

Article

Evaluating the Environmental Factors of Organic Farming Areas Using the Analytic Hierarchy Process

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Abstract: Sustainable agriculture, including organic farming, offers a potential remedy for addressing environmental pollution. Accordingly, the importance of evaluating the environmental benefits of organic agriculture has become evident. Numerous studies have compared organic and conventional farming or focused on specific crops in environmental studies; however, there is a lack of research on indicators that evaluate the positive impact of organic agriculture on the overall agricultural environment. Therefore, this study aimed to develop comprehensive agri-environmental evaluation indicators by utilizing an analytic hierarchy process (AHP). These methods were employed to determine the importance of factors that evaluate the environmental performance of organic agriculture. This study utilized literature reviews, derived and organized indicators, and prioritized evaluation factors using expert surveys and AHP methods. Based on the analysis of experts, physical and ecological agricultural environments were the most crucial evaluation factors, including biological properties. In addition to the physical ecological agricultural environments, the AHP results demonstrated the need for evaluation indicators that evaluate the overall agricultural environment, including the residential ecological environment and village living and cultural environment. Further empirical studies are required for the derivation of additional valid indicators and policy implementation.

Keywords: organic farming; agri-environmental indicators; analytic hierarchy process; importance assessment; sustainable agriculture



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1. Introduction

In recent years, there has been a growing focus on organic agriculture and its environmental evaluation in view of enhancing the sustainability of the agricultural sector. With the increasing degradation of the environment, there is widespread consensus that synthetic compounds, such as agrochemicals, have detrimental impacts on the environment. As the importance of sustainable agriculture has increased, organic agriculture and its environmental evaluation have become priorities worldwide. Therefore, it is necessary to focus on these trends. The IFOAM (International Federation of Organic Agriculture Movements) [1] defines organic agriculture as a production system that maintains the health of soil, ecosystems, and people. It aims to minimize the use of non-renewable resources by excluding negative inputs to the environment while relying on biodiversity and ecological cycles [2]. Organic agriculture incorporates traditional practices, innovative techniques, and scientific knowledge to enhance environmental sustainability, promote fairness, and improve quality of life.

In contrast, conventional farming heavily depends on pesticides, which contaminate water sources, harm beneficial insects, and decrease the nutritional value of crops [3]. According to the UN Food and Agriculture Organization (FAO) [4], intensive crop production causes soil depletion in numerous countries. Therefore, the FAO encourages sustainable agriculture, including organic farming. Consequently, there have been numerous efforts to increase the prevalence of organic agriculture on a global scale. According to a report

by the FiBL and IFOAM, the European Union has set a target of 25% for the area of organic agriculture by 2030, which is a substantial increase from the 9.6% recorded in 2021. Achieving this target would necessitate strong growth and effective management [5]. The report stated that the United States Department of Agriculture (USDA) made its largest investment in organic agriculture in 2022. Furthermore, Japan, with a mere 0.3% organic farming land in 2021, aims to increase its organic farming land to 25% by 2050.

Organic farming, which is of great importance, is influenced by various factors that impact the environment. To implement organic farming successfully, it is necessary to comprehensively investigate its environmental benefits. Some studies have been carried out on the environmental benefits of organic farming [5–8]; however, these studies primarily focused on crops or specific agricultural lands. Moreover, there has been limited research conducted on the factors that can be comprehensively evaluated to determine the environmental benefits of organic agriculture. Therefore, it is important to undertake a study aimed at deriving comprehensive indicators that can evaluate the overall environmental performance of organic agriculture and farms and to present the priorities of environmental evaluation factors.

As the importance of environmental indicators increases, the prioritization of such indicators is required. Therefore, this study aimed to identify and prioritize environmental factors to evaluate the environmental performance of organic agriculture and farms. An analytic hierarchy process (AHP) was employed as the methodology to achieve these study objectives. Specifically, this study proposes indicators to evaluate the overall organic agricultural environment. In addition, it aims to conduct AHP for experts such as academia and government agencies to derive priorities for evaluation factors and explore the implications of AHP results.

The derivation of comprehensive environmental evaluation factors that incorporate the physical and social environments of organic agriculture has novelty. Therefore, this study is expected to contribute to the expansion of organic farming and sustainable agriculture, as well as the development of environmental evaluation fields.

2. Literature Review

With the increasing severity of environmental degradation in recent years, the importance of sustainable agriculture has become apparent, and the environmental benefits of organic agriculture have been emphasized. Several studies have demonstrated the positive environmental effects of organic agriculture [5–8]. Smith et al. [6] discovered that organic agriculture offered a “win-win” solution for environmental sustainability through a global meta-analysis. They found that organic agriculture mitigated the negative impacts on the environment because of the low variability in biotic abundance and richness. Various studies have compared the environmental performance of conventional and organic agriculture [2,9–11]. Gomiero et al. [2] compared the environmental impacts of conventional and organic agriculture. They compared both the physical and social impacts (e.g., labor productivity and economic performance) of conventional and organic agriculture.

The importance of agricultural environmental performance has been recognized, and the European Council meetings in Cardiff (June 1998) and Vienna (December 1998) emphasized the significance of developing agricultural environmental indicators to assess the importance of land use for the preservation of cultural landscapes [12]. During the late 1990s and early 2000s, agricultural landscape monitoring and the development of metrics began in Europe [13]. The OECD (Organization for Economic Cooperation and Development) has established a set of agri-environmental indicators (AEIs) in several countries to increase agricultural productivity and minimize environmental damage [14]. AEIs facilitate the evaluation and comparison of the environmental impacts of agriculture between countries [14,15]. In addition to AEIs, there are a substantial number of agricultural environmental indicators worldwide. Among the various agricultural environmental indicators, the components of AEI by the OECD [16,17], three indicators mentioned in several studies: IRENA Agri-Environmental Indicators of the EEA (European Environment

Agency) [18], Canadian Agri-Environment Indicators [19], Agricultural Sustainability Indicators of the UK [20], and evaluation elements of the agricultural environment of Republic of Korea announced by the Rural Development Administration (<https://www.rda.go.kr/>, accessed on 27 February 2024), have been categorized into 10 distinct categories (Table 1).

