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Climate Change and Food Security Prioritizing Indices: Applying Analytical Hierarchy Process (AHP) and Social Network Analysis (SNA)

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Abstract: Food security and climate change are multidimensional issues. Therefore, a lack of knowledge about the most essential variables made these concepts more complex for decision-making and highlighted the need for credible decision support methods. Here, we aim to develop an accurate tool by using the analytic hierarchy process (AHP) method to explore the priority indicator of food security under climate change in Iran and social network analysis (SNA) to support decisions. The following steps were conducted for the AHP approach: a literature review, a Likert questionnaire and experts' interviews for variable selection and the variables' weight determination and prioritization by pairwise comparison questionnaire, designed based on the hierarchy matrix of the criteria and sub-criteria of food security and climate change. The SNA was employed to understand the robustness of the informants' points of view for indicator selection. After the analysis, 61 criteria were extracted. Sustainability was the important criterion, weighted 0.248. The most important sub-criteria (indicators): groundwater sources, household income, underweight adolescent ratio, food wastage and an annual average of precipitation, weighted 0.095, 0.091, 0.125, 0.227 and 0.236, respectively. The SNA showed that professionals with academic origins focused on the sustainability component. The AHP tool is a credible technique to distinguish the most important criteria. The results might be employed to estimate or predict food security under climate change and simplify decision making in Iran.

Keywords: analytical hierarchy process (AHP); multi-criteria decision-making; weather extreme events; food security; social network analysis (SNA)

1. Introduction

Climate change, war and poverty are three critical drivers of global hunger [1]. The evidence showed global warming affects crop production directly, reducing the primary yields of crops by around 3.1–7.4% for each °C increase in the global mean temperature [2]. Rural and urban people felt the consequences of global warming, which disrupted the agricultural sector and supply chain, raised food prices, diminished purchasing power, endangered human health and demolished property and livelihood with no opportunity to deal with catastrophic impacts and poverty; therefore, all dimensions of food security are in jeopardy [3–6]. Therefore, researchers and policymakers desired more than before to estimate the climate change uncertainty and risks that threaten the environment, agriculture, water, economic and political stabilities [3,4,7,8]. They conducted studies to apply context-specific, precise and reliable tools to enlist the essential variables and estimate the harmful impacts of climate change on different dimensions (availability, accessibility, utilization and sustainability) of food security [9–13]. After a preliminary literature review, we found that previous studies in different countries addressed the acceptable validity of the AHP method to identify the important indicators with accurate weights and use these indicators to predict the uncertainties in various subjects, e.g., environment or food and agriculture [14–20]. Moreover, lessons learned from other countries which tried to improve their adaptation policies evidenced that the development of tools to measure leading climate change and food security indices by the AHP questionnaire is helpful [21–25].

Thus, we developed a reliable and accurate tool by applying the AHP method to prioritize and rank the important variables of food security and climate change in the context of Iran. Moreover, a network analysis of experts' roles and positions in their institutes was conducted to support the indicators' validity prioritization of the AHP questionnaire [26,27].

Evidence showed that some areas in the world are more vulnerable to climate change disturbances, e.g., Middle East countries [28,29]. Iran, located in this region, faces severe weather anomalies in the following decades, for instance, mean temperatures will increase by 2.6 °C in 2035 in comparison to 1961–1990 and precipitation will decline by around 35% in 2016–2030 in comparison to 1982–2009 [30,31]. In addition, due to the geographic profile, Iran stands on the tenth rank of disastrous countries and the fourth rank of flood-experienced countries in Asia, with a total of 11 million Iranians affected by floods in recent years; in addition, Iran experiences prolonged and frequent drought due to water crises and groundwater depletion [32–34]. Therefore, food security is a challenge [35–38]. In recent years, several studies have been conducted to estimate food security and identify the criteria that have a principal role in every dimension of food security in Iran with different methods and tools (AHP, TOPSIS, and PROMETHEE) [39–42]. Nevertheless, those studies did not pay enough attention to the significant role of extreme weather event indicators in their estimation of food security and the limited identification of indicators in each dimension of food security [39–42].

