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# Toward Sustainable Food Security in Tehran Province: Identifying Water Management Priorities

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### Original Article

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### Abstract:

Water scarcity poses a significant threat to food security in Tehran Province, a region challenged by rapid urbanization, population growth, and unsustainable water use. This study investigates the multi-dimensional requirements for developing food security through sustainable water resource management. Adopting a descriptive-analytical approach, the research incorporates both a literature review and expert survey. A structured questionnaire was administered to 120 experts from the Ministry of Agriculture-Jihad, and data were analyzed using Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM) via Smart PLS. The analysis identifies five key dimensions—technological, policy-related, educational-extension, social, and economic—as critical to enhancing food security. Among these, technological requirements exhibited the strongest influence ( $\beta = 0.890$ ), followed by policy ( $\beta = 0.651$ ) and educational-extension requirements ( $\beta = 0.561$ ). Access to improved seeds and innovation in water management emerged as the most influential factors. The findings underscore the need for integrated, cross-sectoral policies and targeted investments in technology, public awareness, and stakeholder engagement to ensure sustainable agricultural development in water-constrained regions. This research provides actionable insights for policymakers seeking to align food and water strategies with long-term sustainability goals.

**Keywords:** Food Security, Water Resource Management, Sustainable Agriculture, Climate Resilience, Technological Innovation.

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## 1. INTRODUCTION

In recent years, the rapid pace of economic development and urbanization has significantly increased water consumption, leading to a growing imbalance between water supply and demand (Ghafari Moghadam et al., 2021). This rising consumption has disrupted natural hydrological cycles and placed increasing pressure on agricultural water demands, thereby threatening food security and reducing ecological flow. Consequently, river health and aquatic biodiversity have deteriorated, undermining regional sustainable development goals (Mohtashami & Tavakoli, 2023).

As Tehran Province faces persistent water scarcity, establishing a sustainable balance among competing water needs has become a strategic priority for resource planners. The interdependent nature of water usage across agricultural, urban, and environmental sectors—each influenced by external drivers such as climate variability and population growth—makes sustainable water management a highly complex challenge (Ghahremanzadeh et al., 2022). Achieving long-term sustainability therefore requires not only identifying the co-evolving processes among these sectors but also integrating such insights into adaptive and coordinated

water governance strategies.

Water is a fundamental input for agricultural production, and its sustainable management is essential for ensuring both food availability and rural livelihoods. In the absence of effective water governance, agriculture becomes highly vulnerable to shortages that can severely reduce crop yields and increase food insecurity. Addressing water needs across diverse agricultural systems—especially in semi-arid regions like Tehran—is thus critical to mitigating hunger, reducing vulnerability, and supporting farmers and rural communities.

Moreover, sustainable water management plays a pivotal role in conserving ecosystems that provide key agricultural services such as pollination, pest control, and nutrient cycling. Healthy ecosystems underpin food systems, and incorporating ecological considerations into food security planning ensures that water resources are used efficiently and with minimal environmental impact (Taheri, 2023). Such a holistic approach not only enhances resilience but also supports environmental sustainability and biodiversity conservation in the long term.

The relationship between water resources and food security is particularly pronounced in Tehran Province, where demographic pressures intensify the challenge. Despite having slightly higher average annual precipitation (~270–280 mm) than the national average (~250 mm), per capita water availability in Tehran is alarmingly low—around 350 m<sup>3</sup>/year—compared to 1,600 m<sup>3</sup> at the national level. This discrepancy is primarily due to Tehran's high population density, which concentrates nearly 20% of Iran's population in only 1% of its land area (Ghafarimoghadam et al., 2021). Such imbalances demand a deeper examination of how water resource limitations impact agricultural productivity and food access in the region.

In response to these challenges, agricultural authorities in Tehran have encouraged the cultivation of medicinal and drought-tolerant plants to enhance water-use efficiency. Over the past several years, nearly 33,000 hectares have been allocated to such crops, resulting in more than 30,000 tons of additional production (Tehran Agricultural Jihad, 2024). These shifts reflect a broader movement away from water-intensive crops toward more efficient irrigation practices, particularly in controlled environments such as greenhouses, which now cover over 4,100 hectares in the province.