Table 1. Various agricultural environmental indicators.

Criteria	OECD	EEA	Canada	UK	Republic of Korea
Land	Land cover	Land use change Land cover change	Agricultural land use	Area of agricultural land Change in land use	
Soil	Soil erosion	Soil quality Soil erosion	Soil cover Soil erosion risk Soil organic matter Soil salinization	Phosphorus levels in soil Organic matter content of soil Heavy metals in topsoil	Soil quality (physical, chemical) Heavy metals Microorganisms
Water	Water use Water quality	Nitrates Pesticides Groundwater levels	Nitrogen Phosphorus Coliforms Pesticides	Water for irrigation Pesticides in rivers Pesticides in groundwater	Water quality (rivers and groundwater) Pesticides
Farms	Farm management	Agricultural income of organic farmers Cropping/livestock patterns Farm management practices	Farm environmental management	Income from farming Adoption of management systems Conversion to organic farming	
Nutrient	Nutrients	Fertilizer consumption		Nitrate and phosphorus losses	Fertilizer consumption Inflow and removal of nitrate and phosphorus
Pesticides	Pesticide use	Pesticide consumption Pesticide soil contamination		Quantity of pesticides used Area treated with pesticides Pesticide residues in food	Pesticide consumption
Climate Change	Ammonia emissions, acidification, and eutrophication Methyl bromide use and ozone depletion GHG emissions and climate change	Share of agriculture in GHG emissions	Agricultural GHG Particulate matter	Ammonia emissions Methane and nitrous oxide emissions	
Energy	Energy consumption	Energy use Production of renewable energy		Indirect energy inputs	
Landscape		Landscape state			
Biodiversity	Genetic diversity Wild species diversity Ecosystem diversity	Population of farmland birds Genetic diversity Impact on habitats and biodiversity	Wildlife habitat capacity on the farmland indicator	Planting of non-food crops Area of cereal margins under environmental management Area of semi-natural grassland	

In this study, the AHP was conducted in the context of Korea. Therefore, the evaluation elements of the investigation into the Korean agricultural environment were also included. These elements are designated as enforcement regulations in Korea. Based on a report by the FiBL and IFOAM [21], the organic area share of total farmland in Republic of Korea was 2.5% in 2021, making it the second highest in Asia after Timor-Leste (8.5%), with a growth rate of 59.7% over a decade; however, the report further stated that local organizations have expressed concerns regarding the revocation of non-pesticide certification and have advocated for improvements to the organic certification system in Republic of Korea. According to this report and the agricultural environmental evaluation elements of Republic of Korea, current evaluation factors tend to excessively focus on pesticide usage while neglecting ecological considerations. Therefore, Republic of Korea requires enhanced agricultural environmental evaluation indicators capable of objectively and quantitatively assessing the effects of organic agriculture and contributing to environmental improvements.

Agricultural environmental indicators provide information on the relationship between agriculture and the environment. This allows governments and other users to appropriately identify, prioritize, and quantify agricultural environmental impacts, advance the targets of agricultural and environmental programs, and evaluate policies [22].

Several studies have evaluated the environmental performance and sustainability of farms or derived indicators for evaluation [23–27]. Agricultural environmental indicators have been created primarily in developed countries such as OECD member countries (Table 1). Thus, it may be difficult to apply these indicators to developing countries. To overcome these limitations, Zhen and Routray [23] have derived indicators suited for this purpose. Studies that evaluated the sustainability of farms using the response-inducing sustainability evaluation (RISE) sustainability assessment tool [24–26] are meaningful in that they evaluated the sustainability of farms at various levels, encompassing social, economic, physical, and ecological themes. Furthermore, Andrade et al. [27] utilized expert evaluations to test the validity of the derived indicators. They identified various indicators, such as AEIs and the European Green Deal (EGD), and incorporated them as dashboard indicators (DBIs) to evaluate the effectiveness of solutions aimed at improving the nutritional recovery of agriculture and livestock production across Europe. They evaluated the potential effectiveness of the technology employed to test the feasibility and relevance of DBIs through professional empirical knowledge using the Delphi method. The evaluation was conducted using the following steps: (1) experts from each technology answered a questionnaire about the potential effects of the technology, (2) researchers identified answers from experts in their field of research, and (3) researchers from each field questioned the experts about their doubts. Through these steps, the potential benefits and hazards of the technology were evaluated through qualitative evaluation using the Delphi method, and the expert evaluation was proven to be useful in deriving valid indicators. However, the Delphi method required multiple rounds of questionnaires from participants; thus, low participation rates and relatively long survey periods were anticipated. Therefore, this study utilized AHP instead of the Delphi method to determine the priorities of environmental evaluation factors in organic agriculture.

The AHP method, the oldest and most widely used technique among multi-criteria decision-making (MCDM) approaches [28], is designed for use in situations where decision-making in a variety of areas is required. Ordu and Der [29] developed the pairwise companion matrix to use AHP in setting the baseline weights, thereby proposing a technique to select the appropriate polymeric material for flexible pulsing heat pipe manufacturing. The developed pairwise companion matrix confirmed acceptability through consistency analysis. Tomar et al. [30] proposed a method for cloud consumers to choose appropriate quality of service (QoS) cloud services among many cloud service providers with various pricing and similar features. They used AHP to measure subjective weights for cloud service quality (via QoS) based on customer preferences.

