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Research article

Feasibility of using vertical farming in northern Iran: A multiple necessity

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ABSTRACT

Agricultural production in vertical farms (VF) will play a prominent role in preventing environmental crises, its good governance and maintaining food security for everyone in the world. The ecological footprint in Guilan province significantly exceeds its biological capacity, indicating considerable pressure on its natural resources and ecosystems. This problem, which is mostly due to the use of traditional production methods in the agricultural sector, requires a change in lifestyle and production methods. The purpose of the current research is the feasibility of VF in Guilan province with the help of the Strengths, Weaknesses, Opportunities, and Threats (SWOT) model and Quantitative Strategic Planning Matrix (QSPM). After identifying internal factors (strengths and weaknesses) and external factors (opportunities and threats) affecting production in VF, the necessary strategies were determined and then prioritized using the QSPM matrix. Necessary information through written scientific sources and survey studies based on key questions between two groups of professors of geography and rural planning, water resources engineering, soil, architecture and experts from the plant production department and the head of the environment department, Jihad Agricultural Organization of Guilan province and the organization Food hygiene was achieved. The statistical population participating in the survey was 30 people. The results of the research showed that 7 strategies were formulated based on strengths, weaknesses, opportunities, and threats and were prioritized based on the importance of four strategies in the QSPM table. The first priority for ensuring food security in Guilan province is to focus on increasing agricultural productivity per unit area. This strategy is crucial considering the challenges of low ownership and limited land availability in the region. Thus, enhancing productivity per unit area should be given utmost priority to meet the food demands of the population. The appropriate strategy for VF production in Guilan province is a competitive-aggressive strategy and being in this position requires attracting the necessary funds. This study fills research gaps by providing a comprehensive assessment of the feasibility of vertical farming in Guilan province. The emphasis on methodology, strategic planning, and addressing food security and environmental challenges contributes to the existing body of knowledge. By highlighting the transferability and adaptability of the research findings, other researchers can utilize the methods and adapt the strategies to their own regions, promoting further research and advancement in the field of sustainable agriculture.

1. Introduction

Population growth, diversity and complexity of socio-economic need on the one hand and environmental constraints on the other, introduced thinking based on planning and organizing the various affairs of societies at both national and regional levels (Jalalian, 2017). The importance of this category aimed at organizing and balancing spatial growth and development and a tool for correcting regional inequalities and the need to protect natural resources (Jalalian, 2017). In other words, human and economic development in today's world has caused environmental erosion and climate change (Wyckhuys et al., 2022). These challenges cannot be solved with traditional approaches (Heidari Sarban, 2019). The Food Agriculture Organization (FAO) has announced that the goals of the third millennium are meeting the nutri-

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tional needs and improving the food security of humans (Svari and Ghanian, 2019). According to the FAO forecast, the number of people suffering from malnutrition is constantly increasing (Chiaranunt and White, 2023).

Agriculture must become more sustainable to provide affordable and healthy food at minimal environmental and social costs (Helfenstein et al., 2022). However, as land resources for agriculture dwindle, policymakers will have difficulty feeding the world's growing population (Benke and Tomkins, 2017), which is estimated to increase to 9.2 billion by 2050 (Taheri et al., 2017). Globally, urban areas are growing at a faster rate than their population, potentially reducing environmental sustainability due to the encroachment of natural and agricultural land (Li et al., 2022). This can have implications for food production in urban areas, affecting the sustainability of production and human health (Kalantari et al., 2017). The challenges that the agricultural industry will face as a result of large population changes require further efforts (Hosseini et al., 2021). As long as only traditional agricultural methods are used to increase production and pursue commercial goals, the sustainability of environmental resources will be challenged (Adem et al., 2020; Yu et al., 2022). According to the indicators of the United Nations and the International Institute for Water Management, Iran is on the verge of a severe water crisis (Agriculture, water and food, 2016). Reducing the costs of setting up and maintaining irrigation systems has been a challenging issue for Iran and the world for a long time (Zamani et al., 2020). Addressing the consequences of climate change threats to agriculture and understanding its coping mechanisms also require increasing the understanding of sustainable management (Azadi et al., 2021). Global climate change, which is influenced by human lifestyles and misbehavior (Naskali et al., 2021), may make it difficult for everyone to progress to a world of food security and it exacerbates food shortages (von Braun, 2020).

Hence, Vertical Farms (VF) can be a new method of production, making agricultural products available to everyone at reasonable prices (Agriculture, water and food, 2016). This production method is a new, dynamic, and ever-changing sector (Buttrini and Marcelis, 2019). This method involves the production and growth of agricultural products throughout structures (a skyscraper or an old warehouse) instead of cultivation in the ground, which saves water and soil resources (Salim Mir et al., 2022). The purpose of VF is to reduce the pressure on traditional agricultural land through the use of soilless production systems (Beacham et al., 2019). Hence, the emergence of VF as a new form of green infrastructure for urban agriculture and horticulture has the potential to increase sustainability (Ping Song et al., 2017). In recent years, the interest of researchers to study this method has increased. For example, Moghimi (2021) considered agricultural product manufacturing in VF to be an innovative and forward-thinking sector with the goal of environmental sustainability. By investigating the optimization process of energy demand in VF, Avgoustaki and Xydis (2021) explored changing the electric load to reduce the cost of lighting. Waller and Gugganing (2021) suggested digital approaches that promote the broad interaction of technology and emphasis on structured business innovation in a pilot VF project. Radad (2019) found it necessary to comply with the principles of location and design of the building body in this production method.

In terms of social, environmental, economic, and sustainable development, Rangelov and Staykova (2020) urged for a more all-encompassing approach to the provision of raw materials and resources in future cities. De et al. (2021) defined the fields as a protected habitat for growing crops with vertical lines, precise lighting, nutrients, and temperature.

Most of the studies have shown that this type of production method for agricultural products has been proposed only in urban areas. These studies, however, did not adequately address the greater issue of food security in urban areas and did not take into account the expanding importance of food systems. Most people live in cities, but most food system studies (e.g., Dzanku, 2019; Rammohan et al., 2019; Nunes et al., 2019) and food security issues focus on the rural poor.

Urban populations consume food differently from rural populations since they are often richer and depend on trade for their food security, which is measured by how well they are able to feed themselves (Ruel et al., 2017). Cities typically lack the inherent ability to independently meet their food requirements. This implies that the food consumed by the city's population is sourced from its local agroecosystems (De Graef, 2019). According to Porter et al. (2014), output from remote regions, both internal and external in terms of a state's authority, enhances a city's food security. The results of this research can be a good reference for research and development regarding the use of new production methods in VF by increasing global knowledge. This is because this method of producing agricultural products is still unknown in many parts of the world, especially in countries that are suffering from lack of land, lack of water resources, and lack of healthy and fertile soil for food production. Many developing and developed countries, due to lack of awareness and to achieve the goals of economic development and food security, cause environmental erosion and climate change. Therefore, VF can be a model of development and a solution to achieve sustainability in the environment, economy, justice, and welfare for the people of the world.