Tehran Province is also a major contributor to national agricultural production, ranking third overall and leading in the output of products such as cherries, mushrooms, milk, eggs, and ornamental plants. However, droughts and unsustainable groundwater extraction have significantly lowered aquifer levels and led to land subsidence (Mahmoudi, 2020; Kaviani Rado et al., 2023). Studies indicate that in hydrological drought scenarios, nearly 14% of agricultural water demand remains unmet, prompting a need to reconfigure cropping patterns toward more sustainable options.

Ultimately, the interplay between population growth, climate change, and water mismanagement poses critical risks to the region's food security and environmental

integrity. Addressing these interlinked challenges requires an integrated approach to water and agricultural planning that aligns with sustainable development goals. This study seeks to explore the nexus of food security and water resource management in Tehran Province, identifying key priorities that can guide policymakers toward more sustainable and resilient agricultural systems.

The main objective of this study is to identify and analyze the essential requirements for the development of food security in Tehran Province through the lens of sustainable water resource management. The specific objectives are as follows:

1. To identify the economic requirements influencing the development of food security under sustainable water management.
2. To explore the social requirements contributing to food security within the context of limited water resources.
3. To assess the technical requirements affecting agricultural practices and water use efficiency related to food security.
4. To analyze the policy-related requirements shaping the governance of food and water systems.
5. To determine the educational and extension requirements needed to promote sustainable food and water systems among stakeholders.

## 2. PRIOR STUDIES

Achieving food security in water-scarce regions such as Tehran Province requires a multi-dimensional understanding of interrelated economic, social, technical, policy, and educational factors. Several studies have examined these elements from a sustainability perspective.

### 2.1 Economic Requirements:

Diaz-Bonilla and Ron (2010) argue that food prices and pricing policies are among the primary determinants of food security in developing regions. Similarly, agricultural subsidies have been shown to improve farmer resilience and production outputs (Haqiya Badisha et al., 2017). Inflation, living costs, and energy prices also influence food affordability and access (Obiura et al., 2023). David et al. (2024) highlights the role of import-export dynamics in shaping regional food availability.

### 2.2 Social Requirements:

According to Thomson and Metz (2018), labor supply and demand, as well as the social infrastructure, play critical roles in ensuring food system functionality. Cultural and social cohesion are also crucial, as pointed out by Mengu et al. (2014). Furthermore, urbanization and population growth intensify the demand for food and water, requiring integrated planning (Wang, 2019). Mitra et al. (2022) emphasize the role of public participation, while Okechukwu et al. (2022) stress the implications of social inequality.

### 2.3 Technical Requirements:

Technological innovation and water-saving irrigation systems can greatly improve water use efficiency in agriculture (Ravieau et al., 2022). Land degradation and

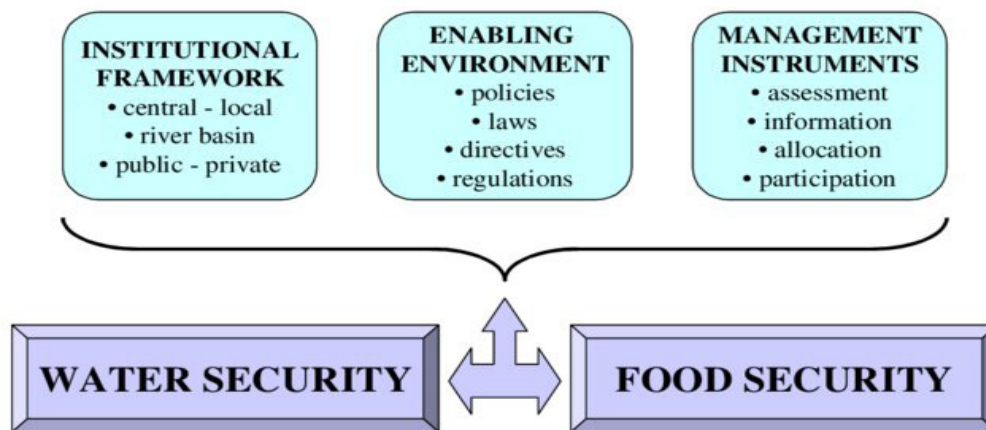


Figure 1. Institutional Framework Linking Water Security and Food Security through Policy, Management, and Stakeholder Participation

the adoption of innovative agricultural water management methods are also pivotal (Kanaan & Anandi, 2020).

