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Identification and prioritization of strategies for achieving sustainable agriculture in rice production (Case study: Guilan Province, Northwest Iran)

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ABSTRACT

Considering the role of rice in ensuring the country's food security, this research examines suitable proposed strategies for achieving sustainable rice production in Guilan Province, Northwest Iran. The statistical population of the research consists of rice farmers in Rasht County and agricultural experts. A total of 383 rice farmers were selected as a sample using a multi-stage sampling method. The sampling of experts was conducted using a complete enumeration method, with a total of 70 individuals included. The validity of the questionnaire was confirmed by 10 university professors and experts from the Agricultural Jihad Organization, and its reliability was established using Cronbach's alpha, resulting in a value of 0.81. In order to prioritize and determine the intensity of the impact of the criteria and sub-criteria for achieving sustainable agricultural development in rice production in Guilan Province, fuzzy analytic hierarchy process (FAHP) approaches were utilized. In this regard, a pairwise comparison questionnaire was designed based on a decision tree, and the necessary information was collected from 15 experts (10 specialists and 5 sample farmers) through in-person interviews and the completion of the pairwise comparison questionnaire. The results indicated that seven factors extracted from exploratory factor analysis (improvement of environmental, social, and educational conditions in rice production; innovation and supportive incentives for rice production; financial strategies; Enhancement of production infrastructure and processes; environmental strategies; support from public and private sectors for rice production; and stringent support for the production of healthy products) explained 72.59% of the variance in the variables. The findings of the fuzzy analytic hierarchy process (FAHP) analysis also showed that the criteria "innovation and supportive incentives for rice production," "financial strategies," and "improvement of production infrastructure and processes" are, respectively, the most important factors for sustainable agricultural development in rice production in Guilan Province, with average relative weights of 21.27%, 19.11%, and 17.25%. Sustainable agriculture is a management approach that can eliminate the negative consequences of traditional agriculture and provide sustainable production, especially in the strategic crop of rice. One of the important provinces in rice cultivation is Guilan province and Rasht city. A study of the status of rice cultivation among rice farmers shows that the level of agricultural knowledge is poor and farmers often use unscientific methods in the rice production process. However, according to experts, innovations and supportive incentives should be used in order to achieve sustainable agriculture in rice production. As a result, the first requirement for sustainable agriculture in rice production is to improve the level of knowledge, increase communication, improve the level of public awareness, and improve the environmental attitude of farmers. Also, financial support and equipping infrastructure can be effective in achieving sustainable agriculture.

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INTRODUCTION

The rural economy is still fundamentally based on agricultural activities (Noori Zamanabadi *et al.* 2016). By reviewing the history of agriculture, three stages can be identified: subsistence agriculture, industrial agriculture, and sustainable agriculture (Ebrahimi & Kalantari 2003). Sustainable agriculture is one of the most important aspects of sustainable development. Today, one of the key policies in the agricultural sector of countries is achieving a sustainable agricultural system (Jamshidi *et al.* 2015). Sustainable agriculture involves the development of policies and practices that ensure people's ability to produce food and clothing while maintaining economic conditions, commercial agriculture, and social values without causing degradation to natural resources. Sustainable agriculture is a system that efficiently utilizes resources. Rice is one of the most important grains and food staples in the world, exclusively cultivated for human consumption. It is a significant economic product and serves as the primary food source for half of the global population, being grown in over one hundred countries (Shirdeli *et al.* 2016). The area under rice cultivation in Iran accounts for approximately 0.36% of the world's cultivated area, with its production representing about 0.34% of global output. In Iran, nearly 19 provinces are involved in rice production. The average area under rice cultivation over the three years of 2017, 2018, and 2019 was about 792 thousand hectares, with 70-80% of that concentrated in Guilan and Mazandaran provinces. The average production of paddy during these three years was 4 million and 29 thousand tons, while the amount of white rice produced was around 2 million tons.