The present study suggests the use of VF as a new method of producing agricultural products in urban and rural areas of Guilan province. The main reasons for this suggestion are the preservation of environmental resources as well as the preservation of production and export roles of smallholder farmers in Guilan province. This is because, by accepting the function of agricultural production, the urban areas of Guilan province will reduce the biological pressure and damage to agricultural lands in rural areas, and by maintaining food security, they will provide the basis for sustainable development. The objective of the regional network strategy is to foster the development of both the city and the village, creating a symbiotic relationship where the city thrives through the growth of the village, and vice versa. The best type of planning for cities and villages is to provide appropriate strategies for their simultaneous development and progress. As a result, the present study is different from others because it used the SWOT analytical model for the feasibility of using the production method in VF in Guilan province in Iran. In other words, with SWOT analysis in this study, the strengths, weaknesses, opportunities, and threats affecting the production of agricultural products in the new VF technique were identified and strategic planning was done.

This study brings a novel contribution to the field of sustainable agriculture by examining the feasibility of vertical farming in Guilan province and addressing the pressing challenges of environmental crises and food security. The novelty of this research lies in its integrated approach, combining the SWOT analysis, Quantitative Strategic Planning Matrix (QSPM), and stakeholder engagement to provide a comprehensive assessment and prioritize strategies. Moreover, this study fills a research gap by emphasizing the transferability of findings, allowing other researchers to utilize the methodology and adapt the results to their own regions. By offering insights into the strategic planning of vertical farming and proposing solutions tailored to the local context, this research opens new avenues for policymakers, planners, farmers, producers, and investors to explore innovative approaches to agricultural production while preserving environmental resources and ensuring food security.

The introduction of this production method aims to verify the feasibility and necessary solutions and strategies at the regional level of Guilan province. Based on the main objectives of this research, the following questions are addressed:

1 How can the existing strengths in Guilan province be used to take advantage of the opportunities facing production in the VF?

2 How can the weaknesses of vertical production be reduced to take advantage of the opportunities before it?
3 How can external barriers to the goal be reduced by considering internal strengths?
4 How can existing weaknesses be reduced to overcome the threats facing the research?

To ensure the broader applicability of the methodology, this study has drawn upon well-established principles and practices in the fields of sustainable agriculture, strategic planning, and environmental assessment. The approach is deeply rooted in the extensive body of literature on sustainable agriculture and vertical farming. The research methodology of this study has been developed by fundamental research conducted by Smith et al. (2017), Gomez and Lopez (2020), and Zhang and Li (2018), as well as other scholars' works. These sources provide a robust theoretical foundation for this study, which can serve as a valuable resource for researchers seeking to apply similar strategies in different regions. Moreover, the study has developed a flexible methodology that considers the diverse factors within different agricultural landscapes, allowing it to adapt to these variations. By highlighting the flexibility and adaptability of this approach, the aim of this study is to encourage researchers from various regions to apply this methodology as a reference point for their own investigations into sustainable agricultural practices.

2. Theoretical framework

Ensuring the constant and regular availability of food is crucial to global food security (Namany et al., 2020). Singh, 2019, the global economy, including private and agricultural institutions, has faced unprecedented challenges due to the COVID-19 pandemic (World Bank, 2020). The outbreak has disrupted supply chains, restricted market access, and led to economic downturns in various sectors. However, amidst these challenges, new technologies have emerged as potential catalysts for growth and resilience (United Nations, 2020). The adoption of digital tools, remote working solutions, and e-commerce platforms has helped businesses adapt to the changing landscape and mitigate the negative impact of the pandemic (World Economic Forum, 2021). Moreover, in the agricultural sector, advancements in precision agriculture, automation, and data analytics have the potential to enhance productivity, optimize resource utilization, and improve overall sustainability (Food and Agriculture Organization, 2021). By embracing these new technologies, private and agricultural institutions can not only navigate the current crisis but also foster long-term growth and development. Therefore, to provide global food until 2050, it is necessary to change agricultural production methods (Md Saad et al., 2021) because production resources are decreasing (Avgoustaki and Xydis, 2020). VF is an emerging technology that focuses on organized business innovation and seeks to achieve sustainable and secure food chains (Waller and Gugganing, 2021; Buyukozkan et al., 2021). This method of production should not be considered a substitute for the conventional agricultural method but should be a way to reduce the amount of pressure on environmental resources (Singh, 2019). There is no doubt that VF is exciting and is gaining traction as a young and forward-looking industry. Solving many of the problems of the current agricultural sector in the world requires innovation and change in production methods (Moghimi, 2021). Due to the low consumption of water, pesticides, and chemical fertilizers, as well as high productivity, VF has received a lot of attention around the world. In the method of food production in VF, engineered growth environments are used (Hosseini et al., 2021). Due to the protection of agricultural products from unpredictable weather changes, production is possible throughout the year (Bheemireddy and Joshi, 2021; van Gerrewey et al., 2022). VF will have many effects on the agricultural sector. Some of the environmental, economic, and social effects of VF have been shown in Fig. 1. The successful implementation of VF is contingent upon several factors, including energy efficiency, enhanced profitability, and supportive public policies within society (Van Delden et al., 2021). Furthermore, the production process in vertical farms must account for various environmental, economic, social, institutional, and technical constraints and drivers (Artmann and Sartison et al., 2018). These considerations play a crucial role in optimizing the efficiency and sustainability of VF operations. By addressing these multifaceted aspects, stakeholders can foster a conductive environment for VF, ensuring its long-term viability and positive impact .

VF strategies are a type of controlled environmental agriculture (CEA) that emerged in the 1700s and traditionally started in greenhouses (Despommier, 2019). All farms use one of the following three systems (Hydroponics, Aeroponics, and Aquaponics) to supply plants with nutrients (Despommier, 2019).

Hydroponics: The predominant system of crop growth in hydroponic fields involves the growth of plants in soil-free nutrient solutions. It signifies that the plant thrives on sand, clay, and stone that is consistently hydrated and rich in minerals and nutrients. This method is widely used by hundreds of thousands of commercial greenhouses and VF around the world (Despommier, 2019).

Fig. 1. Environmental, economic, and social effects of vertical farms.

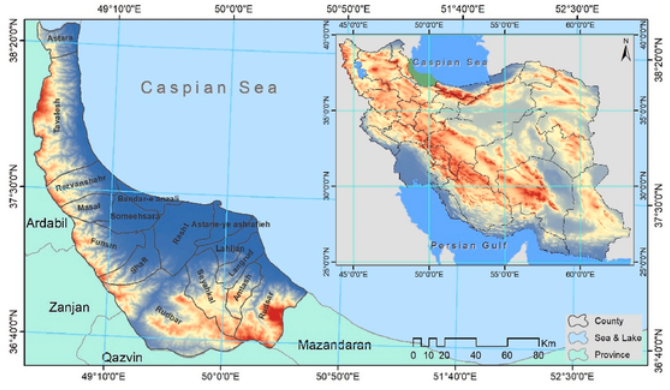

Fig. 2. Geographical location of Guilan province in Iran.