Furthermore, the AHP method has been employed in several studies [31,32] to identify the elements of various environmental variables and prioritize them effectively. For instance, Gómez-Limón et al. [31] used the AHP method to build a composite environmental indicator to measure the environmental performance of olive growth. Moreover, Ismail and Abdullah [32] employed an AHP decision-making tool to propose a new EPI framework for alternative measures to evaluate environmental performance in ASEAN countries. In addition, the AHP can serve as an effective tool for investigating expert opinions and enhancing the validity of environmental evaluation indicators. The AHP is useful for weighting sustainability indicators due to its alignment with the structures of most sustainability frameworks [33]. Additional reasons for selecting AHP as the study methodology include: (1) AHP can be applied even if the subjective judgment of the participants is included, (2) qualitative data can be used, and (3) the consistency of judgment can be measured by obtaining the consistency ratio (CR). AHP contributes to the derivation of reliable indicators by evaluating the relative importance of each element through mutual comparison in the establishment of new organic agri-environmental evaluation indicators that combine physical ecological factors with humanities and social factors.

3. Materials and Methods

The AHP method, developed by Saaty [34], is a multi-criteria decision-making approach in which factors are arranged in a hierarchical structure. This structure starts with the overall goal and leads to the criteria, sub-criteria, and alternatives. This aids decision-makers in evaluating whether problems at each level are of comparable scale, enabling accurate comparisons of homogeneous factors and providing a comprehensive perspective on the complex relationships inherent in a scenario.

This study presents a three-step methodology for evaluating agricultural environmental indicators: identifying indicators, categorizing indicators, and prioritizing indicators through interviews.

First, an extensive literature review was conducted to compile a list of relevant indicators worldwide. From the substantial number of indicators used around the world, five types were selected as reference indicators for deriving evaluation indicators in this study: (1) AELs of the OECD, (2)–(4) three indicators mentioned in the literature review, and (5) indicators from Republic of Korea where the present study was conducted (Table 1). The first step of the AHP involved identifying the most important factors in the decision-making process. These factors were derived using existing indicators (Table 1) that satisfied two criteria: (1) relevant to the overall agricultural environment, such as residential areas and agricultural land, and (2) able to evaluate ecological properties. An expert consultation was carried out during this process to derive more reliable indicators.

Second, the selected factors were organized in a hierarchical manner (Table 2). The hierarchy was divided into three classes: criteria, sub-criteria, and sub-sub-criteria. Class 1 (Criteria) comprised four areas: “Farmland Physical Ecological Environment”, “Residential Physical Ecological Environment”, “Farmland Landscape”, and “Village Living and Cultural Environment”. Each area was further subdivided into Class 2 (sub-criteria) and Class 3 (sub-criteria).

Table 2. Hierarchy of selected factors.

Class 1 (Criteria)	Class 2 (Sub-Criteria)	Class 3 (Sub-Sub-Criteria)
Farmland Physical and Ecological Environment	Farmland Soil Environment	Cropland Soil Chemical Properties Cropland Soil Physical Properties
	Farmland Ecological Environment	Cropland Living Species Cropland Living Population Cropland Water Properties
Residential Physical and Ecological Environment	Residential Soil Environment	Residential Soil Cross-Sectional Properties Residential Soil Cover Properties Residential Soil Chemical Properties Residential Geographical Properties
	Residential Ecological Environment	Residential Biological Habitat Health Residential Biological Properties Residential Vegetation Diversity
	Residential Climate Environment	Residential Soil Moisture Resin Properties Residential Climate Properties
	Residential Water Environment	Residential Water Ecological Properties Residential Water Quality Properties
Farmland Landscape	Agricultural Production Landscape	Cropland Road Farming Methods
	Surrounding Natural Scenery	Buffer Zone Landscape Vegetation Stream and Channel
	Other Landscapes	Resting Facilities Facilities

Table 2. Cont.

Class 1 (Criteria)	Class 2 (Sub-Criteria)	Class 3 (Sub-Sub-Criteria)
Village Living and Cultural Environment	Economics	Rice Farming Total Income Pesticide Consumption Organic Agriculture Direct Payment Benefit–Cost Ratio
	Village Community	Village Organization Village Business Aging Population Public Facility Utilization

Finally, interviews with experts and professionals were carried out.

The survey was conducted between 21 November and 12 December 2023. The interviewees were selected based on either their major fields and affiliated institutions related to organic agriculture or through comprehensive environmental evaluation. An internet survey was conducted using a structured questionnaire. A total of 50 experts in the fields of organic agriculture, the environment, the humanities and social sciences, and policy were invited to participate in the survey via e-mail, and 32 valid samples were obtained (Table 3).

Table 3. Interview methods.

Category	Contents
Subject	Experts in the fields of organic agriculture, the environment, humanities and social sciences, and policy
Method	Web survey using a structured questionnaire
Number of interviewees	32 valid samples
Period	21 November 2023–12 December 2023

The study designed an evaluation scale based on a two-way, nine-point scale by judging the relative importance of a pair of items when evaluating an area or its detailed elements. A pairwise comparison was presented by Saaty in 1977 [35]; the definitions and meanings of each scale are presented in Table 4.

Table 4. Nine-point scale of pairwise comparison.

Scale	Definition	Explanation
1	Equal importance	Two activities have the same contribution to a certain criterion.
3	Weak importance	One activity is slightly preferred to another based on experience and judgment.
5	Strong importance	One activity is clearly preferred to another based on experience and judgment.
7	Very strong importance	One activity is strongly preferred to another based on experience and judgment.
9	Extreme importance	One activity is extremely preferred to another based on experience and judgment.
2, 4, 6, 8	Intermediate values	Comparison value based on experience and judgment falls in the middle of the above values.

In addition to importance weights, a consistency index can be calculated using the AHP method. The consistency ratio (CR) can serve as a measure of inconsistency [36]. According to Saaty, if the CR is less than 0.1, there is no problem with consistency; if it is lower than 0.2, it is tolerable; and if it is more than 0.2, it is necessary to study the problem and revise the judgments [36–38].

Therefore, we utilized 27 samples with a CR value of less than 0.2 for the final analysis (Table 5).

Table 6 presents the characteristics of the respondents included in the final survey analysis.

Table 5. Consistency ratio distribution of the respondents.

