the input, expected output, and undesirable output variables used in the SBM-DEA model for technical efficiency analysis and descriptive statistics of variables that affect technical efficiency.

The average labor used on ‘Seolhyang’ strawberry was 669.48 hours per year which range from 296.08 hours to 1,444.20 hours. On average, the seed cost used on ‘Seolhyang’ strawberry was about 251.23 won/m^2 per year which ranges from 33.00 won/m^2 to 712.50 won/m^2. The variable on the input used among farms was found on the utilization of pesticides

Table 2. Descriptive statistics of the input and output variables.

Index type	Indicator variables	N	Mean	Std. Dev.	Min	Max
Input	Labor used (hours)	99	669.48	259.82	296.08	1,444.20
	Seed cost (won/m^2)	99	251.31	109.40	33.00	712.50
	Cost of pesticides (won/m^2)	99	134.41	177.87	2.13	1,121.10
	Cost of fertilizer (won/m^2)	99	228.83	252.57	17.68	1,782.82
	Cost of water, electricity, gas (won/m^2)	99	423.03	555.65	9.47	3,258.31
	Cost of other materials (won/m^2)	99	1,115.17	1,000.34	92.93	5,545.81
Expected output	Revenue (won/m^2)	99	3,446.19	3,279.34	393.79	21,805.94
Undesirable output	CO_2 emissions (g/m^2)	99	357.08	449.30	32.72	2,595.59

was 134.41 won/m^2 per year with the maximum and minimum approximately 2.13 won/m^2 and 1,121.10 won/m^2 separately. The average expenditure for fertilizer was about 228.83 won/m^2 per year and there was a farmer who spent up to 1,782.82 won/m^2. The mean cost of water, electricity, and gas was 423.03 won/m^2 with a maximum of 3,258.31 won/m^2. The average cost of other materials was 1,115.17 won/ m^2 per year rang from 92.93 won/m^2 to 5,545.81 won/m^2. Under ideal weather conditions and management practices, the average revenue of ‘Seolhyang’ strawberry of the total household survey was about 3,446.19 won/m^2 per year with the minimum revenue at 393.79 won/m^2 and the maximum at 27,805.94 won/m^2. Undesirable output was evaluated by CO_2 emissions which of the mean value was 357.08 g/m^2 and it rang from 32.72 g/m^2 to 2,595.59 m^2 (Table 2). The data used in this paper had a limitation in that there were some significant differences between the minimum and maximum values. This is owning to the fact that the data from RDA were all grouped together as such it was difficult to separate the variables.

Table 3. Descriptive statistics of variables affect technical efficiency.

Variables	Units	N	Mean	Std. Dev.	Min	Max
Strawberry experience	Year	99	12.81	9.63	1	50
CO_2	g/m^2	99	357.08	449.30	32.72	2,595.59
Heating	Dummy variable (1 = Heating, 0 = Non)	99	0.90	0.30	0	1
Land size	m^2	99	4,406.80	2,228.10	1,050	9,961
Organic fertilizer ratio	100%	99	0.37	0.37	0	1

Concerning the farm-specific variables presented in Table 3, it was indicated that the average strawberry experience was 12.81 years, and the longest being 50 years. The average emissions of CO_2 were 357.08 g/m^2. The Heating method was used in about 90% of farms of a total household survey. The average land size of farms was 4,406.80 m^2 with a minimum of 1,050 m^2 and a maximum of 9,961 m^2. The average value of the organic fertilizer ratio was 0.37 with the range from 0 to 1.

3.2 Results of SBM-DEA Model with Undesirable Output

In terms of CO_2 emissions, an SBM-DEA model with undesirable output was used to measure technical efficiency from TE_{CRS}, TE_{VRS}, and SE of 'Seolhyang' strawberry farmers. Frequency distribution of farm-specific on technical efficiency of 'Seolhyang' strawberry production is also presented in Table 4 for 'Seolhyang' strawberry producers. Of the 99 sampled households, 30 (30.3%) households were technically efficient under VRS, while only 14 (14.14%) were technically efficient under both CRS and scale efficiency. On average, the estimated technical efficiency scores of 'Seolhyang' strawberry farms in the study area under TE_{CRS} assumption, TE_{VRS} assumption, and SE assumption were about 0.35 (range from 0.1 to 1), 0.53 (range from 0.1 to 1), and 0.60 (range from 0.2 to 1) respectively. On average, farmers are only earning35% (CRS), 53% (VRS), and 60% (SE) of the output of the best-practices farmers at the same level inputs. This indicated that farms should improve about 65% (CRS), 47% (VRS), and 40% (SE) of the efficiency in the utilization of input at the same production level. However, the sample farms with average technical efficiency score implied that farmers may reduce their use of input by 65% and 47% while holding the same level of 'Seolhyang' strawberry revenue.