Aeroponics: In the 1990s, NASA sought to find efficient ways to produce plants in space and coined the term "aeroponics" to describe plants growing in air/fog without much soil and water. This system is the most efficient plant breeding system for VF and consumes up to 90 % less water than the most efficient hydroponic systems. Plants grown with this technique absorb more minerals and vitamins, resulting in healthier plants (Despommier, 2019).

Aquaponics: It is a combined method that takes the hydroponic system one step further and combines plants and fish in the same ecosystem (Despommier, 2019). Factors such as plant type, production system type, growth medium type, etc. are influential factors in the efficiency of these systems. Effective steps have been taken around the world to invest in optimizing these factors in order to maximize their efficiency (Safi Khani, 2019).

3. Methodology

3.1. Study area

Guilan province is located between the Alborz and Talesh mountain ranges in the north of Iran and in the south of the Caspian Sea (Fig. 2). It is located at 36 ◦ and 33′ to 38 ◦ and 27′ north latitude and 48 ◦ and 32′ to 50 ◦ and 36′ east longitude of the meridian. Guilan province with an area of 14,711 km², 1,547,849 people in urban areas and 982,827 people in rural areas, is ranked 12th in terms of population in Iran. This province has 17 counties, 43 districts, and 2905 villages, of which 2567 villages have residents. In Guilan province, agricultural products are cultivated with traditional farming techniques and greenhouse cultivation. These methods include the cultivation of vegetables and summer crops, including cucumbers, tomatoes, peppers, eggplants, and strawberries, as well as the cultivation of flowers and medicinal plants in soil-based systems (Guilan Provincial Planning Deputy, 2016; Agricultural Statistics, 2019). The main essential aims of Guilan province's land management plan are economic, social, environmental, and regional ecological balance in order to achieve sustainable spatial development (Sarafi, 2017).

For the implementation of vertical agriculture, geographical, economic, social, technical, institutional and environmental drivers and limitations should be considered. The privileged geographical position of Guilan province compared to other provinces of Iran that have faced natural hazards such as drought and land subsidence in recent decades has caused the population of this province to increase. Compared to other hazards, land subsidence has less loss of life, but the bad consequences left behind will directly affect human, industrial, agricultural and civil development (Nasire Zare and Karam, 2023). The arrival of immigrants often in the rural areas of Guilan province and asking for land to build houses has caused the price of land to increase due to high demand and changes in agricultural land (Molaei Hashjin and Alinaghipour, 2021). Although the government of Iran is against the unauthorized change of land use (Parsa et al., 2020), in some circumstances, the permitted land use change has reduced the amount of productive land in the small Malik province of Guilan. The continuation of this trend of self-reliance in the production of agricultural products endangers the maintenance of food security and the export role and economic growth of Guilan province.

In a situation where Guilan province is facing a shortage of productive land in order to achieve its development goals, its ecological footprint has increased to 1.9 times its biological capacity. In fact, the pressure on natural resources is twice its capacity (Sarafi, 2017). Since one of the important goals of producing agricultural products in VF is to align development goals and plans with the environmental capacities of each place, this study investigated the feasibility of production in VF to empower the environmental resources of Guilan province.

As a result, production in VF as a young and forward-looking industry in the villages and cities of Guilan province with the benefits of empowering environmental resources and increasing employment and sustainable income, maintaining the rural population, preventing migration to cities and creating social problems, maintaining food security and export role and the economic growth of the province can have a positive effect on the decision of planners and investors to use this method.

3.2. Data collection and analysis

The present study is applied research in terms of purpose and descriptive research in terms of data collection. The required information was obtained through documentary, library, and field studies. Documentary method has been used to explain the conceptual framework of the research. Moreover, the method of completing documentary studies was the field method and distribution of questionnaires. Experts' opinions were used to select and categorize the most important internal and external factors affecting the subject of the research. The questionnaire's validity was verified by experts, and its reliability was established with a Cronbach's alpha coefficient of 0.89. The opinions of experts and professors were used for appropriate feasibility and providing the necessary solutions for the production of agricultural products in vertical farms.

This survey was conducted based on key questions among 30 people including two groups of experts and professors. As shown in Table 1, the survey participants encompassed individuals from various fields, including geography, urban and rural planning, water engineering, soil science, architecture, and agriculture. The type of questionnaire designed for the research was a closed questionnaire that evaluated the opinions of the statistical community. The validity of each parameter was evaluated from the perspective of experts using the Likert scale, as well as determining the significance coefficient of the relevant parame-

Table 1
Personal characteristics of the respondents.

Specifications		Abundance	Abundance percentage
Age	20–40	9	30
	41–60	19	63.33
	+61	2	6.7
Gender	Male	20	66.7
	Female	10	33.33
Field of study	Geography(urban and rural planning group)	7	23.33
	Water engineering	5	16.7
	Soil engineering	5	16.7
	Architectural engineering	5	16.7
	Agriculture	8	26.7
Education	Bachelor's	5	16.7
	M.A.	8	26.7
	Ph.D.	17	56.7

Table 2
Internal Factor Analysis Summary (IFAS) to production in VF in Guilan province.

Internal Factor	Normal weight	Score	Final score
S_1: Existence of regional, national, and international demand-driven markets	0.2	4	0.8
S_2: Small ownership and lack of productive lands for production in Guilan province due to land use change	0.2	4	0.8
S_3: Damage to fertile soil resources of Guilan province due to excessive production pressure in the conventional method and the use of pesticides	0.12	3	0.36
S_4: The need to preserve water resources in Guilan province to prevent landslide damage	0.12	3	0.36
S_5: Lack of water resources in some parts of Guilan province in the agricultural season	0.1	3	0.3
Sum			2.62
W_1: Dependence of production in VF on technology and limited access of Guilan province to this possibility at present	0.2	2	0.4
W_2: Lack of familiarity of all farmers with production methods in this method (hydroponics, aeroponics, aquaponics)	0.02	1	0.02
W_3: New production method in vertical agriculture and no similar sample in Guilan province	0.1	2	0.2
W_4: Lack of seed production knowledge of greenhouse crops	0.01	1	0.01
W_5: Import of virus-infected seeds in some cases	0.01	1	0.01
			0.64
Sum	1		3.26

Table 3
External Factor Analysis Summary (EFAS) to production in VF in Guilan province.