Category	Number of Respondents	Weight (%)
Total	32	100.0
$CR \leq 0.1$	10	31.3
$0.1 < CR \leq 0.2$	17	53.1
$CR \geq 0.2$	5	15.6

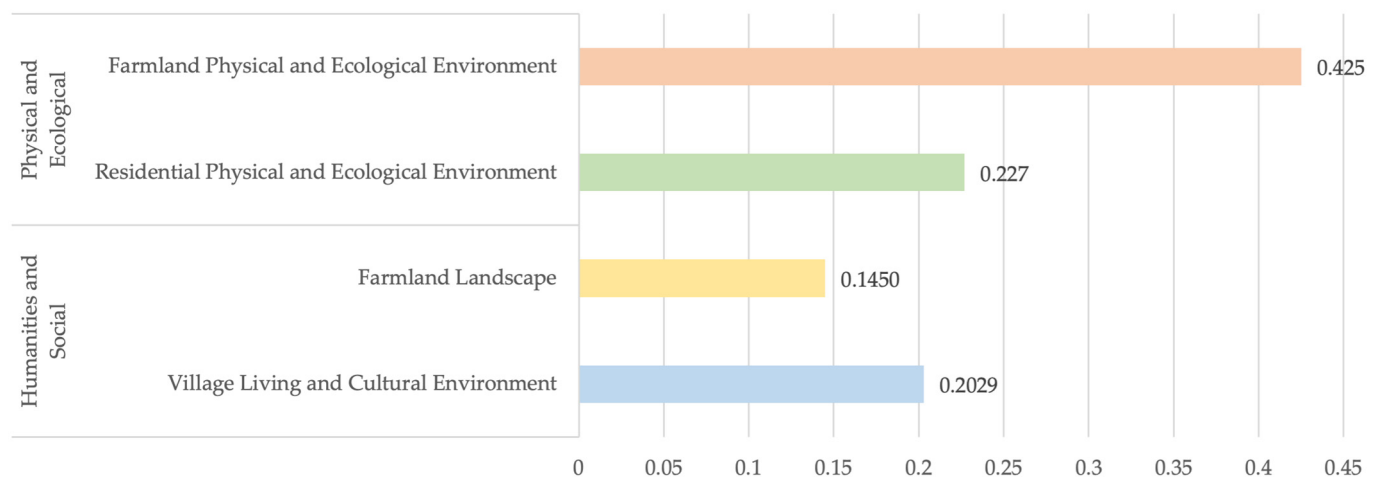
Table 6. Characteristics of respondents.

Category	Number of Respondents	Weight (%)
Total	27	100
Sex	Male	59.3
	Female	40.7
Age	20–30s	33.3
	40s	48.1
	50s	18.5
Major	Agriculture/Environment	18.5
	Landscape Architecture/Forestry	59.3
	Humanities and Social Sciences/Policy	22.2
Work Experience	Under 10 years	29.6
	11–15 years	37.0
	Over 16 years	33.3
Organization	Government/Public Institution	29.6
	University	66.7
	Business	3.7

4. Results

4.1. Importance Assessment of Criteria (Class 1)

Figure 1 shows the results for the importance assessment of criteria (Class 1). The assessment revealed that the environment, in terms of physical ecology, is recognized as more important than humanities and social science. The importance of “Farmland Physical and Ecological Environment” was the highest (0.425), followed by “Residential Physical and Ecological Environment” (0.227) and “Village Living and Cultural Environment” (0.2029). It was “Farmland Landscape” that showed the least importance (0.1450).

**Figure 1.** Importance assessment of criteria.

4.2. Importance Assessment of Sub-Criteria (Class 2)

Figure 2 displays the sub-criteria (Class 2) elements that make up the “Farmland Physical and Ecological Environment” of criteria (Class 1). In this context, the importance of

the “Farmland Ecological Environment” (0.5524), which represents the number of species, populations, and water quality, was slightly higher than that of the “Farmland Soil Environment” (0.4476), which relates to the soil chemistry and soil physical properties of the cultivated land. However, there was no statistically significant difference.

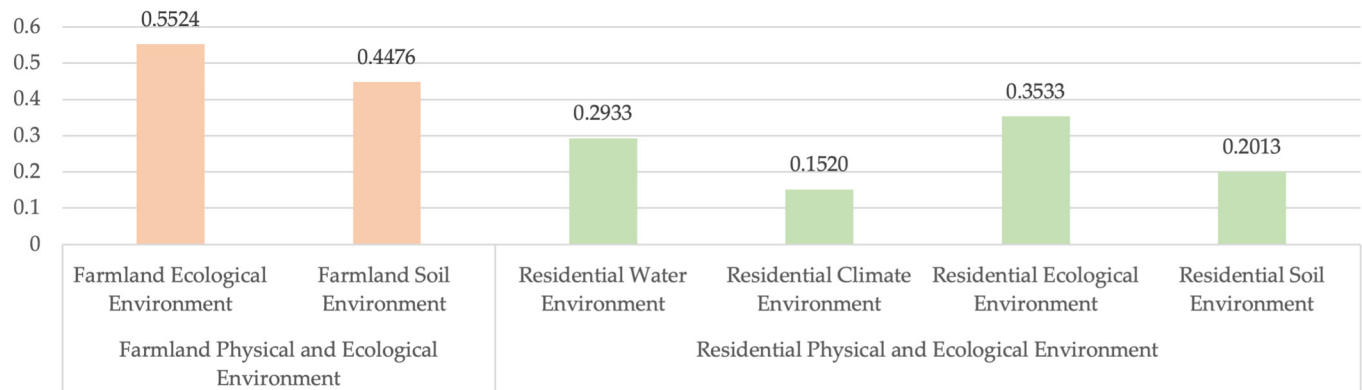


Figure 2. Importance assessment of the sub-criteria “Farmland Physical and Ecological Environment” and “Residential Physical and Ecological Environment”.

