Journal of Agricultural Science and Technology (JAST)
In Press, Pre-Proof Version

Investigating of agricultural ecosystem functions and services in Northern Iran

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Abstract

The agricultural ecosystem provides various functions and services for humans. So, investigating their role and importance in the agricultural land programming and management is one of the goals research. In this research used Common International Classification of Ecosystem Services (CICES) for the identification of the Agricultural Ecosystem Functions and Services (AEFS). Also, Multi-Criteria Decision-Making (MCDM) models used for weighting and prioritizing of the AEFS like Step wise Weight Assessment Ratio Analysis (SWARA) for calculating of their weight, and Simple Additive Weighting (SAW), Additive Ratio Assessment (ARAS), and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) used for prioritization them. The research data extracted with field survey, random sampling and completing the Delphi questionnaire of the 40 agricultural specialist experts in the north of Iran. Also, the R^2 coefficient was used to compare the AEFS prioritization models. The SWARA technique findings showed that provisioning, regulation, and cultural functions with weights of 0.0298, 0.0286 and 0.0250 have the highest weight, respectively. Also, the results indicated that the SAW model with the R^2=0.90 was chosen as the prioritization appropriate model. Provisioning, regulation, and cultural functions with marginal weights of 0.6319, 0.5448, and 0.5092 were ranked the first to third priority respectively. Also, food supply, employment, genetic material supply, and educational and research services were important positive services of the agricultural ecosystem compared to other services. It is suggested that more appropriate programming and more research be done by relevant organizations for the sustainable management of agricultural ecosystems in northern Iran.

Key words: AEFS, Agroecological maintenance, CICES, Final function, Prioritization, Weighting assessment.

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INTRODUCTION

A set of ecosystem services that human life depends on them is provided by agriculture (Heinze et al, 2022); Also, due to the increasing growth of the world population, there is more pressure on agricultural prospects to receive different services (Azaiez et al., 2020). Based on it, a series of factors such as climate, geology, ecology, as well as management methods, technology and skills affect the provision of landscapes ecosystem services. In fact, agriculture ecosystems are both a recipient and a provider of services. Therefore, the sustainability of agricultural ecosystems requires their ability to simultaneously provide services in a balance between the provision and consumption of services. However, the main management approach is based on the preservation of the services for the use of future generations, that the balance between services compared whit other agricultural ecosystems (Altieri, 2018). Therefore, agricultural ecosystem managers are trying to integrate ecosystem services in agricultural ecosystem policies and management by using a set of methods including evaluation of dependencies and effects of ecosystem services, valuation of ecosystem services, scenario creation and other interventions which can become the main basis for resolving conflicts and establishing a compromise between development and nature and guaranteeing the stability of both (Peng et al., 2019). Therefore, access quantitative and qualitative information about the positive services of the agricultural ecosystem is of particular importance to achieve sustainable agriculture (Jia et al., 2021).

Among the diverse ecosystems, the agricultural ecosystem with different functions and services have directly and indirectly role in the economic and human livelihoods (FAO 2018), whose maintenance of them should be the main goal of human activities. Therefore, five classifications include the study of Castanza et al. (1997); De Groot et al. (2012); Millennium Ecosystem Classification (MEA 2005); The Economics of Ecosystems and Biodiversity (TEEB) (2010); and Common International Classification of Ecosystem Services (CICES) (2018) is emphasized for the classification of ecosystem services (Heinz Jung and Putshin 2018). CICES (2018) is the latest classification of ecosystem functions and their services that was developed by the European Environment Agency (EEA) with the aim of providing a standard for the systematic nomenclature, description and classification of ecosystem services. This classification includes three main groups of provision, regulating and cultural functions (European Environment Agency 2016).

Based on CICES classification, provisioning services are products and energy outputs obtained from goods and products. The regulating services include all the ways in which ecosystems can manage the environment in which people live or depend in some way and benefit from them in terms of their health or safety, for example. Finally, the cultural services category refers to all the non-material aspects of an ecosystem that contribute to or are important for humans' mental or intellectual wellbeing. Cultural services are intangible benefits that contribute to human development and culture, including the functioning of local, national, and international cultural ecosystems. Dissemination of knowledge and ideas; and interaction with nature (music, art, architecture). Creativity emerges from dialogue and entertainment (CICES, 2018).

These functions and services are not free and have hidden economic value. If these services are considered free, the agricultural ecosystem will be destroyed (Dick et al., 2018). Currently stated various pressures arising as economic purposes have caused their decline and destruction, and we are witnessing their destruction in every aria of the world. For this reason, the identification of the agricultural ecosystem functions and services (AEFS) has become very important. Obviously, this issue requires the participation of stakeholders and finding out about their preferences for positive services of the agricultural ecosystem, especially the Agricultural Ecosystem of Northern Iran (AENI) (Dumont et al., 2019). So far, different models have been done for ranking and valuation functions and services, but few studies have been done about defining them. Some of the most important ones are mentioned here:

Jia et al. (2021) surveyed agricultural ecosystem services in arid and semi-arid regions of western China based on the equivalent factor method. The study results showed that the factor evaluation method is an accounting tool for the evaluation of ecosystem services. Also, 9 agricultural ecosystem services analyzed in this evaluation. The findings showed that the agricultural environmental services value in Gansu province increased from 2008 to 2017. Also, ecological services are the most important agricultural ecosystem services in arid and semi-arid areas. Sun et al. (2021) assessed agricultural service's North China and predicted their changes under different land use scenarios. The results indicated that agricultural ecosystem services play an important role in the economic and social conditions of society. Also, Wang et al. (2022) assessed the ecological value of China's conventional agricultural ecosystem services in the framework of Energy-Based Life-Cycle Assessment. The findings showed that the importance of agricultural ecosystem provisioning services ecosystem is much higher than the production services provided by them. In this regard, Heinze et al. (2022) investigated farm diversity and its ecosystem services in different land use scenarios of southeastern Mexico. The results indicated that farms provide different services, which provisioning services are more important compared to other services and should be considered in different management methods.

A review of the previous sources showed that despite the existence of research related to the AEFS evaluation with different approaches, no study has been done about the identification, weighting and prioritization of AEFS. Therefore, it has been tried according to a) The importance of the AENI and highlighting its values to the society, b) The tensions resulting from the change of agricultural land use in the north of Iran, c) The possibility of the agricultural lands drought of northern Iran due to the lack of water resources and the phenomenon of climate change in recent years and d) the important role of agricultural ecosystem services in the comprehensive management of water resources. Also, the three main provisioning, regulating and cultural services and the AENI based on the CICES are identified and prioritized for their optimal management.

MATERIALS AND METHODS

A) Study Area

The agricultural ecosystem has an important role in Iran country's economy. The Iran's agricultural land area is 16.5 million ha, of which 14.7 million ha are agricultural lands and the rest are gardens lands. The crops production in the Northern Iran was about 8417436 tons in 2017-2018 which was almost a ninth of the country's total crops.

To carry out this research, the three provinces of Mazandaran, Guilan and Golestan has been selected. Currently, the cultivated area of agricultural lands in Mazandaran province was 476 thousand ha with an annual production of more than three million and 574 thousand tons. Important characteristics of Mazandaran province is the high cultivation coefficient (1.4) compared to the cultivation coefficient total of Iran (0.7). It has made Mazandaran province to the largest producer of rice in the Iran, and it has many capacities in increasing the quality and quantity in this regard. Also, it has caused the annual cultivated land of this province increase to more than 600 thousand ha. On the other wise, there are more than 45 types of cultivated crops in Mazandaran which the most important of them are rice, wheat, barley, soy, rapeseed, corn, fodder plants, vegetables and summer vegetables. Each of these products provide many services to the society. Also, the area of arable land of Golestan province is 850 thousand ha which the agricultural land area is 710 thousand ha (250 thousand ha of irrigated land and 460 thousand ha of dry land). Also, the products of the agricultural ecosystem are very diverse, and some of its products are of special value and importance on a national scale in Guilan province. Therefore, agriculture in Guilan province has both nutritional and commercial value for its producers. The agricultural ecosystem is about 30% of the Guilan province area. The proportion of irrigated and dry lands in this province is 82% and 18% respectively (https://maj.ir/).