To the best of our knowledge, there is no reliable tool to discover the most essential criteria that contributed to food security under climate change in Iran. Also, policymakers requested to know the weight of each important criteria of food security under climate change to make decisions accurately for 85 million people in Iran [43–46]. In summary, we designed this study to distinguish the most important indicators of food security under climate change with the aim to help policymakers in Iran.

Literature Review

Climate change has different socio-economic, health, cultural and environmental impacts, and there are several criteria explored in previous studies which are drivers of climate change [14,47–49]. Furthermore, climate change and food security are multidimensional issues; many stakeholders with different preferences present many ideas and sophisticated decision-making [26,50–53]. To overcome this complexity multi-criteria analysis (MCA) approaches are presented [54–56]. The two types of this approach that were invented by Thomas L. Saaty are the analytic hierarchy process (AHP) and analytic network process (ANP) techniques which are applied in many fields, e.g., engineering, the energy industry, environmental management and agriculture [47,57–60]. These methods have benefits compared to other multi-criteria decisions (MCDs), e.g., comprising numerous qualitative and quantitative factors, flexibility and simplicity of the tool, calculating the importance of each criterion, estimation and control of the internal consistency [61,62]. The AHP and ANP provide decisionmakers with a transformation of subjective judgments on objective estimation. However, there are some differences between the AHP and ANP [62].

The AHP derives relative priorities on absolute scales through paired comparisons in multilevel hierarchic structures [63]. Thus, researchers use primarily straightforward hierarchic foundations consisting of a top-down structure of goal, indicators and sub-indicators [18]. Although, the ANP uses a network that spreads out in all directions and involves cycles between clusters and loops within the same cluster [62,64]. The feedback structure does not have a hierarchical foundation but is similar to a network. Decisions provided from a network could be considerably different from those provided from a hierarchy [62,65]. In the present study, the network connection of indictors was not noteworthy because we made a decision to estimate only the weight of indicators. Consequently, we decided to carry out the AHP technique to develop the AHP questionnaire for prioritizing and ranking the indicators in four dimensions of food security under climate change in the context of Iran. In addition, we applied a social network analysis to support and increase the robustness of informant's decisions which are answering the AHP questionnaire [26,66–68]. Social network analysis (SNA) is a quantitative technique that could express the patterns of interactions between criteria or subjects by graphical features or statistical outputs in complex systems such as networks. SNA has been used to explore the network's structure and functions or the relationship strength between people and organizations and the flow of information between various actors in a network [68].

2. Methods

We conducted this part of study in three phases. First, a literature review and document analysis were conducted in Iran to select the sufficient and suitable food security criteria under climate change. Then, in the second phase, the criteria prioritization by the AHP method was performed, and it was followed in the third phase by the robustness of expert opinions by SNA.

2.1. Tools Assessment

Both climate change and food security are multidisciplinary aspects that need to integrate a wide range of scientific knowledge, such as politics, social sciences, health, natural sciences and skills [6,69]. Therefore, several stakeholders with diverse precedencies over these subjects and different points of view have to deal with a complex situation for decision making and reach a consensus on a single opinion for prioritizing the problems [64]. Scientific evidence demonstrated that humans are poorly equipped to solve these complicated issues in this context [60], because most people, when confronted with such occasions, make an effort to use an intuitive or heuristic approach for clarifying obscure problems and aim to manage the issues. Usually, in this complex situation and with multi-stakeholders, decision making will be difficult because of their value tradeoffs or uncertainty due to lost crucial information or ignored opposite points of view [56].