External Factor	Normal weight	Score	Final score
O_1: Increasing production per unit area instead of worrying about increasing the area under cultivation	0.1	4	0.4
O_2: Creating food quantity and quality security for the current generation and preparing for the future	0.1	4	0.4
O_3: Creating grounds for the elimination of agricultural waste in production stages up to distribution	0.1	4	0.4
O_4: Creating dynamic areas for innovation and education in the field of agricultural production	0.08	3	0.24
O_5: Creating beautiful landscapes for agricultural production at the regional level in Guilan province	0.08	3	0.24
O_6: Ability to produce and distribute cheaper products by reducing intermediaries and the cost of transportation and maintenance	0.1	4	0.4
O_7: Increasing production volume and creating opportunities for export and currency	0.1	4	0.4
O_8: Creating the ground to maintain the initial quality of products	0.06	3	0.18
O_9: Possibility of creating various cultural educational uses (plant restaurant, museum, and farm as an educational class)	0.06	3	0.18
Sum			2.84
T_1: Lack of support for the banking system by providing low-interest facilities to farmers	0.06	2	0.12
T_2: Failure to provide banking facilities at the appropriate time	0.05	2	0.1
T_3: Failure to create suitable opportunities for repayment of facilities after the profitability of products	0.03	1	0.03
T_4: The arrival of powerful competitors	0.03	1	0.03
T_5: Economic instability and problems attracting private sector investor	0.05	2	0.1
			0.38
Sum	1		3.22

ter, which ranged from "very low" to "very high" levels. SWOT matrix, which is sometimes called TOWS, is a tool to identify the threats and opportunities in the external environment of a system and to identify its internal strengths and weaknesses in order to assess the situation and develop a suitable strategy to guide it (Fateh Kabiri Koopai and Amoshahi, 2017). To construct a matrix outlining strengths, weaknesses, opportunities and threats, the following steps should be taken:

1. Identifying the main strengths, weaknesses and creating a matrix (IFE) to evaluate internal factors.
2. Identifying the main opportunities and threats and creating a matrix (EFE) and evaluating external factors.
3. Compiling strategies and the formation of SWOT matrix of threats, opportunities, weaknesses and strengths.
4. Drawing the internal-external matrix (EI) (Fateh Kabiri Koopai and Amoshahi, 2017).

Creating the evaluation matrices for internal (IFE) and external (EFE) factors by listing the strengths, weaknesses, opportunities, and threats in separate tables. Then, assigning a weight to each factor according to its significance within the system. Each parameter or factor is given a weighting coefficient based on its importance in the system between 0 (unimportant) and 1 (very important) and the numbers 1 and 2 for strengths and numbers 3 and 4 are used for scoring. Finally, the total weighted score of the options is calculated, which should be between 1 and 4 and its average is 2.5. If the score is less than 2.5, the study area or system is weak, and if it is more than 2.5, the study area or system has overall strength (Fateh Kabiri Koopai and Amoshahi, 2017).

SWOT analysis is used in most cases in the strategic planning phase (Namugenyi et al., 2019). The coefficient of relevance for assessing and comparing the total of strengths and weaknesses, as well as the sum of opportunities and dangers, was examined. First, the validity of each parameter, which signifies the level of agreement among the sampled population with respect to each parameter, was assessed. Subsequently, the significance coefficient for these parameters was calculated based on the average of the obtained values. Then, according to the importance coefficient of each parameter, the weight of each parameter was obtained in comparison with other parameters of internal and external factors, and in the next step, the validity of each parameter was determined. Finally, the total weight for internal and external factors was obtained, which made it possible to compare quantitative strengths-weaknesses and opportunities-threats.

Table 4 displays the strategies essential for the production of agricultural goods in vertical farms with the aim of realizing objectives such as ensuring food security and promoting environmental sustainability. Then, determining the optimal strategy of vertical farms in Guilan province was drawn using the total weight score of the matrix of internal (IFE) and external factors (EFE), x and y axes in Fig. 3. In the next step, the most important proposed strategies based on SWOT analysis for prioritization based on QSPM were presented in Table 5. Prioritization of strategies extracted in this study using the QSPM matrix was used to determine the attractiveness of strategies. Table 6 shows the ultimate outcome of the strategy prioritization calculation, while Table 7 subsequently outlines the selected tactics for this study in a sequential order. The data extraction was carried out using SPSS software, while the geographical mapping of Guilan province was accomplished using GIS software.

4. Results

4.1. Internal effective factors (SW) in guilan province in for feasibility VF

Table 2 shows the results of the investigation of internal points affecting VF requirements and provides necessary solutions for the sustainability of environmental resources and food security in Guilan

Table 4
SWOT analysis.

Weakness:	Strengths:	(SWOT QUADRUPLE MATRIX) Reviewing the Vertical Farming in Northern Iran: An Environmental Necessity or an Option?
$W_{1:}$ Dependence of production in VF on technology and limited access of Guilan province to this possibility at present $W_{2:}$ Lack of familiarity of all farmers with production methods in this method (hydroponics, aeroponics, aquaponics) $W_{3:}$ New production method in vertical agriculture and no similar sample in Guilan province $W_{4:}$ Lack of seed production knowledge of greenhouse crops W_5: Import of virus-infected seeds in some cases	$S_{1:}$ Existence of regional, national, and international demand-driven markets S_2: Small ownership and lack of productive lands for production in Guilan province due to land use change $S_{3:}$ Damage to fertile soil resources of Guilan province due to excessive production pressure in the conventional method and the use of pesticides $S_{4:}$ The need to preserve water resources in Guilan province to prevent landslide damage in the coming years $S_{5:}$ Lack of water resources in some parts of Guilan province in the agricultural season	

Table 4 (*continued*)

Diversity Strategy (ST): Support of the banking system by providing low-interest facilities and suitable repayment time for using technology in production in a new way ($S_2T_1T_2T_3$). Formulation and implementation of the banking system protection law by providing low-interest facilities to farmers and creating appropriate repayment opportunities after profitability, according to the demand-driven markets ($S_1T_1T_3$)	**Competitive-Aggressive Strategy (SO):** Emphasis on the production of agricultural products per unit area due to small ownership and lack of productive lands in Guilan province in order to maintain food security (S_2O_1) Emphasis on increasing production volume and using regional and national export and exchange opportunities (S_1O_7)	Opportunities: $O_{1:}$ Increasing production per unit area instead of worrying about increasing the area under cultivation $O_{2:}$ Creating food quantity and quality security for the current generation and preparing for the future $O_{3:}$ Creating grounds for the elimination of agricultural waste in production stages up to distribution $O_{4:}$ Creating dynamic areas for innovation and education in the field of agricultural production $O_{5:}$ Creating beautiful landscapes for agricultural production at the regional level in Guilan province $O_{6:}$ Ability to produce and distribute cheaper products by reducing intermediaries and the cost of transportation and maintenance $O_{7:}$ Increasing production volume and creating opportunities for export and currency $O_{8:}$ Creating the ground to maintain the initial quality of products $O_{9:}$ Possibility of creating various cultural educational uses (vegetarian restaurant, museum, and farm as an educational class)
Defensive Strategies (WT): Compensating the dependence of production in VF on technology by providing low-interest and timely banking facilities ($W_1T_1T_2$).	**Review Strategies (WO):** Review of production methods and training of farmers in the production method in VFs by creating dynamic areas for innovation and training of production (W_2O_4) By using technology and advanced technology in vertical agriculture, it is possible to prevent the production of waste while maintaining the quality of products ($W_1O_3O_8$)	Threats: $T_{1:}$ Lack of support for the banking system by providing low-interest facilities to farmers $T_{2:}$ Failure to provide banking facilities at the appropriate time $T_{3:}$ Failure to create suitable opportunities for repayment of facilities after the profitability of products $T_{4:}$ The arrival of powerful competitors $T_{5:}$ Economic insecurity and difficulties in recruiting private-sector investors