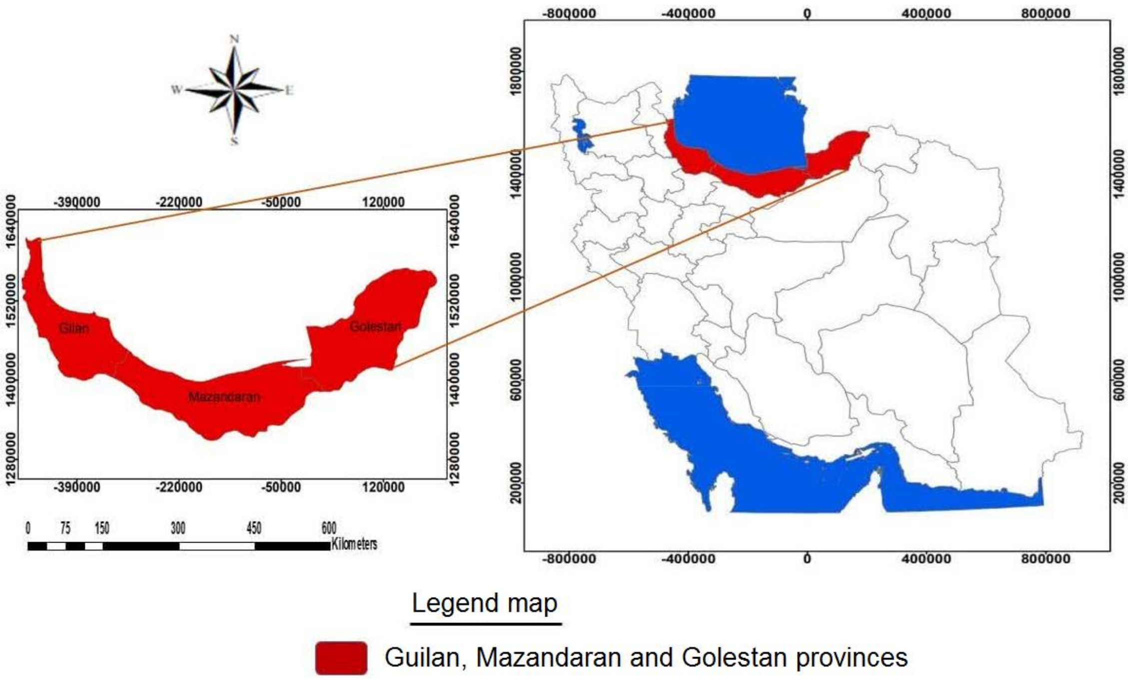

Figure. 1. The location of the case study.

b) Methodology

In this research, in order to weighting and prioritize of the AEFS in northern Iran, firstly; the AEFS were identified and compiled based on the most the CICES. Then the research data was extracted in the form of field survey, random sampling and by completing the Delphi questionnaire and face-to-face interviews with 40 experts of agricultural ecosystem management. Also, information about AEFS in northern Iran write in a Delphi questionnaire in order to familiarize the respondents with AEFS in northern Iran. Then this question asked which of the positive AEFS in northern Iran have more important role in the optimal and sustainable management of the agricultural ecosystem? After express your answers based on one of the five degrees of importance of the Likert scale conations; unimportant=1, little important=2, important=3, great important=4 and very important= 5 (Hosseini et al., 2021). Also, if there are new services, they add them to the questionnaire. Finally; among the 40 questionnaires gathered, 10 questionnaires were removed due to the incompleteness of the information, and the data of 30 questionnaires were used to analyze the information (Table 1).

In order to check the reliability of the Delphi questionnaire, Cronbach's alpha coefficient reliability technique was used (Mengual-Andrés et al., 2016). According to the value of this coefficient ($\alpha = 0.91$), the reliability of the questionnaire was confirmed.

In this study, for weighting and prioritizing each of AEFS used the Multi-Criteria Decision-Making (MCDM) models such as the Step wise Weight Assessment Ratio Analysis (SWARA) in order to calculate the weighting of AEFS (Debnath et al., 2023); the Simple Additive Model (SAW) (Hosseini et al., 2021); the Additive Ratio Assessment (ARAS) (Amor et al., 2022) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) has been used to prioritize functions and services (Ramón-Canul et al., 2021). Finally, the curve slope (R^2) used for comparing and choosing the suitable models for prioritizing the AEFS in the northern Iran.

Spss16 software used to process and statistically analyze the questionnaire data such as calculating the questionnaire reliability with Cronbach's alpha test. Also, Excel software used to implement the weighting and prioritization models analysis.

- **Step-Wise Weight Assessment Ratio Analysis (SWARA)**

The most important advantages of the SWARA method is its ability to evaluate the accuracy of experts' opinions about weight criteria, simple implementation and no need for high volume of comparisons (Ayan et al, 2023). The steps to implement this method are as follows:

• **First step: Sorting criteria (Services)**

At first, the criteria are written based on their importance. The most important criteria are placed in higher categories and less important criteria are placed in lower categories (Debnath et al., 2023).

• **Second step: determining the relative importance of each criterion (S_j)**

In this step, the relative importance of each criterion compared to the previous criteria. This value represented using S_j.

• **The third step: calculating the coefficient K_j**

The coefficient K_j, it is a service of the relative importance of each criterion that is calculated using Eq 1:

$$K_j = S_j + 1 \qquad (1)$$

•**Fourth step: calculate the initial weight of each services**

The initial weight (recalculated weight) of criteria (Q_j) is calculated with Eq 2. In this regard, it should be noted that the weight of the first criterion (the most important criterion) is considered equal to one (Ali Majeeda and Breesam, 2021; Zolfani and Saparauskas, 2013).

$$Q_j = x_j - 1 / K_j \quad (2)$$

•**Step five: Calculate the final normal weight**

In the last step, the final weight of the evaluation criteria is calculated through Eq 3. Normalization is done by simple linear method (Yücenur et al., 2021).

$$W_j = Q_j / \sum_k^n Q_j \quad (3)$$

- **Additive Ratio Assessment method (ARAS)**

The ARAS method was proposed by Zavadsakas et al in 2010. This method is one of the best MCDM models to choose the best option. The best option is to have the greatest distance from negative factors and the least distance from positive factors (Amor et al., 2022). The implementation section of this method are as follows:

- **Formation of the decision matrix**

The first step in this technique is to create a decision matrix. A decision matrix is a matrix for evaluating a number of options based on a number of criteria. That is, a matrix in which each option is scored based on a number of criteria. The decision matrix is denoted by *x* and each term is denoted by x_{ij} (Eq 3) (Fan et al., 2021).

$$X = \begin{bmatrix} x_{11} & x_{12} & x_{1n} \\ x_{21} & x_{22} & x_{2n} \\ x_{m1} & x_{m2} & x_{mn} \end{bmatrix} \quad (4)$$

- **Creation of normal decision matrix**

Normalization or descaling is the second step in solving all MCDM models (Eq 5) (Prayogo et al., 2019).

$$N = \begin{bmatrix} n_{11} & n_{12} & n_{1n} \\ n_{21} & n_{22} & n_{2n} \\ n_{m1} & n_{m2} & n_{mn} \end{bmatrix} \quad (5)$$

- **Formation the normal weighted decision matrix**

In the third step of the ARAS technique, the created normal decision matrix should be weighted. For this purpose, each criterion weight is multiplied in all the regions under the same criterion. The criteria weight should be determined in advance (Eq 6). the SWARA technique is usually used for this purpose (Jocic et al., 2020).

$$V = \begin{bmatrix} v_{11} & v_{12} & v_{1n} \\ v_{21} & v_{22} & v_{2n} \\ v_{m1} & v_{m2} & v_{mn} \end{bmatrix} \quad (6)$$

- **Calculate the utility of each option**

The desirability of each option is calculated by the desirability service in the fourth step of the ARAS technique. The best option is the one that has greater utility. Finally, the degree of desirability must be calculated. The total desirability of each option is represented by S_i that it calculated with Eq 7**:**

$$S_i = \sum V_{ij} \quad (7)$$

The degree of desirability of the option (K_i) is calculated based on the comparison with an optimal value (S_o) using Eq 8. The optimal value can be obtained based on the opinion of experts or the best weighted matrix values (Hosseini et al., 2024)

$$K_i = {}^{S_i}/_{S_o} \quad (8)$$

- **Simple Additive Weighting (SAW)**

In order to use the SAW model for prioritizing AEFS, first, the completed decision matrix was scaled using the linear scaling method, then weight calculated by the SWARA technique multiplying in the unscaled matrix. In this method, taking into account the AEFS weight calculated by the SWARA technique. The score of each service (S_i) is calculated by the weighted average of their values in all services based on Eq 9 (Hosseini et al., 2021).

$$S_i = \sum_j n_{ij} . w_j \quad (9)$$

W_j is weight of each service and n_{ij} is score of each service (Eq 9).