The four sub-criteria (Class 2) elements that make up the “Residential Physical Ecological Environment” area of criteria (Class 1) are also shown in Figure 2. Among these elements, the highest importance (0.3533) was accorded to the “Residential Ecological Environment”, specifically in terms of residential biological habitat health, biological properties, and plant diversity. This was followed by “Residential Water Environment (0.2933)”, “Residential Soil Environment (0.2013)”, and “Residential Climate Environment (0.1520)”.

Figure 3 displays the components (Class 2) of the “Farmland Landscape” area (Class 1). The importance of “Agricultural Production Landscape” (e.g., farmland, road, and agricultural method) was high (0.4995), and the importance of “Surrounding Natural Scenery” (e.g., buffer area, landscape planting, stream, and channel) was also relatively high (0.3495). However, the importance of “Other landscapes” (e.g., rest and agricultural production facilities) was relatively low (0.1510).

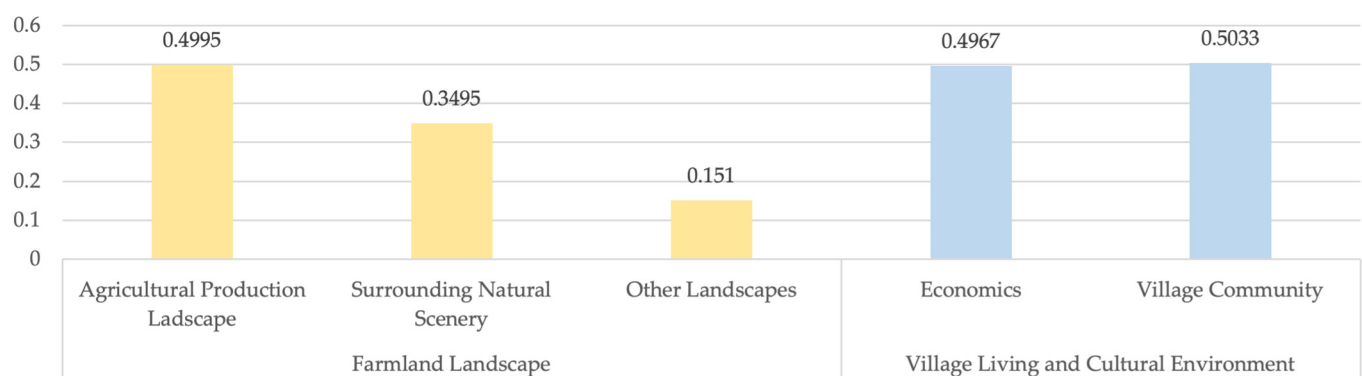


Figure 3. Importance assessment of the sub-criteria “Farmland Landscape” and “Village Living and Cultural Environment”.

Figure 3 also shows the components (Class 2) of the “Village Living and Cultural Environment” area (Class 1). There was no significant difference between the importance of the “Village Community” (0.5033), which includes village organization, village business, aging population, and common facilities, and the importance of “Economics” (0.4967), which includes agricultural sales revenue, organic material use, benefit–cost ratio, and eco-friendly payments.

4.3. Importance Assessment of Sub-Sub-Criteria (Class 3)

First, in terms of importance by sub-sub-criteria (Class 3), the importance assessment of the sub-factors in the “Farmland Soil Environment” within the “Farmland Physical Ecological Environment” area showed that the importance of “Cropland Soil Chemical Properties” (0.5399) was slightly higher than that of “Cropland Soil Physical Properties” (0.4601). Among the sub-factors of “Farmland Ecological Environment” in the same area, the importance of “Cropland Living Species” (0.4817), “Cropland Living Population” (0.2674), and “Cropland Water Properties” (0.2508) were found to be approximately equal in magnitude, as depicted in Figure 4.

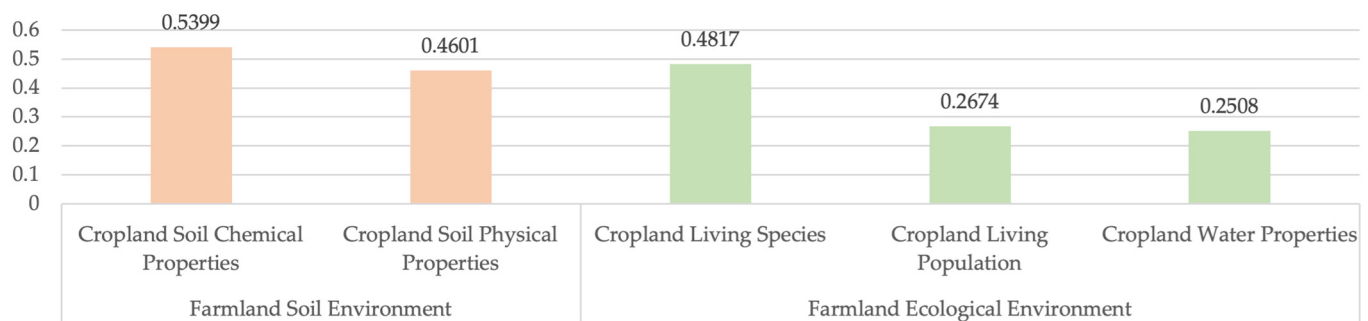


Figure 4. Importance assessment of the sub-sub-criteria “Farmland Physical and Ecological Environment”.

Second, as shown in Figure 5, in the importance assessment of the detailed elements constituting the “Residential Soil Environment”, the following decreasing order of importance was noted: “Residential Physical and Ecological Environment” area, “Residential Soil Chemical Properties” (0.3362), “Residential Soil Cover Properties” (0.2958), “Residential Geographical Properties” (0.2047), and “Residential Soil Cross-Sectional Properties” (0.1633). In the “Residential Ecological Environment”, the importance of “Residential Biological Habitat Health” was the highest (0.5399), whereas the importance values of “Residential Vegetation Diversity” (0.2908) and “Residential Biological Properties” (0.1693) were relatively low. In terms of the “Residential Climate Environment”, the importance of “Residential Soil Moisture Resin Properties” (0.5544) was somewhat higher than that of “Residential Climate Properties” (0.4456). Regarding the “Residential Water Environment”, the importance of “Residential Water Quality Properties” (0.5358), which represents turbidity, PH, TN, TP, and BOD, was found to be somewhat higher than that of “Residential Water Ecological Properties” (0.4642), which includes the Benthic Macroinvertebrates Index (BMI).