#### 2.4 Policy Requirements:

Food and water policies are increasingly shaped by global trade systems and national economic agendas (Apolinaro et al., 2014). Effective food pricing policies and macroeconomic governance are central to securing food systems (Thomson & Metz, 2018). Access to improved seeds and agricultural inputs is also policy-dependent (Abebe et al., 2017), as are energy sector policies (Mirza et al., 2015).

#### 2.5 Educational and Extension Requirements:

Educational interventions, public awareness campaigns, and training programs are essential for shifting toward sustainable practices (Alemayehu et al., 2022). Collaboration between public and private sectors and promotion of research and development can further enhance food security outcomes (Alemayehu et al., 2022; Mohammadi et al., 2023).

Figure 1 presents a conceptual framework linking water security and food security through interconnected institutional components. It highlights enabling factors such as policies, laws, and regulations that shape a management framework for resource allocation. Key elements include central–local coordination, public–private participation, and basin-level directives to ensure sustainable outcomes. The framework emphasizes assessment tools and information systems as critical instruments for decision-making. Together, these components create a structured approach to balancing water and food security priorities. These prior studies underscore the complex interplay between multiple systems that must be addressed through an integrated, sustainable approach to ensure food security in Tehran Province.

### 3. METHODOLOGY

#### 3.1 Research Design

This study is applied in terms of purpose and follows a descriptive-analytical methodology. Initially, a comprehensive review of literature and documents was conducted to identify the key requirements for enhancing

food security in Tehran Province through sustainable water resource management. The research framework includes five dimensions: economic, social, technical, policy-related, and educational-promotional.

#### 3.2 Data Collection Tools and Process

The research was conducted in two phases: Library Research: In the first phase, data were collected through literature review using note-taking techniques. Sources included books, articles, dissertations, and credible databases such as SID, Mag-Iran, ScienceDirect, and Elsevier. Field Research: In the second phase, a researcher-made questionnaire was developed based on the identified indicators. The questionnaire was distributed among experts in water and crop production from the Ministry of Agriculture-Jihad in Tehran Province (2024). Responses were collected to analyze the significance and impact of each dimension and indicator.

#### 3.3 Validity and Reliability

Convergent validity was assessed using the Average Variance Extracted (AVE), where a value above 0.5 indicates acceptable validity. Internal consistency was evaluated using Cronbach's alpha and Composite Reliability (CR), with values above 0.7 indicating strong reliability. As shown in Table 1, all dimensions meet the required thresholds, confirming both the validity and reliability of the constructs.

#### 3.4 Statistical Population and Sampling

The statistical population comprised managers and experts in agriculture, environment, horticulture, and water sectors within the Ministry of Agriculture in Tehran. Using Cochran's formula, the sample size was determined to be 120 respondents, selected through random sampling.

#### 3.5 Data Analysis

Data were analyzed using Confirmatory Factor Analysis (CFA) in Smart PLS. CFA was employed to test the measurement model and examine how well the observed variables represent the theoretical constructs. This method is commonly used in social sciences to verify model validity and ensure structural integrity of the constructs.

**Table 1.** Validity and Reliability Statistics for Each Dimension

Dimension	Cronbach's Alpha	Composite Reliability	AVE
Economic Requirements	0.834	0.919	0.576
Social Requirements	0.739	0.895	0.652
Technical Requirements	0.744	0.934	0.640
Policy Requirements	0.812	0.875	0.504
Educational-Promotional	0.726	0.819	0.603

**Table 2.** Demographic Characteristics of Respondents (N=120)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	88	75%
	Female	32	25%
Age	28–35 years	31	26%
	30–40 years	25	21%
	40–50 years	28	24%
	Above 50 years	36	29%
Education Level	Bachelor's Degree	48	40%
	Master's Degree	56	47%
	Ph.D.	16	13%
Job Category	Agronomy Expert	30	25%
	Agronomy Manager	8	7%
	Water Resources Expert	27	23%
	Water Resources Manager	11	9%
	Horticulture Expert	27	22%
	Horticulture Manager	17	14%

## 4. RESULTS

### 4.1 Descriptive Analysis of Respondents' Demographic Characteristics

To better understand the background of the respondents, descriptive statistics were used to analyze demographic variables including gender, age, education level, job category, and work experience. The total number of participants was 120 experts and managers in the field of agriculture and water resources in Tehran Province.