According to available data for the agricultural year 2020-2021, the area under cultivation and production levels in the country have decreased compared to the previous year. Achieving sustainable agricultural development for rice production requires systematic, precise, and efficient planning. In this context, sustainable agriculture must effectively utilize land and water resources without harming these resources (Cheraghi *et al.* 2020). This goal can only be realized through a comprehensive understanding and precise awareness of the opportunities, capabilities, and limitations (Taghavi & Boshagh 2012). Therefore, adopting appropriate strategies is essential for achieving sustainable development. In developing countries, including Iran, various factors contribute to achieving growth and sustainability in agricultural production. These include a range of individual and professional characteristics, management features, economic, ecological, and technological (innovation) aspects, participatory elements, and constraints related to inputs such as water, fertile soil, technology, knowledge, and attitudes. The overall objective of this research is to determine suitable strategies for achieving sustainable agriculture in rice production in Guilan Province. By defining appropriate strategies for the rice production process, the output of this important product can significantly increase, paving the way for achieving self-sufficiency in rice production. The term "strategy" refers to an operational plan used to coordinate and organize actions to achieve a specific goal. The importance and necessity of formulating strategies arise from the fact that environmental changes are currently accelerating and are more tangible than ever before. Strategic management, relying on a dynamic, forward-looking, comprehensive, and situational mindset, offers solutions to many issues faced by contemporary organizations.

One of the main reasons for the reluctance of countries to develop sustainable development strategies, which should encompass a series of processes, is the lack of understanding and clarity regarding the content of these processes by various governments. Sustainable agriculture is a type of management approach that encompasses a set of strategies and implementation mechanisms. Dessart *et al.* (2019) examined the behavioral factors influencing the adoption of various sustainable agricultural practices, focusing specifically on behavioral acceptance factors such as farmers' attitudes. According to Serebrennikov *et al.* (2020), farmers' environmental and economic attitudes, along with their sources of information, have a strong impact on the adoption of sustainable and organic farming.

They stated that age and education systematically influence farmers' acceptance of organic farming. Zhou & Ding (2022) noted that factors such as the farmer's education level, political status, family income, and farmers' understanding of organic farming and environmental risks significantly affect their willingness to participate in sustainable agriculture. Haq *et al.* (2022) believed that Sustainable agriculture highly depends on the actions taken by the farmers and their ability to make a decision by using their knowledge and information efficiently. Therefore, farmers' perception needs to transfer from a technocratic approach to a social approach for promoting sustainable agriculture. Their study was planned to analyze the tea growers' perception of sustainable agriculture in Rize

Province. The model results showed that education level, age, participation in farming events, watching television, and using the internet affected farmers' perception of sustainable farming in the region. Government should focus on policy-related issues like illegal tea entry, social factors like increasing the communication and socialization level among stakeholders, and environmental problems as a result of farm practices through arranging appropriate workshops. Rizzo *et al.* (2024) provided a comprehensive overview of factors affecting farmers' innovation adoption behavior in developed countries.

The analysis revealed that specific innovation characteristics foster the innovation adoption process, together with individual psychological and socio-demographic features. It emerged that the path to adopting sustainable innovations can be driven by environmental values; for example, when comparing organic and conventional farming, organic farmers have a stronger environmental view and are more likely to take less into account economic gains. On the contrary, complexity of innovation, a high degree of innovation aversion, and a low perceived control over innovation are among the core barriers to the innovation adoption. Rezai *et al.* (2022) found in their research that the most important strategies for sustainable rice production include institutional empowerment and synergy of inter-sectoral capacities to utilize the existing potentials in various governmental and non-governmental sectors, as well as linking sustainable agricultural activities with environmental protection issues. Veisi *et al.* (2015) identified three types of strategies: empowerment, assurance, and implementation, as well as motivational strategies to achieve the social, economic, and ecological goals of sustainable agriculture. Sanai Moghadam *et al.* (2017) stated that five factors—social-participatory, infrastructure service support, ecological, economic productivity, and sustainable agricultural operations—can explain over 85% of the variance in the sustainability of the agricultural system. Soltani Moghadas & Anzai (2017) noted that rice production, in terms of environmental sustainability in the studied villages, scored 0.351, indicating a weak level of sustainability. Some research conducted on suitable strategies for achieving sustainable agricultural development is summarized in Table 1.