Table 4. Frequency distributions of technical efficiency scores obtained from the SBM-DEA model.

Efficiency Scores	CRS		VRS		SE	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
0.00-0.10	0	0.00%	0	0.00%	0	0.00%
0.10-0.20	17	17.17%	3	3.03%	0	0.00%
0.20-0.30	27	27.27%	15	15.15%	5	5.05%
0.30-0.40	17	17.17%	14	14.14%	5	5.05%
0.40-0.50	8	8.08%	17	17.17%	15	15.15%
0.50-0.60	10	10.10%	12	12.12%	11	11.11%
0.60-0.70	5	5.05%	8	8.08%	13	13.13%
0.70-0.80	3	3.03%	2	2.02%	17	17.17%
0.80-0.90	1	1.01%	0	0.00%	11	11.11%
0.90-1.00	0	0.00%	0	0.00%	7	7.07%
1.00	14	14.14%	30	30.30%	14	14.14%
N	99		99		99	
Minimum	0.1		0.1		0.2	
Maximum	1		1		1	
Std. Dev.	0.31		0.33		0.24	
Mean	0.35		0.53		0.60	

Note: VRS = technical efficiency from variable return to scale SBM-DEA;
CRS = technical efficiency from constant return to scale SBM-DEA;
SE = scale efficiency = CRS/VRS.

3.3 Factors Influencing Technical Efficiency

To make appropriate recommendations for relevant policy review and implementation, it is necessary to identify the sources of variation in technical efficiency among various DMUs. Thus, several factors were regressed upon the efficiency scores to identify the determinants of efficiencies. The results of Tobit regression are presented in Table 5. The results show that 4 out of the 5 variables regressed using the Tobit model were statistically significant. Variables such as CO_2 emissions, whether to use heat or not and land size were all negative, meanwhile, Organic fertilizer ratio was positive, but statistically significant, on technical efficiency. Simultaneously, experience of growing strawberry was insignificant. The experience of growing strawberries had no effect on efficiency with undesirable output and was found to be statistically significant. This is because the ‘Seolhyang’ strawberry in the study is an improved new variety. Although some farmers have many years of experience in strawberry planting, their experience in new varieties is also limited. The CO_2 emission had a negative and statistically significant relationship with technical efficiency. This indicated that the lower CO_2 emissions, the higher of technically efficiency with undesired output. The negative but significant Heating coefficient showed that unheated planting was more likely to have lower cost and higher efficiency than heated planting. Because of bigger size land need more CO_2 is

Table 5. Results of the two-limit Tobit model showing factors that influence technical efficiency.

Variables	Coefficient	Std. Err.	t	P>|t|
Strawberry experience (Year)	0.0059996	0.005009	1.2	0.234
CO_2 (g)	-.0002688**	.000116	-2.31	0.023
Heating (1 = Heating, 0 = Non)	-.3131856**	.153991	-2.03	0.045
Land size (m^2)	-.0000395*	.0000235	-1.68	0.095
Organic fertilizer ratio (100%)	.2876865**	0.130052	2.21	0.029
_cons	.9757679***	0.206663	4.72	0.000
Pseudo R^2	.1186			

Note: Standard errors are in parenthesis, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

emitted by the pesticides, fertilizers, and fuel that farmers use to plant strawberries, the land size had a negative and statistically significant relationship with technical efficiency. The coefficient for organic fertilizer ratio had a statistically significant and positive relationship with technical efficiency. This positively estimated coefficient implied that strawberry revenue with increased proportion of organic fertilizer costs tend to be more efficient.

4. Conclusion

This study aimed to analyze the technical efficiency with undesirable output of ‘Seolhyang’ strawberry farms, as well as the challenges faced by smallholder strawberry farmers, and to identify factors that influence the efficiencies of ‘Seolhyang’ strawberry farms. Since high quality of ‘Seolhyang’ strawberry fruit and improved cultivation technology, expanding rapidly in South Korea, it is therefore necessary to examine the efficiency of strawberry planting.