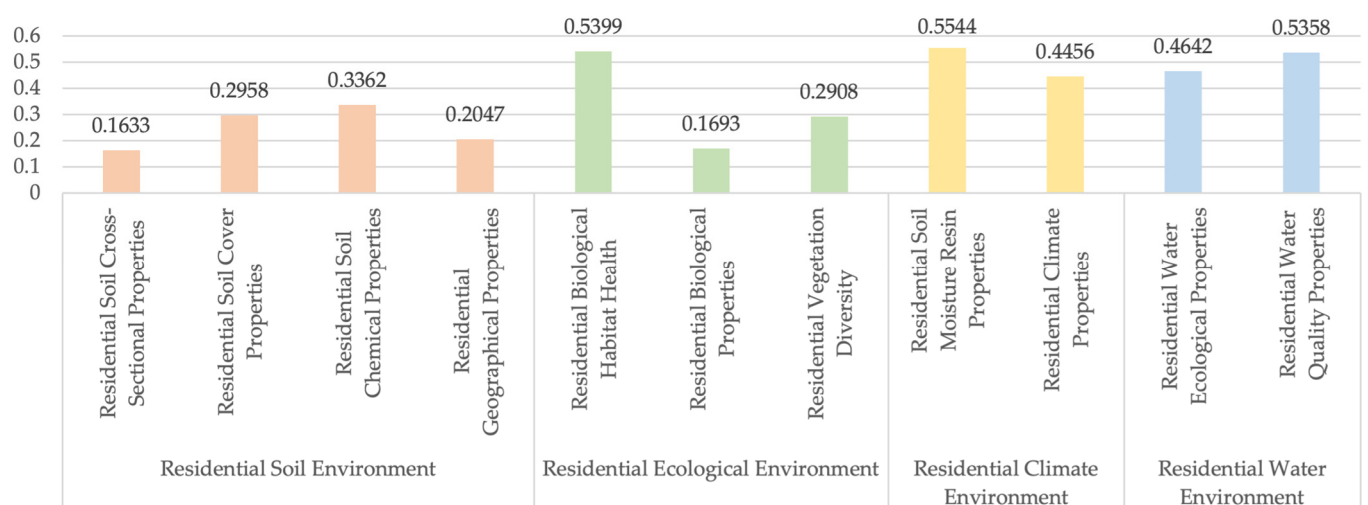


Figure 5. Importance assessment of the sub-sub-criteria “Residential Physical and Ecological Environment”.

Third, as shown in Figure 6, because of evaluating the importance of the detailed elements constituting the “Agricultural Production Landscape” among the “Farmland Landscape” areas, the importance of “Farming Methods”, which includes duck farming methods and complex agriculture, was the highest (0.5685), followed by that of “Cropland” (0.3161) and “Road” (0.1154). Regarding “Surrounding Natural Scenery”, the importance of “Landscape Vegetation” was low (0.1411). In “Other Landscapes”, the importance of “Facilities” (0.5793), which include greenhouses and storage warehouses, was found to be somewhat higher than that of “Resting Facilities” (0.4207), which include benches.

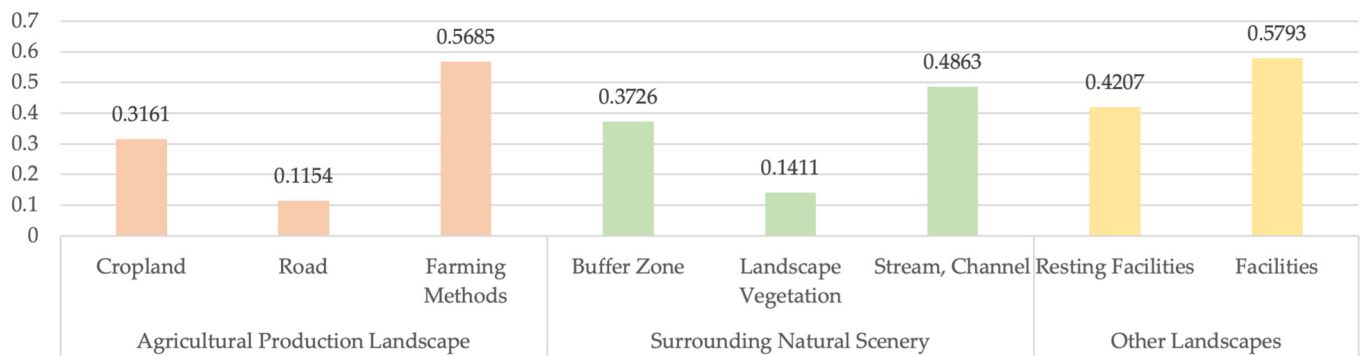


Figure 6. Importance assessment of the sub-sub-criteria “Farmland Landscape”.

Finally, as shown in Figure 7, in the “Village Living and Cultural Environment” area, the importance of the “Benefit-Cost Ratio” (0.3296) was the highest among the four sub-factors that constitute “Economics”. This was followed by “Organic Agriculture Direct Payment” (0.2578), “Rice Farming Total Income” (0.2106), and “Pesticide Consumption” (0.2020). Regarding the “Village Community” factor, the order of importance was as follows: “Village Organization” (0.3346), “Village Business” (0.2997), “Aging Population” (0.2031), and “Public Facility Utilization” (0.1626).