Table 1. Suitable strategies for achieving sustainable agricultural development according to various researchers.

Authors	Suitable strategies
Bachev (2007), Pretty (1996), Zhao *et al.* (2008)	Research on ecological agricultural technologies
Zhao *et al.* (2008)	Development of ecological agricultural engineering models, Ecological intensification of agriculture
Pretty (1996), Vorley (2002), Zhao *et al.* (2008)	Popularization of ecological agriculture through information services and financial support
Bachev (2007), Pretty (1996), Naderi *et al*. (2010), Shabanali Fami (2007), Pender & Gebremedhin (2001) Parminter (2003), Najafi & Zahedi (2005)	Environmental protection and proper using resources
Pretty (1996), Vorley (2002), Shabanali Fami (2007)	Promoting public participation and social capital
Pretty (1996), Shabanali Fami (2007), Pender & Gebremedhin (2001), Parminter (2003)	Government intervention in creating infrastructure
Pretty (1996), Shabanali Fami (2007), Pender & Gebremedhin (2001), Parminter (2003)	Institutional development and pluralism
Bachev (2007), Pretty (1996), Vorley (2002) Shabanali Fami (2007), Pender & Gebremedhin (2001), Najafi & Zahedi (2005), Reyahi Khoram (2006)	Agricultural planning and policymaking
Pretty (1996), Jones (2003), Naderi *et al.* (2010), Reyahi Khoram (2006), OECD (2003)	Development of labelling and certification frameworks, research and extension services
Pretty (1996), Vorley (2002), Jones (2003) Parminter (2003), Reyahi Khoram (2006), OECD (2003)	Incentive policies in the form of financial incentives, collaboration of production chain agents and development of purchasing policies
Pretty (1996), Vorley (2002), Jones (2003) Naderi et al. (2010), OECD (2003)	Legislation in the form of development of regulations and standards
Pretty (1996), Vorley (2002), Pender & Gebremedhin (2001), Najafi & Zahedi (2005), Reyahi Khoram (2006)	Improving access to markets and credit
Pretty (1996), Vorley (2002), Reyahi Khoram (2006)	Improving the level of literacy and knowledge of rural people

Boufous *et al.* (2023) studied of farmers' willingness to adopt sustainable agricultural practices using a meta-analysis. they found that the increasing growth of consumption needs puts pressure on the natural system, harming climate, biodiversity, water, and environment which has induced a recognition that action should be taken to mitigate irreversible damage to the environment.

Sustainability is believed to be obtainable through a change in consumer's and producer's behavior, which can be primarily done through the transformation of our agricultural system using alternative farming approaches that are based on ecological principles. In sum, review shows that on average, farmers are only willing to adopt practices if paid. Moreover, this analysis leads to state that there are still gaps in the literature regarding the analysis of farmers' behavior regarding sustainable agriculture which calls for more research. This point is especially important in relation to strategic and important crops such as rice. A review and analysis of various studies shows that most research has examined the factors affecting the development of sustainable agriculture (not only in relation to rice) and has referred to some of the most important of these factors.

This study, with a new approach, attempted to identify strategies for achieving sustainable agriculture in rice crops and to categorize and prioritize these strategies from the perspectives of two groups of farmers and experts. Also, based on this research, in addition to identifying and prioritizing strategies, the identified strategies have also been localized by consulting experts and using the FAHP fuzzy analytic hierarchy process. Also, the five characteristics for achieving the introduced strategies were examined from the perspectives of the two groups. In this way, consulting experts was considered not only in prioritizing the identified strategies but also in achieving strategies appropriate to sustainable agriculture in rice cultivation.