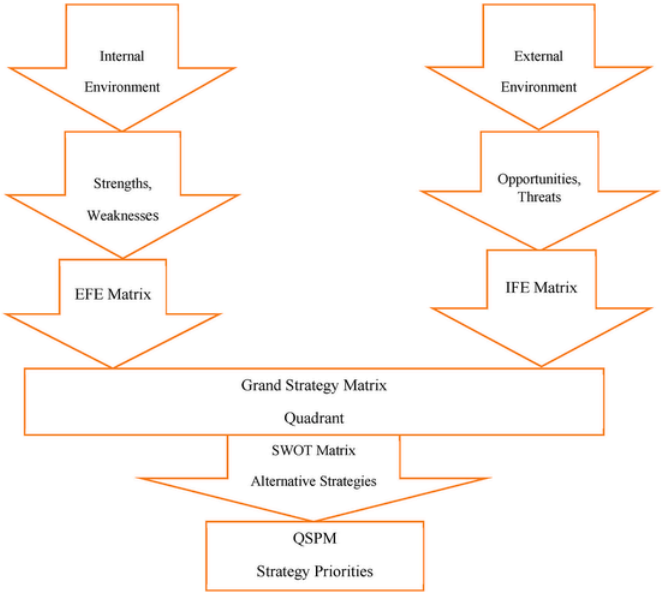

Fig. 3. Conceptual model of the study (adapted from Harisudin et al., 2022).

Table 5
Selected solution.

Row	Selected Strategies
1	Emphasis on the production of agricultural products per unit area due to the small ownership and lack of productive lands in Guilan province in order to maintain food security
2	Emphasis on increasing production volume and using regional, national, and international export and exchange opportunities
3	By using technology and advanced technology in vertical agriculture, it is possible to prevent the production of waste while maintaining the quality of products
4	Support of the banking system by providing low-interest facilities and suitable repayment time for using technology in production in a new way

province. According to the statistics of the agricultural statistics in 2019, Guilan province is the sixth province in Iran in the production of horticultural products due to its favorable geographical location and fertile soil. In addition to other parts of Iran, agricultural products of this province are supplied to countries such as Russia, Kazakhstan, Azerbaijan, Georgia, Armenia, China, India, Iraq, and Vietnam. However, despite issues such as agricultural land use change, population growth, the high average age of farmers, and predicting the damage of environmental resources in the coming years, maintaining the production and export roles of Guilan province is far from the mind. Therefore, it is necessary to have a new approach to the production of agricultural products along with a common method to reduce excessive pressure on environmental resources. The availability of regional, national, and worldwide demand-driven marketplaces has been scored 4 by respondents in the research of internal variables impacting VF production, which has been presented as a new way of production in this study. Due to the high demand for property in the villages and the alteration in the usage of these lands, the tiny ownership of agricultural lands in Guilan province has continued to decline over the past ten years. Consequently, the dearth of land in Guilan province may be one of the major factors influencing class production. According to the respondents, this factor is placed fourth as a factor and a strong point in the case. An effect grade of 3 has been assigned to damage to Guilan province's rich soil resources caused by high production pressure using conventional and traditional methods as well as excessive fertilizer and pesticide use. Due to the crisis of water resources in Iran and the influx of population from different places to the northern provinces, especially Guilan province, in order to preserve water resources and revive groundwater aquifers, new methods of agricultural production should be used more than the current methods. Therefore, Guilan province should think about measures to conserve water resources in order to avoid scarcity and future land subsidence, both of which have an effect rating of 4. The limiting factors that exist as a weakness in the region will be overcome through investment, education, and promotion. Among these, the respondents gave the VF manufacturing method's reliance on cutting-edge technology, which is reliant on resources and knowledge, a rating of 2. The next factor is the lack of familiarity of Guilan province farmers with production in hydroponic, aeroponics, and aquaponics methods. Of course, according to the Guilan province Agricultural Organization, greenhouse owners in the province are familiar with the hydroponic production method and have produced agricultural products. According to the respondents, this factor has an impact rating of 2. The reason for the novelty of the production method in VF and lack of a similar sample in Guilan province is the weakness of the research with an impact rating of 2, which should be given to farmers by agricultural promoters. Lack of knowledge regarding seed production for greenhouse crops with an impact rating of 1 is a significant problem not only in the province of Guilan but also on a national and international scale. Such knowledge can be produced in Iran with the necessary assistance from knowledge-based businesses. Severe food injustice in the world is partly due to costly monopolies on seeds, forcing the farmers to accept the terms of seed companies (Nelson, 2021).

In some rare cases, the seeds of greenhouse crops enter the country through illegal inputs. More monitoring should be done to prevent possible damage to crops by injecting seeds infected with various viruses. A factor of internal weakness and having an influence on the goal of the current study is the entry of infected seeds into different viruses, which has an impact rating of 1.

4.2. External effective factors (OT) in guilan province for feasibility VF

Table 3 shows the results of the examination of the external points affecting the requirements of VF and provides the necessary solutions to the sustainability of environmental resources and food security in Guilan province. Concerns about lack of agricultural land, deforestation, and also excessive pressure on fertile lands in Guilan province can be eliminated by production in VF, which according to respondents, is ranked 4th. Agricultural production in this new way can lead to the production of sufficient and healthy food for the current generation as well as preparation for the coming decades, which has become an important factor for the respondents. In the common method of production, for various reasons, the waste of agricultural products, from the farm to the final consumer, is high. Production in VF and distribution of products at the production site to customers at the regional level do not require transportation and do not damage products. This factor has been rated 4 as an opportunity for research. The two factors of developing dynamic places for innovation and education in agricultural production, as well as building magnificent regional landscapes in Guilan province, as desirable prospects ahead, get a grade of 3. In the common method of production and distribution of agricultural products, the producer does not achieve the desired and real productivity resulting from the production and sale of products. The final consumer gets the product at a price many times the price sold by the producer. This price difference is due to the addition of the product's transfer costs to the demand markets and the impact of its intermediaries. These problems in the production method of VF are reduced to a minimum or zero by eliminating unnecessary intermediaries, which has an impact rating of 4. By producing agricultural products using this cultivation method along with conventional cultivation, export and exchange opportunities for Guilan province are maintained and increased by increasing the production volume, which has an impact rating of 4. Also, the production of agricultural products in this method is done at a regional level

Table 6
Quantitative strategic planning matrix (QSPM).