- **Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)**

In this method, m options are evaluated by n indicators and the options are ranked based on their similarity to the ideal solution (Ramón-Canul et al., 2021). The technique basis is based on the concept that the selected option should have the smallest distance with the positive ideal solution and the largest distance with the negative ideal solution. The steps of this method are as follows (Zavadskas & Turskis, 2010):

- **First step: Converting the existing decision-making matrix into a matrix (unscaled) using Eq (10)**:

$$n_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} r_{ij}^2}} \quad (10)$$

n_{ij}: normalized matrix r_{ij}: score of each criterion

- **The second step: Creating the weight matrix assuming the vector was input to the algorithm (Eq 11)**:

$$W=\{ W_1, W_2, \ldots\ldots W_n \} \quad (11)$$

W is weight of each criterion.

So that ND is a matrix in which the criteria scores are dimensionless and comparable, and $W_{n\times n}$ is a diagonal matrix in which only the main diagonal elements will be non-zero (Eq 12).

$$V = ND.W_{n*n} = \begin{bmatrix} v_{11} & v_{12} & v_{1n} \\ v_{21} & v_{22} & v_{2n} \\ v_{m1} & v_{m2} & v_{mn} \end{bmatrix} \quad (12)$$

V is weight matrix (dimensionless).

- **The third step: Specifying the positive ideal solution (A^+) and the negative ideal solution (A^-) based on Eq 13**:

$$A^+ = \{(max\ V_{ij} \mid j\in J), (min\ V_{ij} \mid j\in J') \mid i = 1, 2 \ldots m\} = \{V_1^+, V_2^+, \ldots, V_j^-, \ldots, V_n^+\}$$

$$A^- = \{(min\ vi\ j \mid j \in J), (max\ V_{ij} \mid j \in J') \mid i = 1, 2, \ldots, m\} = \{V_1^-, V_2^-, \ldots, V_j^-, \ldots, V_n^-\} \quad (13)$$

$$J = \{j = 1, 2 \ldots n \mid j \in benefit\} \qquad J' = \{j = 1, 2 \ldots n \mid j\ Cost\}$$

- **Step 4: Calculate the distance between the i_{th} option and ideals (di) using the Euclidean method based on Eq 14**:

$$d_{i+} = \{ \sum_{j=1}^{n} (V_{ij} - V_j^+)^2 \}^{0.5} \ ; i = 1, 2..\ m \quad (14)$$

$$d_{i-} = \{ \sum_{j=1}^{n} V_{ij} - V_j^-)^2 \}^{0.5} \ ; i = 1, 2..\ m$$

- **The fifth step: Calculating the relative proximity of A_i to the ideal solution (cl_{i+}) using Eq 15**:

$$cl_{i+} = \frac{d_{i-}}{(d_{i+} + d_{i-})} \ ; 0 \leq cl_{i+} \leq 1; i = 1, 2 \ldots m \quad (15)$$

- **The sixth step: Ranking the options based on cli+ descending**.

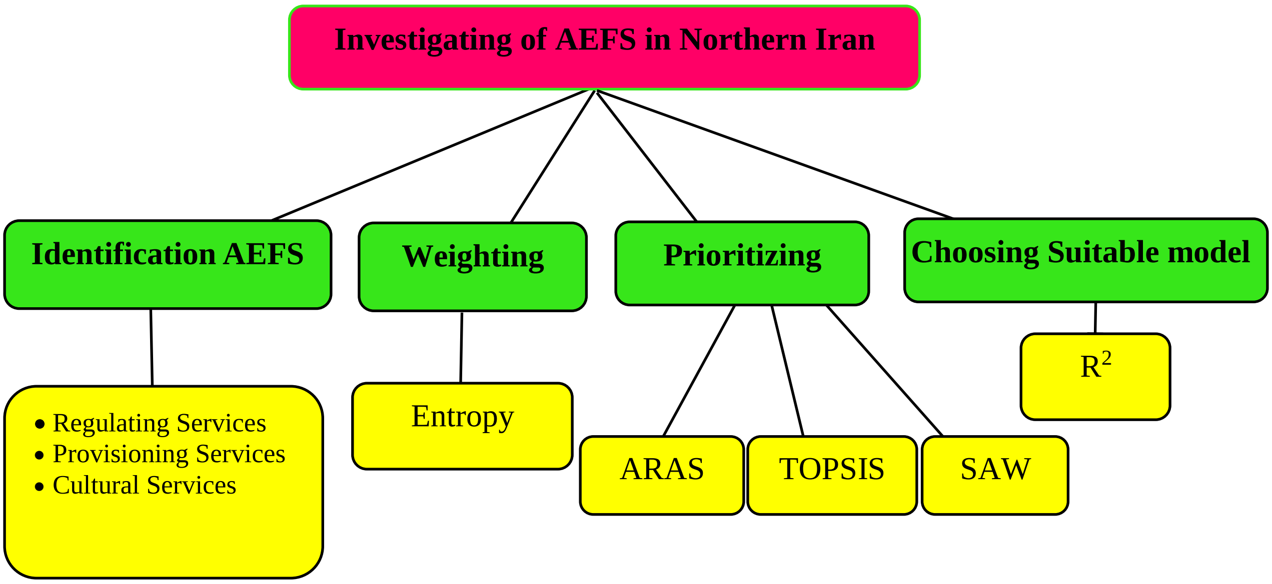

Figure.2. Methodology steps for investigating of agricultural ecosystem functions and services in Northern Iran.

RESULTS

The research results include two parts of identifying and determining of the AEFS in Northern Iran using the Delphi method and prioritizing them with MCDM models. The findings of each part are presented separately below:

- Identifying the AEFS of the Northern Iran

In this research, the AEFS of Northern Iran identified using CICES (Table 1). Then, the questionnaire containing them was distributed among the members of the Delphi group (experts in the field of agricultural ecosystem management with at least 15 years of experience) in order to score based on the Likert scale. In the research, 30 people formed a Delphi group and expressed their opinions regarding the identification of positive AEFS at each stage (Table 1).

Table 1. Delphi members to identify the positive functions and services of the northern Iran agricultural ecosystem.

Row	Delphi members	Education	Number
1	Faculty members of agricultural universities in Iran	Ph.D	15
2	Ministry of Agricultural Jihad of Iran	Msc, Ph.D	10
3	Land Affairs Organization of Iran	Bc, Msc	5

At the end of the first stage of the Delphi method, using the opinions of experts and some specialist expert in this field (Delphi method designer and analyst team), the positive AEFS of northern Iran were modified, integrated and adjusted. Then, three functions and 23 services were determined for the agricultural ecosystem of northern Iran (Table 2).

Table 2. The AEFS of northern Iran.