MATERIALS AND METHODS

The present research aims to achieve appropriate strategies for sustainable agriculture in rice production in Guilan Province. This study is applied in terms of purpose and descriptive in terms of data collection, conducted over a one-year period (agricultural season 2021-2022). The most recent study that estimated the area under rice cultivation in Guilan Province using remote sensing technology and the GEE system was conducted by Rezaei *et al.* (2024). Hence the purpose of this study is to use remote sensing images to estimate the paddy field's area in the Guilan province by the best classification method and solve the shortcomings of field methods. Therefore, Sentinel 2 satellite images were analyzed using 6 supervised classification methods including ML, CART, RF, SVM, GME and RF-NDVI methods in GEE environment.

The ML method was performed in the ENVI environment and the rest of the methods were performed through calculations in the cloud space of the GEE environment. The estimation of the area under rice cultivation in the province with this method showed that the net area of the total paddy land in the province is 218,135 hectares, which is compared to the available statistics of the Agricultural Jihad Organization (238,012 hectares) and the Regional Water Company of Gilan Province (245,000 hectares), respectively 8.35%. and 10.96% was estimated less. Given its objectives, this research has two statistical populations. The first statistical population consists of rice farmers in Rasht County, numbering 89,000, while the second statistical population includes 70 agricultural experts specializing in rice in the province. Data necessary for this research were collected using library studies and a questionnaire, which is the main tool in this study. The validity of the researcher-made questionnaire was confirmed by 10 university professors and experts from the Agricultural Jihad Organization of Guilan Province, and its reliability was obtained using Cronbach's alpha, ranging from 0.70 to 0.91, indicating good reliability of the researcher-made questionnaire. To determine the sample size for the first population, Cochran's formula was used, resulting in a sample size of 383 individuals. Sampling from rice farmers in the selected villages was conducted using a multi-stage and simple random sampling method. Sampling from experts was done through complete enumeration due to their limited number. In the first section of the questionnaire, the individual-professional characteristics of respondents were examined. The second section assessed five characteristics (managerial, economic, ecological, technology usage, and social participation) regarding achieving sustainable agricultural development from the perspective of the respondents. The third section listed and studied proposed strategies for sustainable agricultural development. This list was determined and compiled through library studies and snowball sampling.

To analyze the data, both descriptive and inferential statistics were performed using Excel and SPSS25 software. After collecting the overall information, the first step involved examining the individual-professional characteristics of respondents in the descriptive statistics section. In the inferential statistics section, the

perspectives of two groups—experts and rice farmers—regarding the impact of five characteristics on achieving suitable strategies for sustainable rice agriculture in Guilan Province were compared using the t-test. Additionally, to prioritize the developed strategies, these strategies were first categorized using exploratory factor analysis. Then, through fuzzy analytic hierarchy process (FAHP) and the implementation of the fuzzy AHP technique, seven general criteria/strategies aligned with sustainable agriculture and their sub-criteria were weighted according to agricultural experts' opinions. For this purpose, in an Excel file, the weights of the criteria were obtained using a pairwise comparison matrix. Individuals were asked to provide pairwise comparisons between the criteria, which were then converted into fuzzy numbers using triangular fuzzy numbers and corresponding linguistic variables as outlined in Table 2. Then, the overall matrix was created using the geometric mean of the pairwise comparison matrix. Next, to calculate the inconsistency index, two matrices were extracted: one with the central limits and another using the geometric mean of the upper and lower limits of the overall matrix. The data from these two matrices were then normalized. For this purpose, the sum of the column data for both matrices was calculated, and the numbers were divided by the column totals. Subsequently, two inconsistency indices were computed for the central limits and the upper and lower limits, which should be less than 0.1 to confirm the consistency of the responses.

Table 2. Triangular Fuzzy Numbers and Their Related Linguistic Variables.