Internal and external factors	Significance factor		Strategy 1		Strategy 2		Strategy 3		Strategy 4	
			Emphasis on the production of agricultural products per unit area due to the small ownership and lack of productive lands in Guilan province in order to maintain food security.		Emphasis on increasing production volume and using regional and national export and exchange opportunities.		By using technology and advanced technology in vertical agriculture, it is possible to prevent the production of waste while maintaining the quality of products.		Support of the banking system by providing low-interest facilities and suitable repayment time for using technology in production in a new way.	
			Attraction coefficient	score	Attraction coefficient	Score	Attraction coefficient	score	Attraction coefficient	score
Strengths	S1	0.2	4	0.8	4	0.8	4	0.8	4	0.8
	S2	0.2	4	0.8	4	0.8	4	0.8	4	0.8
	S3	0.12	4	0.48	3	0.36	3	0.36	4	0.48
	S4	0.12	4	0.48	3	0.36	3	0.36	4	0.48
	S5	0.1	4	0.4	3	0.3	3	0.3	4	0.4
Week points	W1	0.2	2	0.4	2	0.4	2	0.4	2	0.4
	W2	0.02	1	0.02	1	0.02	1	0.02	1	0.2
	W3	0.1	1	0.1	1	0.1	1	0.1	1	0.1
	W4	0.01	1	0.01	1	0.01	1	0.01	1	0.1
	W5	0.01	1	0.01	1	0.01	1	0.01	1	0.01
Opportunities	O1	0.1	4	0.4	4	0.4	3	0.3	4	0.1
	O2	0.1	4	0.4	4	0.4	4	0.4	4	0.1
	O3	0.1	4	0.4	3	0.3	4	0.4	4	0.4
	O4	0.08	3	0.24	3	0.24	3	0.24	3	0.24
	O5	0.08	3	0.24	3	0.24	3	0.24	3	0.24
	O6	0.1	4	0.4	4	0.4	4	0.4	3	0.3
	O7	0.1	4	0.4	4	0.4	4	0.4	3	0.3
	O8	0.06	4	0.24	3	0.18	4	0.24	4	0.24
	O_9	0.06	3	0.18	3	0.18	3	0.18	3	0.18
Threats	T_1	0.06	2	0.12	2	0.12	2	0.12	2	0.12
	T_2	0.05	2	0.10	2	0.1	1	0.05	2	0.1
	T_3	0.03	2	0.06	1	0.03	1	0.05	2	0.06
	T_4	0.03	1	0.03	1	0.03	1	0.03	2	0.06
	T_5	0.05	2	0.1	2	0.1	1	0.05	2	0.06
	Total point	1	–	6.9	–	6.28	–	6.35	–	5.67

Table 7
Prioritizing selected strategies.

Selected Strategies	Score attractiveness strategies	Priority
Strategy 1: Emphasis on the production of agricultural products per unit area due to the small ownership and lack of productive lands in Guilan province in order to maintain food security	6.9	1
Strategy 2: Emphasis on increasing production volume and using regional, national, and international export and exchange opportunities	6.28	3
Strategy 3: By using technology and advanced technology in vertical agriculture, it is possible to prevent the production of waste while maintaining the quality of products	6.35	2
Strategy 4: Support of the banking system by providing low-interest facilities and suitable repayment time for using technology in production in a new way	5.67	4

based on the estimation of customers' demand, and the transportation of goods reaches a minimum and zero. The initial quality of agricultural products in the vertical production method will be maintained more than in the traditional method, and this feature has been rated 3 by the respondents. Production in VF at the regional level of Guilan province, in addition to the favorable opportunities mentioned, creates the possibility of creating various cultural, educational, and recreational uses, which has an impact rating of 3. Among them is the support of the banking system by providing low-interest facilities to farmers and not providing them at the right time, which has an impact rating of 2. In most cases, the facilities provided are paid with high-interest rates and not when necessary. It is preferable to consider repayment of the facility after the profitability stage, taking into account the essential potential for farmers. So, producers have the ability to compete with powerful partners while remaining in the production sector. It is clear that in conditions of economic or political instability and insecurity, investing in uncertain productivity is not acceptable to private, corporate, and even public sector investors. The government should have supportive and facilitative roles in production, as well as a favorable overseer in this regard, and setting aside the role of the intervener. This issue has a 2 impact rating as a factor endangering the new manufacturing strategy, which should be favorable a condition in such situations to attract the necessary capital.

4.3. SWOT strategies

In the current research, the internal (strengths and weaknesses) and external (opportunities and threats) effective factors were investigated using the SWOT analytical model for the feasibility of using the new VF method in the production of agricultural products in Guilan province. In order to identify strategic points and formulate the necessary solutions or strategies, the model was quantified and the factors with the highest weight points were extracted from Tables 2 and 3 The weighted points of each of the four factors of strengths, weaknesses, opportunities, and threats are in Tables 2 and 3 The total weighted scores of strengths, opportunities, weaknesses, and threats were 2.62, 2.84, 0.64, and 0.38, respectively. Therefore, the importance of the existing strengths and the opportunities ahead of the study will be greater than the existing weaknesses and threats and their effectiveness will be higher. Table 4 presents the proposed strategies in the form of competitive-aggressive strategies (SO), diversification strategy (ST), review strategy (WO), and defensive strategy (WT).

4.3.1. Competitive aggressive strategies (SO)

1 Emphasis on the production of agricultural products per unit area due to small ownership and lack of productive lands in Guilan province in order to maintain food security.
2 Emphasis on increasing production volume and using regional and national export and exchange opportunities.

4.3.2. Diversification strategy (ST)

1 Given the smallholder ownership and limited available land for ensuring food security in Guilan province, it is crucial for the banking system to assist farmers by promptly offering low-interest facilities and establishing favorable opportunities for repayment ($S_2T_1T_2T_3$).
2 The formulation and implementation of the banking system protection law are essential, involving the provision of low-interest facilities to farmers and the creation of suitable repayment opportunities, driven by the existence of demand-driven markets and subsequent profitability ($S_1T_1T_3$).

4.3.3. Review strategy (WO)

1 Review of production methods and training of farmers in the production method in VFs by creating dynamic areas for innovation and training of production (W_2O_4).
2 By using technology and advanced technology in vertical agriculture, it is possible to prevent the production of waste while maintaining the quality of products ($W_1O_3O_8$).

4.3.4. Defensive strategy (WT)

1 Compensating the dependence of production in VF on technology by providing low-interest and timely banking facilities ($W_1T_1T_2$).