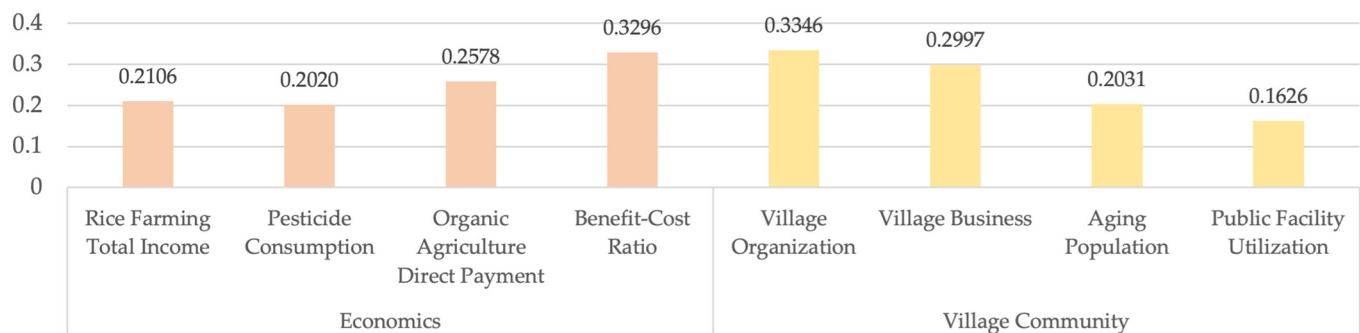


Figure 7. Importance assessment of the sub-sub-criteria “Village Living and Cultural Environment”.

4.4. Total Weighted Value

Table 7 illustrates the total weighted value derived by multiplying the evaluated importance of Classes 1–3 (criteria, sub-criteria, and sub-sub-criteria). By comprehensively analyzing the weights of the three classes, the total weighted value of the “Cropland Living Species” (0.1131) was evaluated to be the highest among the 32 sub-factors, followed by “Cropland Soil Chemical Properties” (0.1027), “Cropland Soil Physical Properties” (0.0875), “Cropland Living Population” (0.0628), and “Cropland Water Quality Properties” (0.0589).

Conversely, elements related to the “Residential Soil Environment” or facilities such as “Landscape Vegetation”, “Residential Soil Cross Sectional-Properties”, “Road”, “Resting Facilities”, and “Residential Geographical Properties” were given a low total priority ranking, indicating that they were not closely associated with the organic agricultural environment.

Therefore, it is necessary to review or exclude these elements based on the relevance, measurability, and acceptability of organic agricultural areas as evaluation indicators.

Table 7. Total weighted value and priority ranking.

Criteria (Class 1)		Sub-Criteria (Class 2)		Sub-Sub-Criteria (Class 3)		Total Weighted Value (A × B × C)	Total Priority
Area	Weighted Value (A)	Factors	Weighted Value (B) (A × B)	Detailed Elements	Weighted Value (C)		
Farmland Physical and Ecological Environment	0.420	Farmland Soil Environment	0.4476 (0.1902)	Cropland Soil Chemical Properties	0.5399	0.1027	2
				Cropland Soil Physical Properties	0.4601	0.0875	3
		Farmland Ecological Environment	0.5524 (0.2348)	Cropland Living Species	0.4817	0.1131	1
				Cropland Living Population	0.2674	0.0628	4
				Cropland Water Properties	0.2508	0.0589	5
Residential Physical and Ecological Environment	0.2270	Residential Soil Environment	0.2013 (0.0457)	Residential Soil Cross-Sectional Properties	0.1633	0.0075	31
				Residential Soil Cover Properties	0.2958	0.0135	26
				Residential Soil Chemical Properties	0.3362	0.0154	24
				Residential Geographical Properties	0.2047	0.0094	28
		Residential Ecological Environment	0.3533 (0.0802)	Residential Biological Habitat Health	0.5399	0.0433	6
				Residential Biological Properties	0.1693	0.0136	25
		Residential Climate Environment	0.1520 (0.0345)	Residential Vegetation Diversity	0.2908	0.0233	15
				Residential Soil Moisture Resin Properties	0.5544	0.0191	20
		Residential Water Environment	0.2933 (0.0666)	Residential Climate Properties	0.4456	0.0154	23
				Residential Water Ecological Properties	0.4642	0.0309	11
		Farmland Landscape	0.1450	Agricultural Production Landscape	0.4995 (0.0724)	Residential Water Ecological Properties	0.5358
Cropland Road	0.3161					0.0229	16
Farming Methods	0.1154					0.0084	30
Surrounding Natural Scenery	0.3495 (0.0507)			Buffer Zone	0.3726	0.0189	21
				Landscape Vegetation	0.1411	0.0072	32
				Stream and Channel	0.4863	0.0246	14
Other Landscapes	0.1510 (0.0219)			Resting Facilities	0.4207	0.0092	29
		Facilities	0.5793	0.0127	27		
Village Living and Cultural Environment	0.2029	Economics	0.4967 (0.1008)	Rice Farming Total Income	0.2106	0.0212	17
				Pesticide Consumption	0.2020	0.0204	19
				Organic Agriculture Direct Payment	0.2578	0.0260	13
				Benefit–Cost Ratio	0.3296	0.0332	10
		Village Community	0.5033 (0.1021)	Village Organization	0.3346	0.0342	9
				Village Business	0.2997	0.0306	12
				Aging Population	0.2031	0.0207	18
				Public Facility Utilization	0.1626	0.0166	22

5. Discussion

This study is one of the first to analyze the priorities of evaluation factors using the AHP method to derive an environmental evaluation indicator of organic agriculture that can evaluate the overall agricultural environment. The indicator used in the AHP method was derived by reviewing various agri-environmental evaluation indicators around the world [16–20]. Also, to evaluate the impact of organic agriculture on the overall agricultural environment, the derived indicators are characterized by including not only the physical ecological environment of the farmland but also the physical ecological environment of the residential area, the landscape of the farmland, and the village living and cultural environment in the evaluation factors.