Intensity of importance	Definition	Fuzzy numbers
1	Equal importance	1,1,1
2	Equal to moderate importance	1,1.5,1.5
3	Moderate importance	1,2,2
4	Moderate to strong importance	3,3.5,4
5	Strong importance	3,4,4.5
6	Strong to very strong importance	4,4.5,5
7	Very strong importance	5,5.5,6
8	Very strong to extremely strong importance	5,6,7
9	Extremely strong importance	5,7,9

To calculate the weights of the criteria, the overall matrix was used to estimate their importance. Various methods have been proposed for calculating the weights of criteria and sub-criteria in fuzzy analytic hierarchy process studies. In this research, Chang's quantitative analysis method, introduced in 1996, was employed to compute the weights of criteria and sub-criteria, which includes the following steps (Chang 1996):

1. Calculating the value of fuzzy composite.
2. Calculating the degree of probability.
3. Calculating the weight vector.
4. Calculating the consistency index.
5. Calculating the consistency ratio (CR), which is obtained by dividing the consistency index (CI) by a random index (RI). If the resulting value is less than 0.1, the matrix is considered consistent and usable.

If both of the above indices are less than 0.1, the fuzzy matrix is considered consistent. If both indices are greater than 0.1, the decision-maker is requested to revise the presented priorities. If only $CR^m (CR^g)$ exceeds 0.1, the decision-maker will need to reconsider the mid-range (limits) of the fuzzy judgments.

RESULTS

Descriptive Analysis

The most important individual and professional characteristics of the rice farmers and experts studied indicate that the majority of rice farmers are male, with an average age of 50 years and 26 years of agricultural experience. Most of them hold a high school diploma and are engaged in farming on their own land. The average household size of the rice farmers is about 4 members, and their average rice field area is 1.1 hectares. Most rice farmers utilize family members as labor for their farming activities, and the satisfaction level of the majority of these farmers regarding rice cultivation is moderate (69.7%). The individual and professional characteristics of the

experts show that most of the studied experts (n=70) are male, with an average work experience of 16 years, and hold a bachelor's degree in agronomy.

Inferential analysis

The inferential statistics section consists of four stages, which were conducted as follows:

A. Examination of data normality. The normality of the data was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. According to Table 3, the significance levels of both the Kolmogorov-Smirnov and Shapiro-Wilk tests indicate that the data is normally distributed.

B. Hypothesis testing: In this stage, the five characteristics—managerial, economic, ecological, technology usage, and social participation—were compared between the two groups of rice farmers and experts (Table 4). The results of the comparison of the perspectives of the two groups indicated that there is a significant difference between the views of experts and rice farmers regarding the impact of these five characteristics on achieving suitable strategies for sustainable rice agriculture in Guilan Province.

Table 3. Examination of the Normality of Data Distribution.

Variable	Kolmogorov-Smirnov test		Shapiro-Wilk test	
	Value of the Statistic	Significance	Value of the Statistic	Significance
Managerial characteristics	0.30	0.45	0.26	0.25
Economic characteristics	0.22	0.31	0.85	0.43
Ecological characteristics	0.21	0.30	0.97	0.47
Using technology	0.17	0.21	0.90	0.41
Social participation of rice farmers	0.11	0.12	0.94	0.42
Achieving appropriate agricultural strategies (Factor analysis)	0.14	0.17	0.89	0.35

Table 4. Results of the Comparison of Experts' and Rice Farmers' Perspectives on the Impact of Five Key Characteristics for Achieving Appropriate Strategies for Sustainable Rice Cultivation in Guilan Province.

Variable Under Investigation	Study Participants	Average Rank	Standard Deviation	t-value	Significance
Managerial Characteristics	Experts	2.54	0.36	-3.85	0.000**
	Rice farmers	4.60	4.48		
Economic Characteristics	Experts	0.40	0.05	2.13	0.03*
	Rice farmers	0.45	0.02		
Ecological Characteristic	Experts	0.36	0.04	5.29	0.000**
	Rice farmers	0.38	0.02		
Using Technology	Experts	2.59	0.47	4.97	0.000**
	Rice farmers	2.27	0.51		
Social Participation of Rice Farmers	Experts	2.54	0.37	4.11	0.000**
	Rice farmers	2.30	0.49		

Note: *$p < 0.05$, **$p < 0.01$, and ^{ns} indicates no significant difference.