As shown in the Table 2 The majority of respondents were male (75%). Most respondents were aged over 50 years (29%), while the lowest proportion (21%) was in the 30–40-year age group. Nearly half held a Master's degree (47%), followed by Bachelor's (40%) and Ph.D. degrees (13%). The largest groups were agronomy experts (25%) and horticulture experts (22%), with fewer in managerial positions.

### 4.2 Normality Test of Variables

Before testing the relationships between variables, it

is essential to assess the normality of the data. The Kolmogorov–Smirnov test was applied for this purpose. The significance levels for all variables—economic, social, technical, policy-related, and educational-extension requirements were less than 0.05, indicating that none of the variables follow a normal distribution. Therefore, the null hypothesis ( $H_0$ ), stating that the variables are not normally distributed, is accepted. Consequently, PLS (Partial Least Squares) software was employed for data analysis due to its suitability for non-normal data.

### 4.3 Structural Model Estimation (Standardized Coefficients)

The structural equation modeling (SEM) results, based on standardized path coefficients, illustrate the relationships between five key independent constructs—economic requirements, social requirements, technological requirements, educational-extension requirements, and policy requirements—and the dependent latent variable food security. As shown in Table 3, the strongest direct effect on food security comes from technological requirements

**Table 3.** Structural Equation Modeling Results: Standardized Path Coefficients, R<sup>2</sup> Values, and Key Indicators of Latent Constructs

Latent Construct	Standardized Path Coefficient ( $\beta$ )	Coefficient of Determination (R <sup>2</sup> )	Key Observed Variables (Standardized Weights)
Technological Requirements	0.890	0.792	- Access to improved seeds and inputs (0.890) - Innovation in agricultural & water management (0.855)
Policy Requirements	0.651	0.423	- Macroeconomic policymakers (0.853) - Energy sector policies (0.852)
Educational-Extension Requirements	0.561	0.315	- Awareness and public education (0.823) - Awareness campaigns (0.820)
Social Requirements	0.501	0.251	- Social cooperation and collaboration (0.869) - Social responsibility of stakeholders (0.845)
Economic Requirements	0.454	0.206	- Access to financial resources (0.883) - Financial incentives (0.836)

( $\beta = 0.890$ ), followed by policy requirements ( $\beta = 0.651$ ), educational-extension requirements ( $\beta = 0.561$ ), social requirements ( $\beta = 0.501$ ), and economic requirements ( $\beta = 0.454$ ). The coefficient of determination (R<sup>2</sup>) for food security is highest with technological requirements (R<sup>2</sup> = 0.792), suggesting it explains the largest portion of variance in food security, followed by policy requirements (R<sup>2</sup> = 0.423), educational-extension requirements (R<sup>2</sup> = 0.315), social requirements (R<sup>2</sup> = 0.251), and economic requirements (R<sup>2</sup> = 0.206). These values indicate the relative predictive power of each construct in explaining food security within the study context. Overall, the model shows a strong theoretical and statistical foundation, supporting the hypothesis that multidimensional requirements significantly influence food security, with technological and policy-related factors playing the most prominent roles.

The results demonstrate that all five dimensions—economic, social, technological, educational-extension, and policy requirements—have significant positive effects on food security, confirming the multidimensional nature proposed in the objectives. In particular, the dominance of technological and policy requirements in explaining food security highlights the crucial role of innovation, efficient water management, and supportive governance frameworks in achieving sustainable food systems.

## 5. DISCUSSION

The results of the structural equation modeling (SEM) highlight the complexity of factors influencing food security through the lens of sustainable water resource management. Among the latent constructs, technological requirements demonstrated the highest predictive power emphasizing the importance of technological advancements in coping with water scarcity challenges. The most significant observed variable was access to improved seeds and inputs

(standardized weight = 0.890). This finding is consistent with previous research underscoring the role of climate-resilient seeds in increasing agricultural productivity under drought and heat stress (Tesfaye et al., 2016). For example, in India, the introduction of flood- and drought-resistant rice varieties has shown measurable improvements in yield stability (AP News, 2023). Similarly, in sub-Saharan Africa, the use of drought-tolerant crops such as sorghum and millet has enhanced resilience against water shortages (AP News, 2023). The second most impactful technological variable was innovation in agricultural and water management methods (0.855). The Netherlands has successfully integrated controlled-environment agriculture and hydroponics to reduce water inputs while maintaining high yields (Agrirevu, 2023).