Functions	Services	Description
Regulating services	Local and regional climate regulation	The plants of the agricultural ecosystem can create a more addictive microclimate by creating shade and lowering the temperature.
	Improve air quality	Carbon storage by plants causes reduction of greenhouse gas and consequently improves air quality.
	Hydrological cycle and groundwater maintenance (including regulation of surface water flow; groundwater recharge; basin drainage)	In the agricultural ecosystem, the high rate of water infiltration causes the regulation of surface flows and maintaining the flow of underground water.
	Regulating water quality (water purification)	The vegetation of the agricultural ecosystem causes its filtration by breaking down and removing nutrients and other water pollutants.
	Pollination and seed dispersal	Wind causes seeds to disperse by moving plants in the agricultural ecosystem.
	Pest and disease control (biological pest control)	Some agricultural plants help to regulate and control the abundance of pathogens.
	Smell reduction, noise reduction, visual screening	Vegetation reduces noise pollution in addition to creating visual appeal and creating a pleasant smell, agricultural.
	Natural hazard regulation	Agricultural vegetation prevents soil erosion and landslides and prevents floods by absorbing rain.
	Soil erosion control	Vegetation increases resistance to erosion; It also prevents soil erosion by keeping sediments.
	Soil formation	Agricultural vegetation facilitates soil formation by depositing organic matter.
	Regulating soil moisture and maintaining soil fertility	Agricultural vegetation regulates soil moisture and maintains soil fertility.
	Ecosystem connectivity	The agricultural ecosystem provides the migration paths of plants and animals to other ecosystems and provides ecosystem connectivity.
	Nutrient cycle	The living organisms in the agricultural ecosystem play an important role in the decomposition of plant and animal organic matter and the cycle of carbon, oxygen, nitrogen, etc. elements.
	Role in food webs and prey/predator relationships	Agricultural ecosystem connects several food chains. It also causes communication between different species (such as coexistence, competition and hunting and hunter).
	Providing and maintaining habitats (biodiversity)	The agricultural ecosystem provides suitable habitats for the life, reproduction of all kinds of plant and animal species, invertebrates and vertebrates.
	Primary production	The consumption of carbon dioxide by plants in the process of photosynthesis causes the production of organic substances, which in addition to plant growth, also produces oxygen.
Provisioning services	Water supply	Water supply systems are very important for the proper functioning of communities. It can be achieved with various engineering projects such as wells or reservoirs.
	Food supply	Commercial and subsistence production of food and crops
	Energy production (renewable)	Production of fuel energy
	Fiber, fuel, fodder	Providing renewable and extractable raw materials for fuel and fiber, including plant stumps, shrubs and fodder and wood (fuel wood); providing fiber from plants (water hyacinth, straw, etc.); Charcoal production from the processing of many plants.
	Biological materials (biotics)	The use of agricultural plants as building materials, the production of various secretions such as gum, resin, handicrafts, etc.

	Providing genetic materials, natural medicines and biochemistry (biochemical)	Including the extraction of genetic material from plants in the agricultural ecosystem for biomass production, biochemical, industrial and pharmaceutical processes (such as drugs, fermentation, detoxification), breeding programs (examination of genes for resistance to plant pathogens)
	Creating a green belt (protective walls)	The agricultural ecosystem with diverse vegetation plays a very important role in beauty and reducing the amount of air pollution and preventing floods and soil erosion, etc.
	Carbon sequestration	The agricultural ecosystem with diverse vegetation reduces the concentration of carbon dioxide in the atmosphere.
	Fauna and Flora habitat and shelter	The agricultural ecosystem is home to some small rodents that feed on invasive and non-native plants.
Cultural services	Spiritual, religious and therapeutic services	Agricultural ecosystem has spiritual and religious value in many religions, some plant species have spiritual importance.
	Recreation and ecotourism	The agricultural ecosystem provides opportunities for recreational activities such as hiking, hunting, observing plant and animal species, recreational camps, nature watching, etc.
	Cultural heritage values and sense of place	The agricultural ecosystem represents the culture and civilization of many years of indigenous communities located around it.
	Conservation values	Endangered native species are preserved in the agricultural ecosystem and its margins.
	Aesthetic, inspiring culture, art and design	The existence of spectacular landscapes is one of the aesthetic aspects of the agricultural ecosystem.
	Health and Mental Well-being	Reducing stress by spending time near the agricultural ecosystem, enjoying recreational activities such as group camps in the vicinity of the agricultural ecosystem.
	Education and Research	Agroecosystem can be used to develop many research and education (educational ecosystem services mean formal and informal educational opportunities created by access to particular ecosystems such as providing condition for education and research about ecosystem services such as biotechnology research, thesis research, toxicology research on the ecosystem services and etc).
	Existence values	People feel pleasure and satisfaction from the plant and animal species in and around it.
	Employment (creating job)	The agricultural ecosystem directly by creating employment in field of agricultural products, crops, livestock, fish, and aquaculture and indirectly by attracting investments and businesses that support tourism and eco-tourism to help contributes to the economy of the region
	Meetings and social relations	Agricultural ecosystem connects people, places and other forms of life and causes social interaction. Also, agricultural ecosystem is a suitable place for holding ceremonies.
	Security	The establishment of protection units and recreational activities in the vicinity of the agricultural ecosystem increases security and reduces crime for agritourism.

In this research, in order to investigate the reliability of the questionnaire questions, the Cronbach's alpha coefficient was used. Cronbach's alpha coefficient obtained $\alpha = 0.97$ which it was confirmed.

- **Weighing and prioritizing the AEFS of Northern Iran**

After collecting and analyzing the questionnaires, the SWARA technique in order to determine the weight of the AEFS, the SAW, ARAS and TOPSIS method have been used for priority AEFS. The findings models are presented below.

- **Determining the weight of the AEFS of Northern Iran with the SWARA technique**

The results of AEFS weighting indicated in Table 3. The weighting findings showed that the food supply, employment, supply of genetic materials, and educational and research services respectively have the highest weight.

Table 3. Calculating the AEFS weight in Northern Iran using the SWARA technique.

Functions	Services	W_j
Regulating services	Local and regional climate regulation	0.0305
	Improve air quality	0.0309
	Hydrological cycle and groundwater maintenance	0.0306
	Regulating water quality (water purification)	0.0279
	Pollination and seed dispersal	0.0311
	Pest and disease control (biological pest control)	0.0252
	Smell reduction, noise reduction, visual screening	0.0267
	Natural hazard regulations	0.0270
	Soil erosion control	0.0319
	Soil formation	0.0286
	Regulating soil moisture and maintaining soil fertility	0.0267
	Ecosystem connectivity	0.0248
	Nutrient cycle	0.0275
	Role in food webs and prey/predator relationships	0.0288
	Providing and maintaining habitats (biodiversity)	0.0290
	Primary production	0.0301
Provisioning services	water supply	0.0163
	food supply	0.0397
	Energy production (renewable)	0.0304
	Fiber, fuel, fodder	0.0290
	Biological materials (biotics)	0.0238
	Providing genetic materials, natural medicines and biochemistry (biochemical)	0.0367
	Creating a green belt (protective walls)	0.0338
	Carbon sequestration	0.0346
	Fauna and Flora habitat and shelter	0.0239
Cultural services	Spiritual, religious and therapeutic services	0.0154
	Recreation and ecotourism	0.0221
	Cultural heritage values and sense of place	0.0236
	Conservation values	0.0236
	Aesthetic, inspiring culture, art and design	0.0323
	Health and Mental Well-being	0.0161
	Education and Research	0.0365
	Existence values	0.0260
	Employment	0.0384
	Meetings and social relations	0.0257
	Security	0.0148

According to the results of Table 4, the provisioning function has the most weight among other functions of the agricultural ecosystem in northern Iran (Table 4).

Table 4. Calculating the weight of agricultural ecosystem functions in Northern Iran using the SWARA.

Function	W_j	Rank
Provisioning	0.0298	1
Regulating	0.0286	2
Cultural	0.0250	3

- Determining the priority of the AEFS in northern Iran

The results obtained from the implementation of ARAS, TOPSIS and SAW models to determine the priority of the AEFS are presented in 5 and 6 tables.

Table 5. Final weights of the AEFS in Northern Iran.