4.4. Internal-external matrix (IE)

At this stage, based on the final scores obtained from the evaluation matrix of internal and external factors, the position of Guilan province for the production of agricultural products in VF among the four strategies (competitive-aggressive, diversification, review and defensive) is extracted. Accordingly, in the evaluation table of the Internal Factor Matrix (IFE), the total weight score obtained is 3.26 and the total weight score of the External Factor Matrix (EFE) is 3.22. Therefore, in the current research, in line with the goal ahead, the importance of opportunities and strengths will be far greater than threats and weaknesses, and their effectiveness will be greater. Then, in this step, these numbers are drawn on the X and Y axes to show the position according to all the factors in the graph. According to the obtained results, the position of Guilan province is in a competitive-aggressive position (SO) that by investing in the existing strengths, maximum exploitation of the opportunities in front of the target can be obtained.

According to the scores obtained from the effective internal and external factors in this research, the optimal strategy in the feasibility of the new approach to the production of agricultural products in Guilan province is the competitive-aggressive strategy based on Fig. 4. Therefore, in Guilan province, the existing strengths and upcoming opportunities should be used to achieve self-reliance and food security and maintain the province's export position at the national and international levels, while strengthening environmental resources. Accordingly, the most important suggested strategies based on SWOT analysis for prioritization based on QSPM are presented in Table 5.

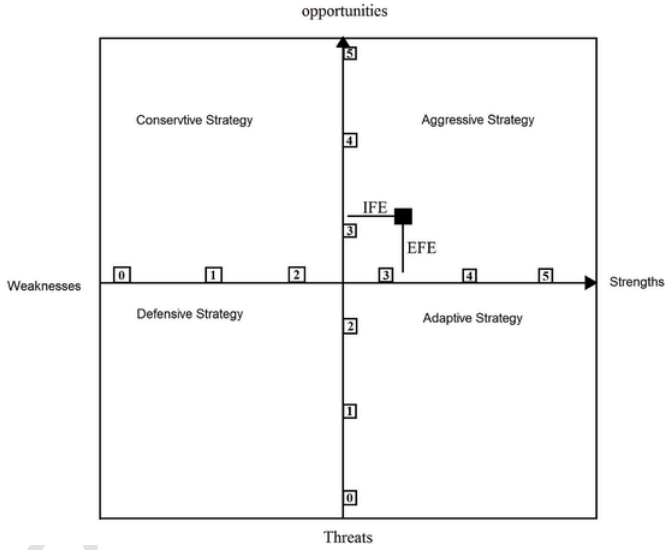

Fig. 4. Position of the optimal strategy for production in VF in Guilan province.

4.5. Quantitative strategic planning matrix (QSPM)

The QSPM is an analytical tool used to evaluate the feasibility and prioritize the chosen strategies. This requires accurate judgment, knowledge, and expertise (Budihardjo et al., 2023). This analytical tool is used to facilitate decision making or problem solving process (Mallick et al., 2020). In prioritizing strategies using the QSPM matrix, the most common technique to evaluate strategic options is the quantitative planning matrix. In addition, this quantitative planning matrix is used to determine the attractiveness of strategies. This technique determines which of the selected strategic options is feasible and in fact, prioritizes these strategies (Raisi et al., 2020). Decisions about acceptable strategies in planning are made using scientific analysis and intuitive judgment (Raisi et al., 2020). The QSPM matrix incorporated factors such as normalized weight, Attractiveness Score (AS), and Total Attractiveness Score (TAS). The AS was rated on a scale of 1–4, with 1 indicating "not attractive", 2 for "less attractive", 3 for "moderate", and 4 for "very attractive," as defined by Budihardjo et al. (2021). The ultimate outcomes of the strategy prioritization, as determined using the QSPM model, are provided in Table 6.

Table 7 reveals that four of the tactics chosen for the study are ranked first, third, second, and fourth, respectively. The strategy of emphasizing the production of products per unit area is the first priority due to the small ownership of farmers and lack of agriculturally productive lands in Guilan province in order to maintain food security. Emphasis on increasing production volume and using export and exchange opportunities of Guilan province and Iran was the third priority. Also, the use of advanced technology in VF to maintain product quality and prevent waste production was the second priority, and support of technology in the production of new methods by providing low-interest and timely banking facilities was the third priority.

5. Discussions

Due to the increase in environmental crises in the world, farmers and producers must be able to produce healthy food products while maintaining the sustainability of environmental resources. In order to achieve food security, welfare, and a sustainable environment, sustainable economic development models are needed. Song et al. (2022) examined vegetable production, resource efficiency, and environmental performance in advanced and conventional technology agricultural systems for urban agriculture in tropical Singapore. Derikvand et al. (2023) stated that in order to ensure the food security of the expanding

population of urban settlements and the sustainable development of these communities, variables affecting new production systems are needed. Ending the global crises of malnutrition and hunger, according to Beyene Chichaibelu et al. (2021), requires investment and ongoing support for agricultural productivity. According to Table 2, the effective internal factors for feasibility, proposing the necessary solutions and strategies for VF in Guilan province, five strong points with a final score of 2.62, and five weak points with a final score of 0.64 were obtained. On the other hand, according to Table 3, the external factors affecting the goal are nine opportunities with a final score of 2.84 and five threats with a final score of 0.38. These final scores were obtained from the product of the normal weight of each factor in the score given by the respondents to the internal and external factors. In order to identify strategic points and formulate the necessary solutions or strategies, the factors with the highest scores were extracted from Tables 2 and 3 The total weighted scores of strengths, opportunities, weaknesses, and threats were 2.62, 2.84, 0.64, and 0.38, respectively. The importance of the existing strengths and the opportunities ahead of the study is greater than the internal weaknesses and the threats ahead, and therefore, their effectiveness will be greater. Then, the proposed strategies of the study, in the form of competitive-offensive strategies (SO), diversification strategies (ST), revision strategies (WO), and defensive strategies (WT) were presented in Table 4. Therefore, for the competitive-offensive strategy (SO), two strategies, for the diversification strategy (ST), two strategies, for the review strategy (WO) and finally one strategy was set for the defensive strategy. In the next step, to evaluate the success of the strategies, the total score of internal and external factors was extracted. In Table 2, the total weight score of the internal factors matrix was 3.26 and in Table 3, the total weight score of the external factors matrix was 3.22. Therefore, in examining the feasibility of using VF in Guilan province, the importance and effectiveness of strengths and opportunities, based on the opinion of experts, were more than weaknesses and threats. Fig. 4 shows the location of optimal strategies for production in VF in Guilan province, which is an aggressive strategy. In line with this optimal strategy, 4 suggested strategies based on SWOT analysis for prioritization based on the SQPM model were presented in Table 5. The prioritization of strategies was done using the SQPM matrix, based on the evaluation of strategic options and the determination of the attractiveness of the strategies used in the decision-making stage, which is presented in Table 6. Finally, Table 7 shows that the four selected tactics are ranked first, third, second, and fourth, respectively.