Classification of Appropriate Strategies in Sustainable Agricultural Development for Rice Production in Guilan Province: To conduct a more precise analysis and better classification of appropriate strategies for sustainable agricultural development in rice production in Guilan Province from the perspectives of both groups (rice farmers and experts), exploratory factor analysis was employed. The KMO index value was 0.61, and the significance of Bartlett's test at the one percent level indicates the suitability of the internal correlation among the variables and the possibility of forming a set of variables (factors). The seven extracted factors, along with their eigenvalues, percentage of variance, and cumulative percentage of variance, are presented in Table 5.

Based on Table 7, seven factors extracted from the exploratory factor analysis explained 72.59% of the variance in the variables. The placement of the variables and the factor loadings associated with each were reported, assuming that only variables with factor loadings greater than 0.4 were included. This was done after rotating the factors using the orthogonal method and the Varimax technique, as shown in Table 6. To prioritize and analyze suitable strategies for sustainable agriculture in rice production in Guilan Province, the fuzzy AHP technique was

employed. Initially, relative weights were assigned to the established criteria and sub-criteria. The results are presented in Table 7. The rice of Guilan province has been examined from the perspective of the studied individuals, and the results are reported in Table 8.

Table 5. Factors extracted from exploratory factor analysis along with eigenvalues, percentage of variance, and cumulative percentage of variance.

Factors	Eigen values	Percentage of Variance	Cumulative Percentage of Variance
Improvement of environmental, social, and educational conditions for rice production	4.66	16.06	16.06
innovation and supportive incentives for rice production	3.46	11.92	27.98
financial strategies	3.33	11.47	39.45
Improvement of production infrastructure and production processes	3.002	10.35	49.8
Environmental strategies	2.46	8.48	58.28
Support from the public and private sectors for rice production	2.25	7.77	66.05
Strict support for healthy product production	1.88	6.54	72.59

Table 6. Factor loadings of the variables extracted from the rotated matrix.

Factors	Variables	Factor loadings
Improvement of environmental, social, and educational conditions for rice production	Biological control and soil fertility in rice production process	0.79
	Using various green, animal, and organic fertilizers in the rice production process	0.77
	Soil improvement	0.61
	Increasing social capital of rice farmers	0.73
	Establishment of rice farmers' cooperatives	0.78
	Utilization of services from research and educational centers	0.64
	Establishment and enhancement of agricultural educational information systems to improve farmers, extension workers, and researchers	0.81
Innovation and supportive incentives for rice production	Using incentives (Financial, credit, tax exemptions, etc.) for the production of healthy and organic products	0.67
	Development of educational activities for empowering rice farmers	0.73
	Using modern technology (Improved seeds, machinery, irrigation methods, etc.) in rice cultivation	0.79
	Using modern agricultural plans (Land leveling, irrigation canals, etc.)	0.76
Financial strategies	Guaranteed purchase of rice	0.63
	Guaranteed purchase of organic products	0.81
	Price regulation of products in the market in favor of produced organic products	0.77
	Increased agricultural insurance allocation for healthy and organic products	0.61
	Provision of suitable retirement and social security insurance for farmers	0.81
Improvement of production infrastructure and production processes	Enhancement of production factor productivity and increase in production efficiency	0.62
	Development of rice cultivation infrastructure by the public and private sectors	0.78
	Provision and development of necessary and cost-effective inputs for rice production	0.63
	Government support and policies (Legislation, drafting laws, etc.) for healthy product production	0.60

Environmental strategies	Establishment of a sustainable utilization system considering environmental issues	0.68
	Establishment of a waste management system and continuous monitoring in the rice production process	0.77
	Implementation and reform of laws regarding the production, distribution, and using pesticides and chemical fertilizers in rice cultivation	0.79
Support from the public and private sectors for rice production	Support and role of non-governmental organizations in rice cultivation	0.74
	Government Support for Environmental Projects Related to Rice Production	0.71
Stringent support for the production of healthy products	Imposing higher taxes on environmentally polluting farmers	0.59
	using machinery (mechanization) in planting, cultivation, and harvesting stages	0.69
	Government support for healthy products	0.55

Table 7. Relative weights of criteria and sub-criteria for achieving sustainable agricultural development in rice production in Guilan Province.