Code	Services	Models		
	Regulating services	**ARAS**	**SAW**	**TOPSIS**
A_1	Local and regional climate regulation	0.7679	0.6091	0.5422
A_2	Improve air quality	0.7782	0.7252	0.5114
A_3	Hydrological cycle and groundwater maintenance	0.7713	0.6179	0.5493
A_4	Regulating water quality (water purification)	0.7048	0.5198	0.5000
A_5	Pollination and seed dispersal	0.7850	0.6772	0.5449
A_6	Pest and disease control (biological pest control)	0.6365	0.4392	0.4661
A_7	Smell reduction, noise reduction, visual screening	0.6724	0.4586	0.4551
A_8	Natural hazard regulations	0.6809	0.4590	0.4661
A_9	Soil erosion control	0.8055	0.6226	0.4551
A_{10}	Soil formation	0.7201	0.5369	0.5061
A_{11}	Regulating soil moisture and maintaining soil fertility	0.6741	0.4705	0.4696
A_{12}	Ecosystem connectivity	0.6246	0.3864	0.3965
A_{13}	Nutrient cycle	0.6945	0.5013	0.4878
A_{14}	Role in food webs and prey/predator relationships	0.7270	0.5593	0.5228
A_{15}	Providing and maintaining habitats (biodiversity)	0.7304	0.5561	0.5174
A_{16}	Primary production	0.7594	0.5782	0.5199
	Provisioning services	**ARAS**	**SAW**	**TOPSIS**
B_1	Water supply	0.4113	0.2487	0.3754
B_2	Food supply	1.0000	1.1024	0.6667
B_3	Energy production (renewable)	0.7662	0.6138	0.5469
B_4	Fiber, fuel, fodder	0.7304	0.5503	0.5124
B_5	Biological materials (biotics)	0.6007	0.3764	0.4120
B_7	Providing genetic materials, natural medicines and biochemistry (biochemical)	0.9249	0.8950	0.7509
B_8	Creating a green belt (protective walls)	0.8515	0.7227	0.4871
B_9	Carbon sequestration	0.8737	0.7623	0.5135
B_{10}	Fauna and Flora habitat and shelter	0.6024	0.4157	0.4690
	Cultural services	**ARAS**	**SAW**	**TOPSIS**
C_1	Spiritual, religious and therapeutic services	0.3891	0.2314	0.3696
C_2	Recreation and ecotourism	0.5580	0.4149	0.4815
C_3	Cultural heritage values and sense of place	0.0141	0.4369	0.4706
C_4	Conservation values	0.0141	0.3826	0.4313
C_5	Aesthetic, inspiring culture, art and design	0.0263	0.6772	0.4255
C_6	Health and Mental Well-being	0.0065	0.2376	0.3512
C_7	Education and Research	0.0337	0.8917	0.4824
C_8	Existence values	0.0170	0.4522	0.4645
C_9	Employment	0.0371	1.0207	0.5796
C_{10}	Meetings and social relations	0.0167	0.6456	0.6772
C_{11}	Security	0.0055	0.2102	0.3392

Table 6. Prioritization of agricultural ecosystem services in Northern Iran.

ARAS	**SAW**	**TOPSIS**
B_2	B_2	B_7
B_7	C_9	C_{10}
B_9	B_7	B_2
B_8	C_7	C_9
A_9	B_9	A_3
A_5	A_2	B_3
A_2	B_8	A_5
A_3	C_5	A_1
A_1	A_5	A_{14}
B_3	C_{10}	A_{16}
A_{16}	A_9	A_{15}
A_{15}	A_3	B_9
B_4	B_3	B_4
A_{14}	A_1	A_2
A_{10}	A_{16}	A_{10}
A_4	A_{14}	A_4
A_{13}	A_{15}	A_{13}
A_8	B_4	B_8
A_{11}	A_{10}	C_7
A_7	A_4	C_2
A_6	A_{13}	C_3
A_{12}	A_{11}	A_{11}
B_{10}	A_8	B_{10}
B_5	A_7	A_8
C_2	C_8	A_6
B_1	A_6	C_8
C_1	C_3	A_7
C_9	B_{10}	A_9
C_7	C_2	C_4
C_5	A_{12}	C_5
C_8	C_4	B_5
C_{10}	B_5	A_{12}
C_4	B_1	B_1
C_3	C_6	C_1
C_6	C_1	C_6
C_{11}	C_{11}	C_{11}

The final weight of the agricultural ecosystem functions with ARAS, TOPSIS and SAW models is indicated in table (7). The finding showed that the provisioning functions have gained more weight among other functions at the three models (Table 7).

Table 7. The final weight and priority of the agricultural ecosystem functions in Northern Iran.

Functions	**Final weight**			**Priorities**		
	TOPSIS	SAW	ARAS	TOPSIS	SAW	ARAS
Provisioning	0.5260	0.6319	0.7512	1	1	1
Regulating	0.4944	0.5448	0.7208	2	2	2
Cultural	0.4611	0.5092	0.1016	3	3	3

- **Statistical analysis of selecting the appropriate model for prioritizing the AEFS in Northern Iran**

In order to compare the models for prioritizing the AEFS in northern Iran, the curve slope (R^2) of the factor weight used in three models (Figure 3). The slope curve of the relative proximity of the weights in the SAW model is a descending exponential function with an explanatory degree of 0.90, which indicates the obvious difference between the AEFS of Northern Iran.

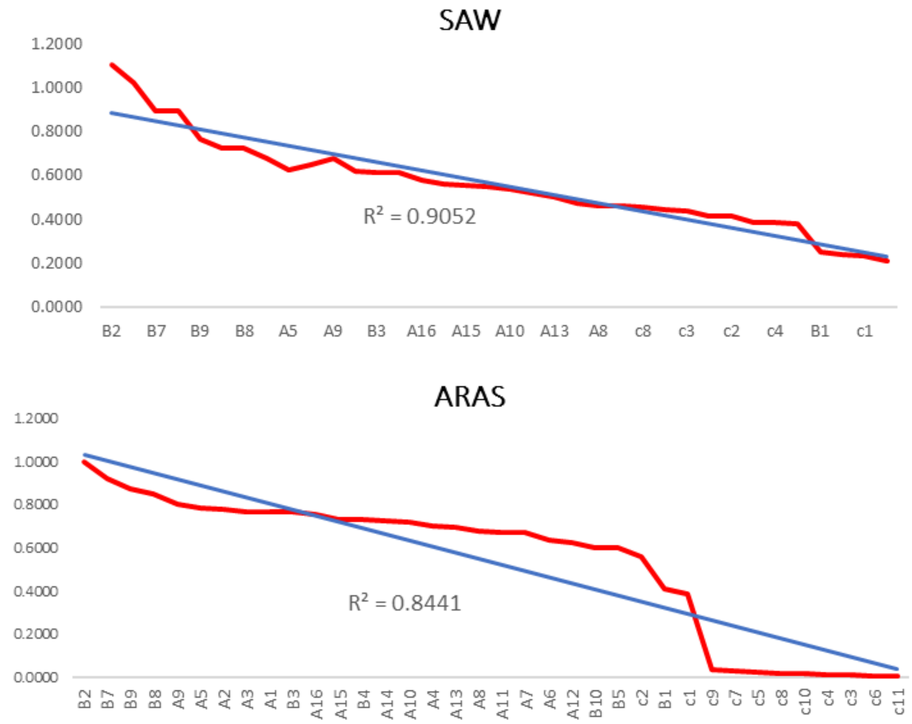

Figure. 3. Curve slope (R^2) in ARAS, TOPSIS and SAW models.

The R^2 in the SAW model is higher and closer to one than the other models. Based on the finding and the consensus of some experts, the result prioritization of the AEFS of Northern Iran in the SAW model has been closer to reality. Therefore, the SAW model is suggested as a suitable model for prioritizing the AEFS in Northern Iran.

4- Prioritizing the AEFS in Northern Iran based on suitable model (SAW model)

Based on the results of the best model for prioritizing the AEFS of Northern Iran (SAW model), provisioning, regulating and cultural functions are the most important functions of the agricultural ecosystem of Northern Iran respectively.