In such conditions, multi-criteria decision analysis (MCDA) tools will be applied to estimate the value judgments of individual decisionmakers. MCDA is used to quantify value judgments by risk-based decision analysis [56]. Various project alternatives will be scored according to the criteria of interest. In addition, the desirable course of action will be simple in electing. The optimization methods are multi-attribute utility theory or multi-attribute value theory (MAUT/MAVT) and the analytical hierarchy process (AHP) [54]. They apply numerical scores to communicate the competence of 1 option in comparison to others on a single scale. Other MCDA approaches such as Fuzzy Theory, ELECTRE and PROMETHEE are employed for weighing or evaluating decision making [53,56]. In this study, we employ the AHP approach.

2.2. Building the AHP Model

The intuitive judgments of a decisionmaker and consistency in comparing pairwise variables in the decision-making process are fundamental parts of this technique. Researchers [70] suggested that the "strength of this approach is its organizes tangible and intangible factors in a disciplined way and offers a structured, simple solution to decision-making problems" [59,71].

2.3. AHP Scoring

The nine-point scale method was designed for AHP model [60]. This scaling method operates to compare the importance of criteria and sub-criteria (indicators) pairwise. Furthermore, each pair represents the priority of the target options. The priority among criteria is rated between 1 and 9, which is defined and presented in Table 1.

It helps experts concentrate on two indicators or criteria and select one without paying attention to other variables [15,60,64]. By calculating the consistency ratio (CR), the consistency of judgments was checked.

Find the formula below:

$$C.R. = C.I./R.I.$$

where CI is consistency index and RI is random index. With:

$$C.I. = (\lambda max - n)/(n - 1)$$

where λmax is the eigenvalue of the matrix and n is the size of the matrix.

The consistency rate is an indicator that shows possible inconsistencies in the pairwise comparison matrix. It takes the value 0 (complete consistency) when λ¬max = n. The random index takes the values 0, 0, 0.58, 0.9, 1.12, 1.24, 1.32, 1.41, 1.45, 1.49, corresponding to the number of criteria n = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, respectively. The acceptable C.R. level should exceed 10%. Normally, C.R. > 0.10 is acceptable (CR indicates the amount of allowed inconsistency (0.1 or 10%)). However, an inconsistency ratio of up to 10% is tolerable, yet slight deviations do not pose a problem. Large deviations, however, imply that the judgments are not optimal and have to be improved [60]. The expert choice software calculates an inconsistency ratio (IR) and the ratio of under 0.1 in this study was acceptable. Hence, the CR was not calculated by researchers.

AHP Tool.

Table 1. The scale of priority and definitions.

Intensity of Importance	Definition
1	Equal importance both elements
3	Weak importance of one indicator over another
5	Substantial importance of one indicator over another
7	Very strong or demonstrated importance of one indicator over another
9	The extreme importance of one indicator over another
2, 4, 6, 8	Intermediate values between two adjacent judgments

2.4. Data Collection and Analysis

It is necessary to employ credible approach for selecting the essential criteria because it could be beneficial to apply a decision-making tool such as the AHP. However, before assessing the priority, it is essential to select the proper variables of food security and extreme weather events in Iran. Therefore, a literature review and document analysis were conducted in the first phase. Then, the important criteria used to assess food security and climate change were listed. Later, the Likert questionnaire, was designed and sent to 120 experts; then, 50 experts answered and completed this tool. Finally, 61 indices were selected in this stage. The AHP model was formulated to prioritize these criteria by AHP pairwise questionnaire in the second phase. The sample of the questionnaire which is designed for scaling and criteria priority was presented in Table 2.

Table 2. Questioner design of scaling and criteria priority (sample).

Criteria A	9	7	5	3	1	3	5	7	9	Criteria B
Climate change	9	7	5	3	1	3	5	7	9	Food availability

2.5. AHP Development and Data Analysis

We developed an AHP questionnaire to calculate the most important indicators to predict food security under climate change: 5 indicators were addressed as criteria. Moreover, at the sub-criteria level, 61 indicators were categorized, containing 54 indicators for four dimensions of food security (availability 17, accessibility 18, utilization 12, sustainability 7) and 7 indicators for climate change (extreme weather events).