Conducting research in various fields necessitates not only the knowledge and abilities of researchers but also diverse circumstances and facilities, as well as the demands of the study subject. Hence, this study also has limitations like other studies. The fact that Guilan province has atmospheric precipitation and fertile soil has created the idea that traditional methods of production, in addition to maintaining the role of food security and export, can also maintain the necessary resources for future generations. The environmental constraints and the ecological footprint (1.9 times the biocapacity) in Guilan's smallholder province are indicative of an environmental resource crisis, primarily resulting from excessive reliance on the land for production. This issue requires a change in lifestyle and the way agricultural products are produced. In other words, one of the current limitations that must be informed and expanded by planners and the creative community is a lack of attention to natural resources and their sustainability. Of course, the respondents' opinions about this effect are positive and in favor of using vertical green infrastructure to achieve economy, well-being, and a sustainable environment. Also, the limited knowledge and expertise of production in the method of production in VF in Guilan province are one of the limitations that can be overcome by the efforts of agricultural promoters.

Factors can be generalized by considering their applicability and relevance beyond the specific study area. In this study, the feasibility of vertical farming in Guilan province is examined. While the findings are region-specific, the underlying factors and considerations identified can be extrapolated to other areas sharing similar characteristics and challenges. To generalize the factors, it is important to understand the commonalities and similarities between different regions. Researchers can adapt and modify the research methodology employed in the study to suit their own region. This involves collecting region-specific data, conducting surveys or interviews with local experts, and employing analytical tools or frameworks that are appropriate for the particular context. By making these adaptations, researchers can generate data and insights that can be generalized and applied to other regions. It is crucial to acknowledge the limitations and specificities of each study and avoid overgeneralization without considering the unique characteristics of different regions. Researchers should conduct comparative analyses, validate findings with local stakeholders, and ensure that the proposed strategies are adapted to the specific context of the region of interest. By considering these factors and conducting further research and validation in different regions, researchers can contribute to the generalizability and broader applicability of the findings, facilitating the implementation of sustainable agricultural practices such as vertical farming in various contexts.

6. Conclusions

In today's world, the imperative to adapt economic, social, and environmental dimensions of development to environmental conditions necessitates a shift in production and consumption patterns based on environmental resources. Sustainable development, with its focus on multidimensional growth and environmental preservation, provides a framework to achieve economic progress without compromising other areas such as the environment. The production of agricultural products using new methods, such as VF, emerges as a vital strategy to prevent environmental crises and ensure the availability of resources for future generations.

This study proposes VF as an environmentally friendly approach to agricultural production in Guilan province, following comprehensive feasibility studies. It is important to note that VF is not intended to replace traditional methods but rather to alleviate the pressure on environmental resources. In the context of Guilan province in recent years, the inheritance law and the tourism industry, as well as drought and land subsidence in other provinces and migration to this province, have caused an increase in land demand, a change in the use of agricultural land, and a lack of productive land. Therefore, to achieve sustainable development goals, the infrastructure and production factors of VF must operate at their highest possible levels to enhance profitability and efficiency.

The sixth development plan of Iran (2017–2021) recognizes the importance of greenhouse development in increasing production, ensuring food security, promoting agricultural exports, generating sustainable employment, and improving water resource efficiency. Consequently, planning and investment in this sector are crucial. Addressing the research questions posed in this study, several solutions have been proposed. Firstly, supporting farmers through low-interest financial facilities and repayment opportunities can alleviate the challenges of limited ownership and land availability for production and food security in the province. Additionally, the formulation and implementation of protective banking system laws, offering low-interest facilities and repayment options based on market demand, can further support farmers.

In order to achieve greater productivity in agricultural production, it is necessary to attract capital from public, private, and participatory sectors. Strategies to facilitate community investment and achieve self-sufficiency in seed production for greenhouse crops should be explored in future research. Given the significant changes in agricultural land use and the need to reduce rice imports, further investigation into the conditions and requirements of rice production in new ways is warranted.

Similarly, a study on animal feed production in Guilan province can contribute to self-reliance, reasonable pricing, and import reduction in the livestock breeding sector.

Finally, this research provides valuable insights into the feasibility and strategic planning of VF in Guilan province, highlighting the significance of sustainable agricultural practices for environmental preservation and food security. The recommendations put forth in this study serve as a starting point for policymakers, investors, and researchers to address the challenges and seize the opportunities in implementing VF. Future research directions include exploring strategies for attracting investment, achieving seed self-sufficiency, investigating new approaches to rice production, and enhancing animal feed production. By pursuing these avenues, we can pave the way for a more sustainable and prosperous agricultural sector in Guilan province and beyond.

Consent to participate

All authors contributed equally to the preparation of this manuscript.

Consent to publish

All authors have read the manuscript and agree to its publication.

Disclosure of potential conflicts of interest

There is no conflict of interest.

Research involving human participants and/or animals

None.

Informed consent

All authors have read the manuscript and agreed to its submission.
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CRediT authorship contribution statement

Zahra Akbari: Writing – original draft. **Arasto Yari Hesar:** Supervision, Validation. **Narges Siamian:** Writing – review & editing. **Christine Fürst:** Writing – review & editing. **Rando Värnik:** Writing – review & editing. **Hossein Azadi:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendice 1.

Table A1
. Some vertical farms in different countries of the world and their main products

United State (USA)	Aero farms, Plenty unlimited, Bowery farming, Freight farms, Bright farms, Sananbio, Growpod solution, Green sense farms, 4DBios inc,Vertical Harvest, Vertical Roots	
Australian	Vertical farm system, Stacked Farm, Urban Green Farms, Vertical Pastures	
Belgium	Crop solutions, PLNT, Smart Farmers	
China	Noonty, Sananbio	
Emirates	Badia, Crop one,Themar Al Emarat, Veggitech Farm	
England	Jonse food, Vertical farmers, Plant lab, Square Mile Farms, Growing Underground	
Finland	Valoya, iFarm	
France	Agricool, Infarm, Refarmers, LaCaverne, Tower Farm	
Germany	Infarm, Agrilution systems, Ecf farm Berlin, Osram	
Japan	Spread	
Kuwait	Nox management, Hydroponic	

Netherlands	One farm, Growx, Urban farmers, Plant lab, Floating Farm
Scotland	Growth solutions, Vertegrow
Singapore	Sky greens, Comcrop, Citiponics urban farm, Grobix
South Korea	Nexton
Sweden	Agrilution
Taiwan	Yeshealth ifarm, Everlight electronics, Sky Greens
Thailand	Nobitter, Wangree fresh

Source: Research findings

Table A1 shows some of the most well-known vertically oriented agricultural companies in the United States, European countries, Asia and Australia will the goal of dealing will the problems caused by devastating earthquakes and tsunamis (Japan), lack of land and fertile soil, agricultural production, conservation they operate food security, import reduction and environmental sustainability.

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