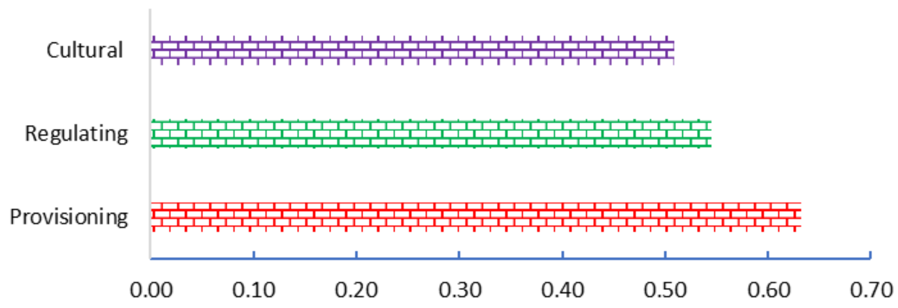

Figure 4. The priority of the functions of the agricultural ecosystem of Northern Iran in the SAW model.

The findings of prioritizing agricultural ecosystem services in Northern Iran with the SAW model are presented in figures 5, 6 and 7. The results indicated that food supply, employment, air quality improvement services of provisioning, and cultural regulating functions had the first priority respectively compared other agricultural ecosystem services in the north of Iran.

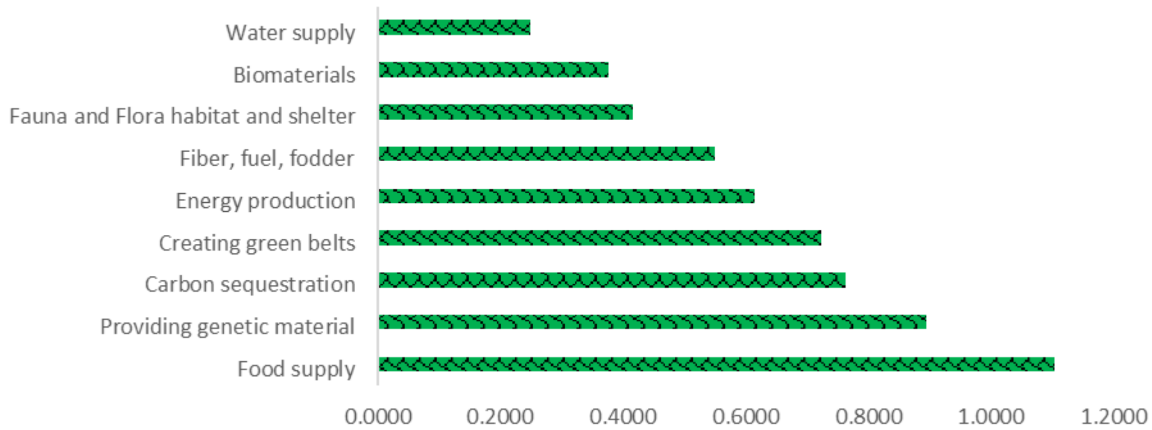

Figure 5. The priority of the provisioning services.

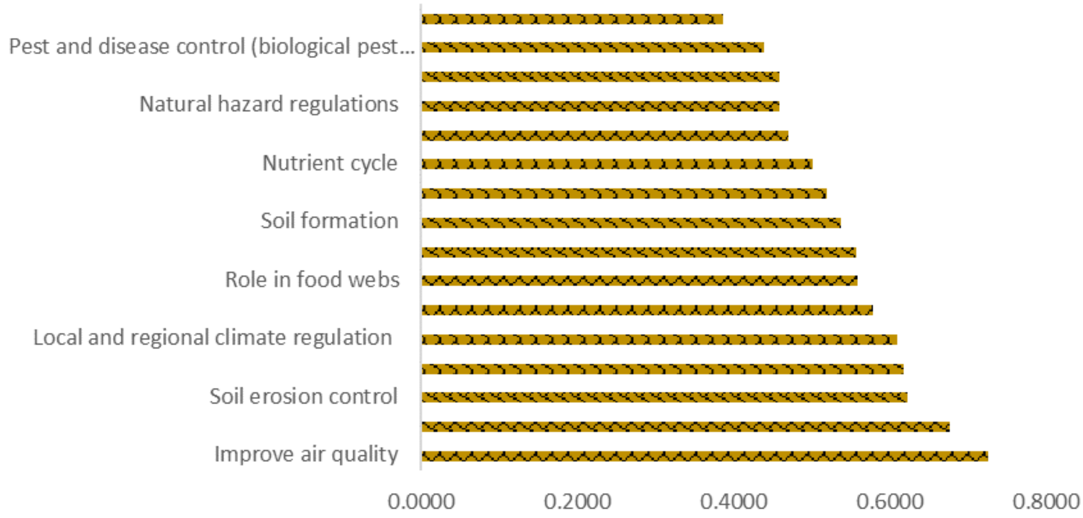

Figure 6. The priority of regulating services.

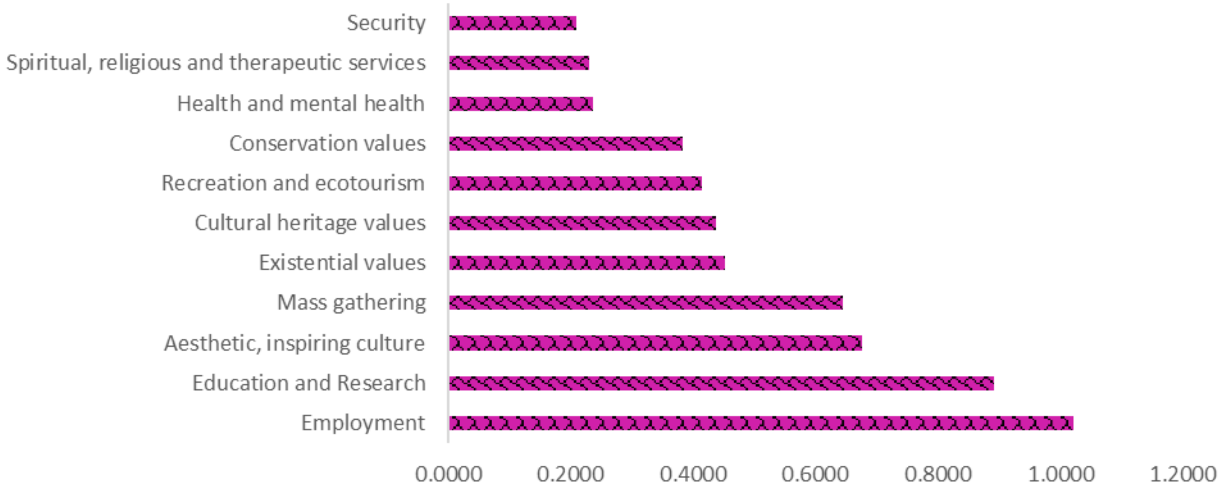

Figure .7. The priority of cultural services.

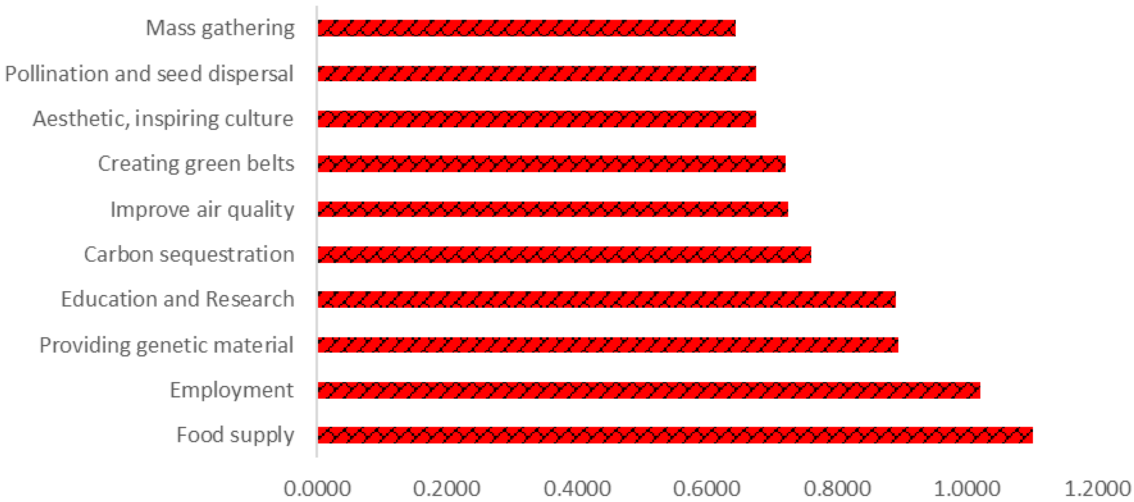

Figure .8. The most important agricultural ecosystem services in northern Iran.