Hence, we asked two questions according to this systematic procedure. The first: what is the hierarchy matrix of variables, the criteria and sub-criteria? Then, the second, what is the weight of each index in the pairwise selection stage? Consequently, we first designed the hierarchical matrix between food security and climate change indices. Then, designed a pairwise questionnaire for 66 variables with gradation in 3 levels [60]. (Figure 1). In this study, there was no alternative to define. Therefore, the hierarchical framework was made by 3 levels: goal, criteria, sub-criteria.

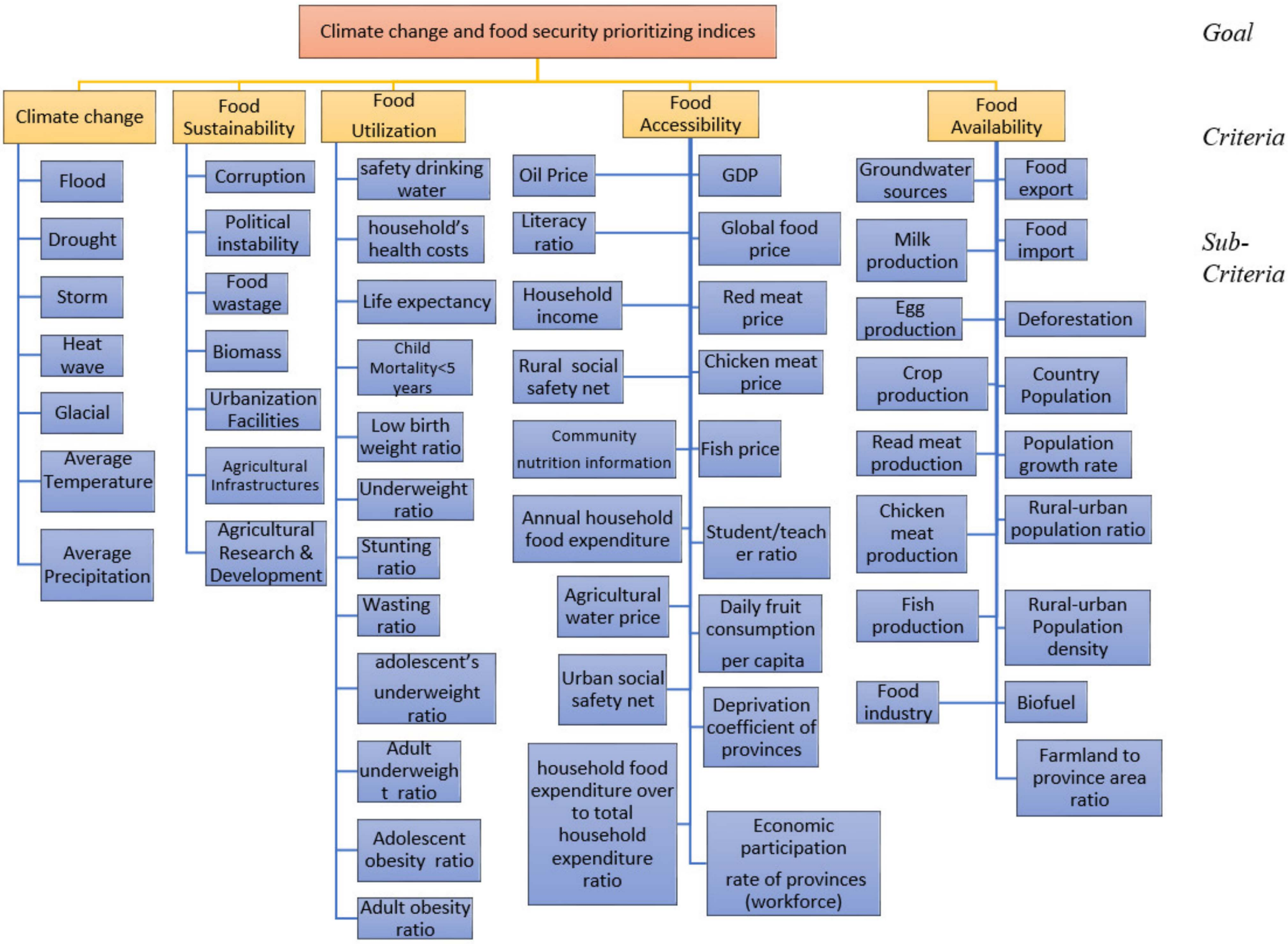

Figure 1. The hierarchical framework of criteria, sub-criteria (indices) prioritization for food security under climate change in Iran.