In the political requirements domain ( $\beta = 0.423$ ), macroeconomic policymakers (0.853) and energy sector policies (0.852) were most influential. These findings echo previous studies linking macroeconomic and energy policy reforms with improvements in water governance. In Iran, energy subsidy reforms have been key in promoting water-saving technologies and discouraging wasteful practices (Siddiqi & Anadon, 2011).

The educational-extension requirements ( $\beta = 0.315$ ) revealed that awareness and public education (0.823) and awareness campaigns (0.820) are vital components. Evidence from Australia and California suggests that public education initiatives can significantly reduce agricultural water consumption by increasing awareness of best practices (Arbues et al., 2010).

Under social requirements ( $\beta = 0.251$ ), social cooperation and collaboration (0.869) and social responsibility of stakeholders (0.845) were paramount. Participatory irrigation management (PIM) programs in Nepal and Mexico have shown how local engagement can lead to more equitable and efficient water use (Meinzen-Dick, 2007).

Lastly, economic requirements ( $\beta = 0.206$ ) were best represented by access to financial resources (0.883) and financial incentives for sustainable practices (0.836). Access to microfinance has enabled farmers in countries like Kenya and Bangladesh to invest in water-saving technologies and diversify livelihoods, enhancing their resilience (Agrawala & Carraro, 2010; Zand et al., 2021). To deepen the critical engagement with the limitations of existing issues, it is important to note that despite the demonstrated significance of technological and policy interventions, their effectiveness is often constrained by institutional fragmentation, lack of coordination among governance bodies, and insufficient infrastructure for technology dissemination. For instance, the adoption of advanced irrigation technologies or improved seeds may be limited by high initial costs, inadequate technical training, and weak extension systems, particularly in developing regions. Moreover, while policy frameworks can promote innovation, the absence of consistent enforcement mechanisms and political continuity often reduces their long-term impact. These structural barriers highlight the gap between theoretical advancements and practical implementation in achieving sustainable food and water security.

Another limitation concerns the social and economic dimensions of food security, which remain under-addressed despite their recognized importance. Socioeconomic inequalities, restricted access to credit, and limited community participation continue to hinder inclusive progress. Many smallholder farmers, especially women and marginalized groups, face barriers to accessing resources, technologies, and markets, reducing the overall resilience of food systems. Furthermore, most existing initiatives prioritize short-term productivity gains over long-term sustainability and equity. Addressing these challenges requires not only technical and policy innovation but also institutional reforms, social inclusion strategies, and participatory governance to ensure that the benefits of sustainable water and food management are equitably distributed.

#### Practical Implications

The practical implications of these findings emphasize a multi-dimensional approach to strengthening food security through sustainable water resource management. Technological advancements, particularly access to improved seeds and innovations in irrigation and cultivation methods, must be prioritized in agricultural policy and investment strategies. Policymakers should support research and dissemination of climate-resilient crops, as proven effective in regions like India and sub-Saharan Africa. Equally important is reform in macroeconomic and energy policies that align incentives toward water conservation, as seen in Iran's energy subsidy reforms. Education and awareness campaigns should be expanded to empower farmers with best practices, replicating successes from countries like Australia. Social participation through cooperative water management can enhance efficiency and equity, as demonstrated by participatory programs in Nepal and Mexico. Finally, improved access to financial resources

and targeted incentives can drive sustainable practices, especially for smallholder farmers. These strategies must be pursued in an integrated manner to build resilient, productive, and climate-adaptive agri-food systems.

Future research can build upon the findings of this study by exploring several critical areas. One promising direction involves assessing the role of controlled-environment agriculture in enhancing water-use efficiency and food security, particularly in semi-arid regions where climate stress is increasingly severe. Another important avenue is the examination of policy innovation and cross-sectoral governance to promote sustainability in water-food systems, especially within drought-prone provinces of Iran. Additionally, future studies should investigate the impact of educational and extension programs on farmers' adoption of water-saving technologies in regions experiencing rapid urbanization, as such efforts are pivotal for ensuring long-term agricultural resilience and resource sustainability.

#### Authors' Contributions

Mohammad Reza Talebi contributed to study conceptualization, methodology design, and data analysis. Maryam Omidi Najafabadi\* led the manuscript writing, review, and overall coordination of the study. Amir Mohammadi Nejad participated in interpretation and revision of the manuscript.

#### Availability of Data and Materials

The datasets generated and analyzed during the current study are available upon reasonable request.

#### Conflict of interest

The authors state that there is no conflict of interest.

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