Few farmers were found to be technically efficient in their revenue. Most of the farmers operated at below 60% technical efficiency, while 23.23% of the sampled households operated at above 60% technical efficiency or closer to the frontier output. Therefore, there is considerable scope for inefficient DMUs to either increase their efficiency or reduce their input costs by maintaining the same production level. In the short run, policy strategies aimed at improving technical efficiency should emphasize an effective and efficient use of existing technologies and enhance the capacity of the farmers to use inputs efficiently.

According to the results of the two-limit Tobit model showing factors that influence technical efficiency, 4 factors were affecting technical efficiency. Our findings indicated that CO_2 emissions, unheated planting, land size and organic fertilizer ratio were the main determinants. This study found lower CO_2 emissions unheated planting and smaller land size tended to be more efficient. Also, higher organic fertilizer ration may lead to the acquisition of better efficiency over time.

Therefore, shortly, agricultural policies should include measures for reducing the cost of pesticides and fuels that emit high emissions and Improve the use of organic fertilizer proportion to apply the available technology more efficiently by improving efficiency of 'Seolhyang' strawberry production. In addition, due to the lower environmental efficiency of farmers considering the emission of CO_2, it is necessary to carry out regular cultivation education and agricultural guidance for farmers about ways to plant strawberry more environmentally friendly, and improve productivity through more scientific, effective, and ecological production methods.

The cross-sectional character of the dataset entails certain limitations with regards to the interpretation of the results. First of all, water quality, climate, soil and other geographical environmental factors based on strawberry varieties were not considered. Also, cross-sectional data limits the interpretation of our results in terms of causality. Finally, there may be a distortion because of the grouped data. Despite this, ecological factors were considered in the management efficiency of 'Seolhyang' strawberry farmers, it will be helpful to improve the ecological efficiency of farmers' management and promote the economic and environmental sustainability of the strawberry growing industry in Korea. In addition to this, it is indeed necessary to conduct more studies focusing on environmental efficiency measures showing the relationship between farming activities and environmental efficiency as well as the effect factors of environmental efficiency which could be useful information for policymakers to supplement strategies for the sustainable development of agriculture.

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Yu-Cong Sun [Regular member]

- Jun. 2012 : JiLin Agricultural Univ., Information and Computing Science, BS
- Jun. 2018 : JiLin Univ., Agriculture and Forestry Economic Management, MM
- Sept. 2018 ~ current : Kangwon Univ., Dept. of Agricultural and Resource Economics, PhD Program

〈Research Interests〉
Livestock Economy, Consumer Behavior

Shi-Yong Piao [Regular member]

- Jun. 2015 : Yanbian Univ., Agriculture and Forestry Economic Management, BM
- Jun. 2018 : Kangwon Univ., Agricultural and Resource Economics, MSAE
- Sept. 2018 ~ current : Kangwon Univ., Dept. of Agricultural and Resource Economics, PhD Program

〈Research Interests〉
Livestock Economy, Food Consumption

Yu-Shuang Hu [Regular member]

- Jun. 2017 : Yanbian Univ., Agriculture and Forestry Economic Management, BM
- Jun. 2019 : Yanbian Univ., Rural Regional Development, MSC(Agr)
- Sept. 2019 ~ current : Kangwon Univ., Dept. of Agricultural and Resource Economics, PhD Program

〈Research Interests〉
Agriculture Circulation, Consumer Behavior

Sung-Chan Kim [Associate member]

- Feb. 2021 : Kangwon Univ., Agricultural and Resource Economics, BSAE
- Mar. 2021 ~ current : Kangwon Univ., Dept. of Agricultural and Resource Economics, MSAE Program

〈Research Interests〉
Livestock Economy, Food Consumption

Jong-In Lee [Regular member]

- Feb. 1987 : Kangwon Univ., Animal Science, BSC(Agr)
- Feb. 1993 : Kangwon Univ., Livestock Management, MM
- Aug. 1997 : Missouri Univ., Agricultural Economics, MSAE
- Dec. 2000 : Oklahoma Univ., Agricultural Economics, PhD
- Feb. 2006 ~ current : Kangwon Univ., Dept. of Agricultural and Resource Economics, Professor

〈Research Interests〉
Livestock Management, Livestock Economy, Food Consumption