DISCUSSION and CONCLUSIONS

Although the primary goal of agriculture is to produce food, the importance of agriculture is beyond the production of crops (Swinton et al., 2015). And a set of ecosystem services that human life depends on is provided by agriculture (Rabbinge & Bindraban, 2012). The knowledge and skills of farmers in managing agro ecosystems can play an essential role in improving the balance between ecosystem services. Based on this, the management approach of each agro ecosystem is very important, so that sustainable agro ecosystems are involved with ecosystem services. However, the main management approach is based on maintaining these services for use Future generations are stable (Altieri, 2018).

The AEFS prioritization results in Northern Iran using MCDM models indicated that the provisioning and regulating functions have the first priority at among all the prioritization models. In other words, provisioning and regulating functions are the most important functions of the agricultural ecosystem in Northern Iran. According to the agricultural specialist experts' opinions of Northern Iran, the higher priority of the provisioning function is due to the fact that the agricultural ecosystem of Northern Iran was one of the richest ecosystems in terms of providing food, genetic material, carbon sequestration, creating a green belt and etc., that each of them has many benefits for the region communities. The result is in accordance with the findings studies of Jia et al. (2021) and Heinze et al. (2022). Also, De Groot et al. (2012) stated regulating services include maintaining essential ecological processes and environmental protection systems. The study results showed that the agricultural ecosystem regulating services such as air quality improvement, pollination and seed dispersal, soil erosion control have the highest priorities compared to other services in northern Iran.

Cultural services provide opportunities for spiritual, aesthetic, educational and scientific enrichment. In this regard, the results obtained from the prioritization of agricultural ecosystem services in the north of Iran indicated that the services of creating employment, education and research are the most important agricultural ecosystem cultural services. In other words, the agricultural ecosystem of Northern Iran has created many employment, educational and research opportunities for various academic researchers. Also, the presence of beautiful landscapes on the edge of the agricultural ecosystem of Northern Iran has provided a suitable potential for tourism and ecotourism. The improvement of recreational conditions and tourism facilities provided tourism income for investment this area which it is one of the reasons for getting higher priority of employment creation services from the point of view of communities on the edge of the agricultural ecosystem in Northern Iran. The studies' result Sohrabi et al. (2021) in Iran and Assandri et al. (2018) confirm these results in the Trentino, Italy. The findings showed that the cultural function was one of the most important functions of the agricultural ecosystem.

Unfortunately, the lack of information and insufficient recognition of the positive services of the agricultural ecosystem in Northern Iran has caused the amount of damage to the ecosystem to increase and its habitat desirability to decrease. Meanwhile, most of the economic researches published in developing countries are focused on the direct benefits of the agricultural ecosystem. The lack of proper understanding of these functions and the services produced by them is considered a serious danger for the society. Therefore, it is suggested to inform the communities about the importance of the positive services of the agricultural ecosystem in northern Iran in order to protect them.

As seen, the current research has been done at a relatively limited level. Therefore, it is necessary to pay attention to the agricultural ecosystem services in a large area. In addition to the opinions of experts, the opinions of native and non-native communities should be considered in determining priority. Because knowing, classifying and prioritizing the services will be the guidance for policy making, management and how to use the agricultural ecosystem (De Groot et al., 2010). Also, it is necessary for future researchers to pay more attention to the role and importance of the functions and services of the and to survey the environmental behaviors of people in relation to the Northern Iran AEFS. Because the concept of agricultural ecosystem services by including all social, economic and ecological dimensions is a suitable framework for integration in the planning and management of the agricultural ecosystem.

Acknowledgements

The present study is done at Sari Agricultural Sciences and Natural Resources University (SANRU). We thank and appreciate the cooperation of experts and specialists in the field of agricultural ecosystem management at the SANRU and Agricultural Jihad Organization in Iran for doing this research.

Reference

1. Ali Majeed R., Breesam H., 2021. Application of SWARA technique to find criteria weights for selecting landfill site in Baghdad governorate. IOP Conf. Ser.: Mater. Sci. Eng. 1090 012045. DOI 10.1088/1757-899X/1090/1/012045

2. Altieri, M.A. 2018. Agroecology: The science of sustainable agriculture. Westview Press; 2 edition (October 13, 1995).

3. Altieri, M.A., 2018. Agroecology: The Science of Sustainable Agriculture. Westview Press; 2 edition (October 13, 1995).

4. Amor, W., López, L., Frikha, H., 2022. A multigranular linguistic additive ratio assessment model in group decision making. World academy of science, engineering and technology.
Int. j. comput. sci. eng.16 (8), 2022.

5. Assandri, G., Bogliani, G., Pedrini, P., Brambilla, M., 2018. Beautiful agricultural landscapes promote cultural ecosystem services and biodiversity conservation. Agriculture. 256, 200-210.

6. Ayan, B., Abacıo˘glu, S., Basilio, M.P. A., 2023. Comprehensive review of the novel weighting methods for multi-Criteria decision-making. Information 14, 285. https://doi.org/10.3390/info14050285.

7. Azaiez, N., Alleoua, A., Baazaoui, N., Qhtani, N., 2020. Assessment of soil loss in the Mirabah Basin: an overview of the potential of agricultural terraces as ancestral practices (Saudi Arabia). Open J Soil Sci 10,159–180. https://doi.org/10.4236/ojss.2020.105008

8. Bishop, J. T., 1999. Valuing forests: A Review of method and application in developing countries. International Institute for Environment and Development (IIED). 53-67. London: WC1 ODD, U.K.

9. Chen, T., YU, S., 2022. Study on the risk level of food production enterprise based on TOPSIS method. Food Science and Technology. Food Sci. Technol, Campinas. 42, e29721. DOI: https://doi.org/10.1590/fst.29721

10. Czúcz, B., I., Arany, M., Potschin-Young, K., Bereczki, M., Kertész, M., Haines-Young, R., 2018. Where concepts meet the real world: A systematic review of ecosystem service indicators and their classification using CICES. Ecosyst. Serv. 29, 145-157 pp.

11. De Groot, R. S., Alkemade, R., Braat, L., Hein, L., Willemen, L., 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecol. Complex. 7, 260–272.

12. De Groot, R., Brander, L., Ploeg, S., 2012. Estimates of the value of ecosystems and their services in monetary units. Ecosyst. Serv. 1, 50–61.

13. Debnath, B., Baria, M., Haqa, M., Pachecob, J., Khan. M., 2023. An integrated stepwise weight assessment ratio analysis and weighted aggregated sum product assessment

framework for sustainable supplier selection in the healthcare supply chains. Supply Chain Analytics, 100001

14. Dick, J., Turkelboom, F., Woods, H., 2017. Iniesta-Arandia, I., Primmer, E., et al. 2018. Stakeholders' perspectives on the operationalisation of the ecosystem service concept: results from 27 case studies. Ecosyst. Serv. 29, 552–565. https://doi.org/10.1016/j.ecoser.2017.09.015.