In the results of the study, it is worth paying particular attention to the priority ranking of the total weighted value. All of the top five elements of the ranking are included in the “Farmland Physical Ecological Environment” area.

Among the “Farmland Physical and Ecological Environment” areas, soil quality is already recognized as a concept that includes functions such as environmental conservation as well as improving agricultural productivity [39]. Therefore, it has been recognized that soil environmental properties are important for evaluating the impact of organic

agriculture on the agricultural environment. The results of this study have also proven the importance of soil quality. However, the results of this study also emphasize that, as much as the physical and chemical properties of soil are important, the ecological properties of the whole agricultural area, such as the biological species, population, and health of the biological habitats, are also important factors in environmental evaluation.

The evaluation factors of the “Farmland Ecological Environment” being surveyed with a very high ranking in the top five areas are meaningful. The “Cropland Living Species” and “Cropland Living Population” were ranked first (total weighted value 0.1131) and fourth (total weighted value 0.0628), respectively. Therefore, when evaluating the impact of organic agriculture on the environment, it has been proven that not only the chemical and physical properties of the soil are important (ranked second and third, total weighted value 0.1027 and 0.0875) but also the ecological factors.

The SDG indicator 2.4.1 by the FAO, which provides an assessment of progress towards sustainable agriculture, also includes ecological factors such as biodiversity, in addition to soil health and pesticide risk [40]. Furthermore, the ecological principles of the agricultural environment provide a vision for future agricultural systems that promote sustainable food production [41]. Therefore, consideration of ecological factors is essential in the sustainability assessment of agriculture.

However, in the case of Republic of Korea, the existing agricultural environment survey and evaluation criteria tend to focus on the chemistry and physical properties of the soil, which are usually determined by pesticide usage [21]. As an ecological evaluation factor, only a wide category of “public interest functions of agriculture” exists. Through the results of this study, it was proven that more specific ecological environment evaluation factors such as “Cropland Living Species” or “Cropland Living Population” are necessary to improve the agri-environmental evaluation indicators in Republic of Korea. Including indicators of ecological factors that are considered crucial in sustainable agriculture will contribute to a comprehensive evaluation of the sustainability of organic agriculture.

In addition, in order to evaluate the overall environmental quality of agricultural areas, an integrated approach that considers the residential ecological environment and some humanities and social factors is needed, rather than viewing the farmland environment from a fragmented perspective. The ranking of “Residential Biological Habitat Health” in sixth place (total weight of 0.0433) holds great significance. As a result of reviewing various agricultural environment indicators, it was found that there was no indicator considering the residential area, but the results of the study proved that not only agricultural land but also the ecological environment of the residential area and the living and cultural environment of the village should be considered important in evaluating the environment of organic agriculture. If the environmental quality of agricultural land changes due to the practice of organic farming, the residential areas around the agricultural land will also be affected. For example, the “Cropland Living Species” in the agricultural ecological environment could be linked to the “Residential Biological Habitat Health” in the residential ecological environment.

Moreover, notably, several humanities and social factors ranked in the top 10. Agricultural production landscape according to the “Farming Method” ranked seventh (total weight of 0.0412), the “Village Organization” for environmental management of the entire village ranked ninth (total weight of 0.0342), and economic factors, such as the “Benefit-Cost Ratio”, that provide agricultural workers with a strong incentive to enhance the agricultural environment ranked tenth (total weight of 0.0332), evaluated as being high priority by experts.

This study makes a meaningful attempt to combine physical and ecological factors with humanities and social factors in evaluating the environment of organic agriculture. The indicators used in the AHP method in this study will be applicable in various countries because the indicators of several countries were considered. One limitation is that there may be independent cases in which indicators cannot be applied, depending on the situation in each country. In addition, since the AHP method used in this study was only conducted

for experts in Republic of Korea, there may be a difference in priorities when applied to other countries. Finally, another limitation is that an empirical analysis, which can confirm the applicability of the indicators, was not conducted in this study. To overcome these limitations, further studies should be conducted using the AHP method to target experts of various nationalities. In addition, more reliable and valid indicators should be developed by conducting additional empirical analyses and gathering further evidence.

6. Conclusions

With growing recognition of the contribution of organic agriculture to sustainable farming, objective indicators are needed to assess the impact of organic farming on environmental improvement. Although various indicators are available for evaluating the agricultural environment, there is a lack of comprehensive indicators specifically designed for evaluating organic agriculture, including settlement environments.

To address this gap, this study proposes indicators that can evaluate the overall organic agricultural environment. In addition, it aims to collect expert opinions on the prioritization of evaluation factors to improve the validity of the indicators.

In this study, experts from government/public institutions, universities, and enterprises were employed to prioritize agricultural environmental evaluation indicators. The agricultural environmental evaluation indicators were divided into four criteria and 32 detailed subcategories. The derivation process involved collecting various agricultural environmental evaluation indicators worldwide, including those specific to Republic of Korea, where the experts involved in this study are based.

The indicator is characterized by dividing the spatial range into agricultural land and villages for the evaluation and selection of elements capable of assessing ecological properties. Furthermore, by utilizing an organized indicator, the priorities of agricultural environmental evaluation factors were determined.

The priorities of the evaluation elements were derived using a questionnaire administered via a webpage created for this study. It used a nine-point scale and involved 32 experts.

According to the AHP results, the priority of factors related to the ecological environment of farmland was high. This result proves the need to improve the standards for evaluating the agricultural environment in Republic of Korea, which is excessively concentrated in the soil environment, depending on the use of pesticides.

In addition, the results showed that the residential ecological environment factors and humanities and social factors such as “village living and cultural environments” are highly important. The necessity of improving agricultural environment indicators around the world has been proven.

This study offers valuable insights for establishing sustainable organic farming areas by employing reliable agricultural environmental indicators. Moreover, the findings have practical implications for government decision-makers; they demonstrate the possibility of introducing a new environmental evaluation indicator system that combines physical–ecological factors and humanities–social evaluation factors, which can induce the development of the environmental evaluation field.

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