Criteria	**Relative Weight (%)**	**Priori**	**Sub-criteria**	**Relative weight (%)**	**Priori**
Improvement of environmental, social, and educational conditions for rice production	12.45	4	Biological control and soil fertility in the rice production process	18.41	2
			Using various green, animal, and organic fertilizers in the rice production process	12.19	4
			soil improvement	9.89	7
			Increasing the social capital of rice farmers	11.73	5
			Establishment of rice farmers' associations	15.49	3
			Utilization of research and educational center services	10.83	6
			Establishment and enhancement of an agricultural educational information system to improve farmers, promoters, and researchers	21.46	1
Innovation and supportive incentives for rice production	12.27	1	Using incentives (financial, credit, tax exemptions, etc.) for the production of healthy and organic products	11.12	4
			Development of educational activities for empowering rice farmers	12.31	3
			Using modern technology (improved seeds, machinery, irrigation methods, etc.) in rice cultivation	35.38	2
			Using modern agricultural plans (land leveling, irrigation canals, etc.)	41.19	1
Financial strategies	19.11	2	Guaranteed purchase of rice	16.2	4
			Guaranteed purchase of organic products	24.82	2
			Price Regulation of products in the market in favor of produced organic products	29.96	1
			Increased agricultural insurance allocation for healthy and organic products	10.49	5
			Provision of suitable retirement and social security insurance for farmers	18.53	3

Improvement of production infrastructure and production processes	17.25	3	Enhancement of production factor productivity and increase in production efficiency	27.81	2
			Development of rice cultivation infrastructure by the public and private sectors	38.59	1
			Provision and development of necessary and cost-effective inputs for rice production	16.36	4
			Government support and policies (legislation, drafting laws, etc.) for healthy product production	17.24	3
Environmental strategies	12.23	5	Establishment of a sustainable utilization system considering environmental issues	28.73	3
			Establishment of a waste management system and continuous monitoring in the rice production process	34.56	2
			Implementation and reform of laws regarding the production, distribution, and using pesticides and chemical fertilizers in rice cultivation	36.71	1
Support from the public and private sectors for rice production	10.27	6	Government support and the role of non-governmental organizations in rice cultivation	42.88	2
			Government support for environmental projects related to rice production	57.12	1
Stringent support for the production of healthy products	7.42	7	Imposing higher taxes on environmentally polluting farmers	26.79	2
			Using machinery (mechanization) in planting, cultivation, and harvesting stages	47.23	1
			Government support for healthy products	25.98	3

Table 8. Prioritization of sustainable agricultural development strategies to achieve sustainable agriculture in rice production in Guilan Province.

Relative Weight of Sustainable Agricultural Development Strategies for Achieving Sustainable Agriculture				
Strategies	**Perspective of experts**		**Perspective of Rice Farmers**	
	Relative weight (%)	**Priority**	**Relative weight (%)**	**Priority**
Management characteristics	18.59	3	16.46	3
Economic characteristics	22.35	2	29.72	1
Ecological characteristics	15.57	5	16.11	4
Using technology	27.23	1	23.48	2
Social participation of rice farmers	16.26	4	14.23	5

DISCUSSION AND CONCLUSION

The results of the research regarding the individual, professional, and technical characteristics of rice farmers in Guilan revealed that their average age is 50 years, with over 26 years of experience in rice cultivation, and their education level is below high school. The majority owns one hectare of land, and the income generated from this land is their primary source of livelihood. Furthermore, most of them do not have secondary occupations, and the majority of rice production operations—such as planting, maintenance, and harvesting—are carried out using traditional methods.