15. Fan, J., Han, D., Wu, M., 2023. Picture fuzzy Additive Ratio Assessment Method (ARAS) and VIseKriterijumska Optimizes I Kompromisno Resenje (VIKOR) method for multi-attribute decision problem and their application. Complex Intell. Syst. https://doi.org/10.1007/s40747-023-01007-5

16. Heinze, A., Bongers, F., Marcial, N., Barrios, L., Kuyper Th., 2022. Farm diversity and fine scales matter in the assessment of ecosystem services and land use scenarios. Agric. Syst. 196, 103329.

17. Hosseini, S., Amirnejad H., Azadi, H., 2024. Impacts of Hyrcanian forest ecosystem loss: the case of Northern Iran. Environment, Environ Dev Sustain, 22 pp. https://doi.org/10.1007/s10668-023-04408-1

18. Hosseini, S., Oladi, J., Amirnejad, H., 2021. The evaluation of environmental, economic and social services of national parks. Environ. Sci. Dev. 23, 9052-9075.

19. Jaukovic Jocic, K., Jocic. G., Karabasevic, D. et al., 2020. A novel integrated PIPRECIA-interval-valued triangular fuzzy ARAS model: E-learning course selection. Symmetry (Basel).12 (6), 928, 2020.

20. Jia, Y., Liu, Y., Zhang, S., 2021. Evaluation of Agricultural Ecosystem Service Value in Arid and Semiarid Regions of Northwest China Based on the Equivalent Factor Method. Environmental Processes. 8,713–727. https://doi.org/10.1007/s40710-021-00514-2

21. Jia, Y., Liu, Y., Zhang, S., 2021. Evaluation of Agricultural Ecosystem Service Value in Arid and Semiarid Regions of Northwest China Based on the Equivalent Factor Method. Environ. Process. 8, 713–727 (2021). https://doi.org/10.1007/s40710-021-00514-2

22. MEA (Millennium Ecosystem Assessment), 2005. Ecosystems and Human Well-Being: Synthesis. Island Press, Washington D.C.

23. Mengual-Andrés, S., Roig-Vila, R., Mira, J.B. 2016. Delphi study for the design and validation of a questionnaire about digital competences in higher education. Int J Educ Technol High Educ, 13, 12. https://doi.org/10.1186/s41239-016-0009-y

24. Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-being: Synthesis. Island Press, World Resources Institute, Washington, D.C, 155P.

25. Prayogo, M. A., Suseno, J. E., Nugraheni, D. M. K., 2019.Selecting palm oil cultivation land using ARAS method," in International Seminar on Research of Information Technology and Intelligent Systems (ISRITI). 358-362.

26. Rabbinge, R., Bindraban P.S. 2012. Making more food available: Promoting sustainable agricultural production. Journal of Integrative Agriculture. 11: 1–8.

27. Ramón-Canul, L., Margarito-Carrizal, D., Limón-Rivera R., et al. 2020. Technique for order of preference by similarity to ideal solution (TOPSIS) method for the generation of external preference mapping using rapid sonometric techniques. J Sci Food Agric. 101 (8): 3298-3307. https://doi.org/10.1002/jsfa.10959

28. Schmidt, M., Weißhuhn, P., Augustin, J., Funk, R., Häfner, K., König, H., Loft, L., Merz, C., Meyer, C., Piorr, A., Reutter, M., Stachow, U., Stein-Bachinger, K., Matzdorf, B. 2017. Evaluation of the ecosystem services approach in agricultural literature. One Ecosystem. 2: e11613. https://doi.org/10.3897/oneeco.2.e11613

29. Sohrabi S., Veisi H., Khoshbakht K.2021. A Comparative Analysis of Ecosystem Services Valuation in Alternative Agricultural Systems (Case of Dezful County, Khuzestan Province). Environmental Researches.11 (22):45-56.

30. Sun, Q., Qi, W., Yu, X., 2021. Impacts of land use change on ecosystem services in the intensive agricultural area of North China based on multi-scenario analysis. Alex. Eng. J. 60(1), 1703–1716. https://doi.org/ 10.1016/J.AEJ.2020.11.020.

31. Swinton, S.M., Jolejole-Foreman, C.B., Lupi, F., Ma, S., Zhang, W., Chen, H. 2015. Economic value of ecosystem services from agriculture. The Ecology of Agricultural Landscapes: Long-Term Research on the Path to Sustainability. Oxford University Press, New York, New York, USA.

32. Wang, Y., Liu, G., Cai, Y., Giannetti, B., Agostinho, Fet al., 2022. The Ecological Value of Typical Agricultural Products: An Emergy-Based Life-Cycle Assessment Framework. Front. Environ. Sci. 10:824275. Doi: 10.3389/fenvs.2022.824275

33. Yücenur, G.N., Ipekçi, A., 2021. SWARA/WASPAS methods for a marine current energy plant location selection problem, Renew. Energy, 163. 1287–1298

34. Zavadskas, E., & Turskis, Z., 2010. A new additive ratio assessment (ARAS) method in multicriteria decision-making, Technol. Econ. Dev. Econ. 16(2), 159-172. DOI: 10.3846/tede.2010.10.

35. Zolfani S., Saparauskas J.2013. New application of SWARA method in prioritizing sustainability assessment indicators of energy system. INZ EKON. 24 (5).408-414. DOI: https://doi.org/10.5755/j01.ee.24.5.4526.

بررسی کارکردها و خدمات اکوسیستم کشاورزی در شمال ایران

ساره حسینی، و فهیمه کریمپور

چکیده

اکوسیستم کشاورزی کارکردها و خدمات مختلفی را برای انسان فراهم می کند. لذا بررسی نقش و اهمیت آنها در برنامه ریزی و مدیریت اراضی کشاورزی یکی از اهداف تحقیق می باشد. برای شناسایی کارکردها و کالاها و خدمات اکوسیستم کشاورزی از طبقه بندی مشترک بین المللی خدمات اکوسیستمی (CICES) استفاده گردید. همچنین جهت وزن دهی و اولویت بندي کارکردها و خدمات اکوسیستم کشاورزی از تکنیک های تصمیم گیری چند معیاره شامل تحلیل نسبت ارزیابی وزن دهی تدریجی (SWARA) به منظور محاسبه وزن کارکردها و خدمات، و مدل های مجموع ساده وزین (SAW)،ارزیابی نسبت جمعی (ARAS) و تکنیک ترجیحات بر اساس مشابهت به راه حل ایده‌آل (TOPSIS) برای اولویت بندی آنها استفاده شده است. در این مطالعه داده هاي پژوهش به صورت پیمایش میدانی، نمونه گیری تصادفی و با تکمیل پرسشنامه دلفی توسط 40 نفر از خبرگان کشاورزی در شمال ایران استخراج گردید تا نمایان شود کدامیک از کارکردها و خدمات مثبت اکوسیستم کشاورزی دارای اهمیت بیشتری در مدیریت بهینه آن می باشند. همچنین برای مقایسه مدل های اولویت بندی از ضریب R^2 استفاده شد. یافته هاي تکنیک SWARA نشان داد که کارکردهای تامینی، تنظیمی و فرهنگی به ترتیب با کسب وزن های 0/0298، 0/0286 و 0/0250 بیشترین وزن را به خود اختصاص داده اند. همچنین نتایج نشان داد که مدل SAW با کسب R^2= 0/90 به عنوان مدل مناسب انتخاب گردید. طبق نتایج اولویت بندی این مدل، کارکردهای تامینی، تنظیمی و فرهنگی با وزن های 0/6319، 0/5448 و 0/05092 به ترتیب در اولویت اول تا سوم جهت مدیریت بهینه اکوسیستم کشاورزی شمال ایران قرار گرفتند. همچنین در میان خدمات اکوسیستمی، خدمات تامین غذا، اشتغال، تأمین مواد ژنتیکی و خدمات آموزشی و پژوهشی جزء خدمات مهم و مثبت اکوسیستم کشاورزی شمال ایران نسبت به سایر خدمات می باشند. لذا پیشنهاد می شود برنامه ریزی مناسب تر و تحقیقات بیشتر توسط سازمان های ذیربط جهت مدیریت پایدار اکوسیستم های کشاورزی صورت پذیرد.