The level of agricultural knowledge is weak. In terms of managerial, ecological, and new technology application indicators, the results indicate that various rice production operations at all stages (plowing, frequency of plowing, using pesticides, pest control, etc.) are performed in an unstandardized and unscientific manner. Additionally, they do not utilize new technologies (such as improved seeds, hybrid seeds, new inputs, integrated pest management, etc.). Regarding the participation index, most rice farmers do not use communication networks to establish connections and enhance awareness. They are not members of rural organizations and rarely participate in promotional training classes, showing minimal involvement in preparing and formulating promotional plans. The results of the t-test also indicated that there is a significant difference between the perspectives of the two groups regarding the level of achievement in sustainable agriculture among rice farmers in Guilan Province. There is a need for scientific planning alongside the provision of financial resources, along with the involvement of both the public and private sectors, to enhance farmers' knowledge and attitudes and improve the indicators of the five mentioned factors. The individual characteristics of rice farmers regarding general knowledge and agricultural knowledge, along with an increase in scientific agricultural information, should be complemented by the refinement of technical skills and the improvement and delivery of new skills through a series of educational and promotional programs. Improving the economic status of rice farmers is an effective step towards the purchase and application of appropriate technology, the using new inputs, and adherence to ecological indicators. Enhancing the economic conditions of rice farmers can be achieved through the creation of new job opportunities, the establishment of non-agricultural employment, the implementation of managerial indicators—especially those that play a role in reducing production costs—and attention to participatory indicators such as coordination and collaboration among farmers.

Establishing effective communication with experts and extension workers can facilitate the dissemination of new ideas and accelerate their spread. Ultimately, this will lead to a reduction in production costs and an increase in farmers' income. By improving the five key indicators, the perspectives and attitudes of Guilan's rice farmers regarding sustainable agriculture will change and improve. Based on the results of the research, the strategies for sustainable agricultural development in rice production can be categorized and divided into seven main strategies. Accordingly, the study participants believe that improving environmental, social, and educational conditions for rice production, fostering innovation and supportive incentives for rice production, financial strategies, enhancing production infrastructure and processes, environmental strategies, support from both public and private sectors for rice production, and stringent support for producing healthy products are among the factors that can lead to sustainable development in rice production. As noted, alongside financial and infrastructural support, the importance of environmental and organic dimensions has also been specifically considered among the proposed strategies by the individuals surveyed. This finding is also confirmed by Serebrennikov *et al.* (2020); Zhou & Ding (2022); Rizzo *et al.* (2024) and these researchers believe that the path of adoption of sustainable innovations can be guided by environmental values. The categorized strategies for achieving sustainable agricultural development in rice production in Guilan Province were weighted by experts, and the results indicated that the three strategies of innovation and supportive incentives, financial strategies, and improvement of production infrastructure ranked as the first to third priorities, respectively, and are the main factors in sustainable agricultural development which should be especially considered to achieve successful sustainable agriculture, because with the wider using rice production innovations, financial support, and improvement of production infrastructure, it is possible to move away from traditional and unscientific production and hope for the production of organic and sustainable rice products.

Other researchers also confirm this finding. For example, Haq *et al.* (2022) believed that Sustainable agriculture highly depends on the actions taken by the farmers and their ability to make a decision by using their knowledge and information efficiently. Veisi *et al.* (2015) and Sanai Moghadam *et al.* (2017) have placed special emphasis on infrastructure support services and economic strategies.

Based on the research findings, the following recommendations are suggested:

- Providing appropriate technology for sustainable agriculture should be a priority for relevant authorities. To this end, offering low-interest loans and utilizing knowledgeable experts can enhance the financial and economic capacity of rice farmers and improve the adoption of technology within the agricultural community.

- Implementing financial policies and utilizing strategies such as guaranteed rice purchases, guaranteed purchases of organic products, regulating the prices of organic products in the market, and allocating more agricultural insurance to healthy and organic products can enhance the conditions for sustainable rice agriculture.
- The improvement and development of rice cultivation infrastructure in Guilan by both public and private sectors, along with the provision and development of necessary inputs for rice production, as well as government support and policymaking (legislation, drafting laws, etc.), will create the necessary conditions for sustainable agricultural development.

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