We sent an AHP questionnaire to all 50 informants from different parts of the food system, climate change (weather center) and other organizations with enough related responsibility, experience or academic knowledge in governmental, official, unofficial, NGOs and private sectors. Ultimately, criteria were all weighted based on 11 experts who filled in the AHP questionnaire and were interviewed. Supplementary File S1, AHP Questionnaire.

Expert Choice software (version 11) was applied to analyze the pairwise criteria (indices) of the AHP tool.

2.6. Social Network Analysis

Roles and workplaces conducted network analyses on data collected from 11 experts who participated in the AHP development tool. The characteristic of experts is presented in Table 3.

Table 3. The experts' characteristics, answered AHP questionnaire.

Person	Workplace	Education Level	Work Experience (Year)	Sex	Role of Institute (Actors)
P1	MoHME	PhD	10	M	Supportive
P2	IRIMO	PhD	29	M	Responsible
P3	MSRT	PhD	7	M	Cooperative
P4	MoHME	MSc	25	M	Supportive
P5	MAJ	MSc	15	M	Responsible
P6	MoHME	PhD	30	M	Supportive
P7	DoE	MSc	12	F	Cooperative
P8	MAJ	PhD	23	M	Responsible
P9	MAJ	PhD	18	M	Responsible
P10	DoE	PhD	29	M	Cooperative
P11	SCHFS	MSc	28	F	Supportive

Note: MoHME (Ministry of Health and Medical Education), IRIMO (Islamic Republic of Iran Meteorological Organization), MSRT (Ministry of Science, Research and Technology), MAJ (Ministry of Agriculture Jihad), DoE (Department of Environment), SCHFS (Supreme Council for Health and Food Security). M (Male), F (Female).

The questionnaire was distributed to subject matter experts in climate change and food security from various official and unofficial organizations and universities, including the food and nutrition faculties, the agricultural ministry departments, environmental and geography departments.

Table 4 shows the sample types of questions used for data collection.

We address the substantial experts' role in 3 categories, according to their formal responsibility and positions of their institute in this study: 1—supportive, 2—cooperative, 3—responsive. Gephi (version 9) software was administered to analyze the expert criteria and design network graphs. The network analysis and graphs are presented in the Section 3.

Table 4. The questionnaire used for the position and role of institute data collection.

Institute (Actors)	Role of Institute (Actors)		
	Supportive	Cooperative	Responsible
Ministry of Health and Medical Education (MoHME)	✓		
Islamic Republic of Iran Meteorological Organization (IRIMO)			✓
Ministry of Science, Research and Technology (MSRT)		✓	
Ministry of Agriculture Jihad (MAJ)			✓
Department of Environment (DoE)		✓	
Supreme Council for Health and Food Security (SCHFS)	✓		

3. Results

According to the hierarchical framework in Figure 1, the sixty-one indicators were categorized into 5 criteria and 56 sub-criteria matrixes based on the weights of criteria and sub-criteria (indicators) for food security components and climate change extreme events. The weights and ranks of each indicator and the estimated value of inconsistency were presented in Figures 2 and 3 and Table 5. The definition and source of the indicators were mentioned in this table. These are also mentioned in Figure 4 and Supplementary Figure S1. The social network analysis of food security and climate change experts' decisions according to their organizations was shown in Figure 4, parts B1–B6, and the social network analysis of food security and climate change stakeholders according to the role of the institute was showed in Supplementary Figure S1, parts G1–G6.

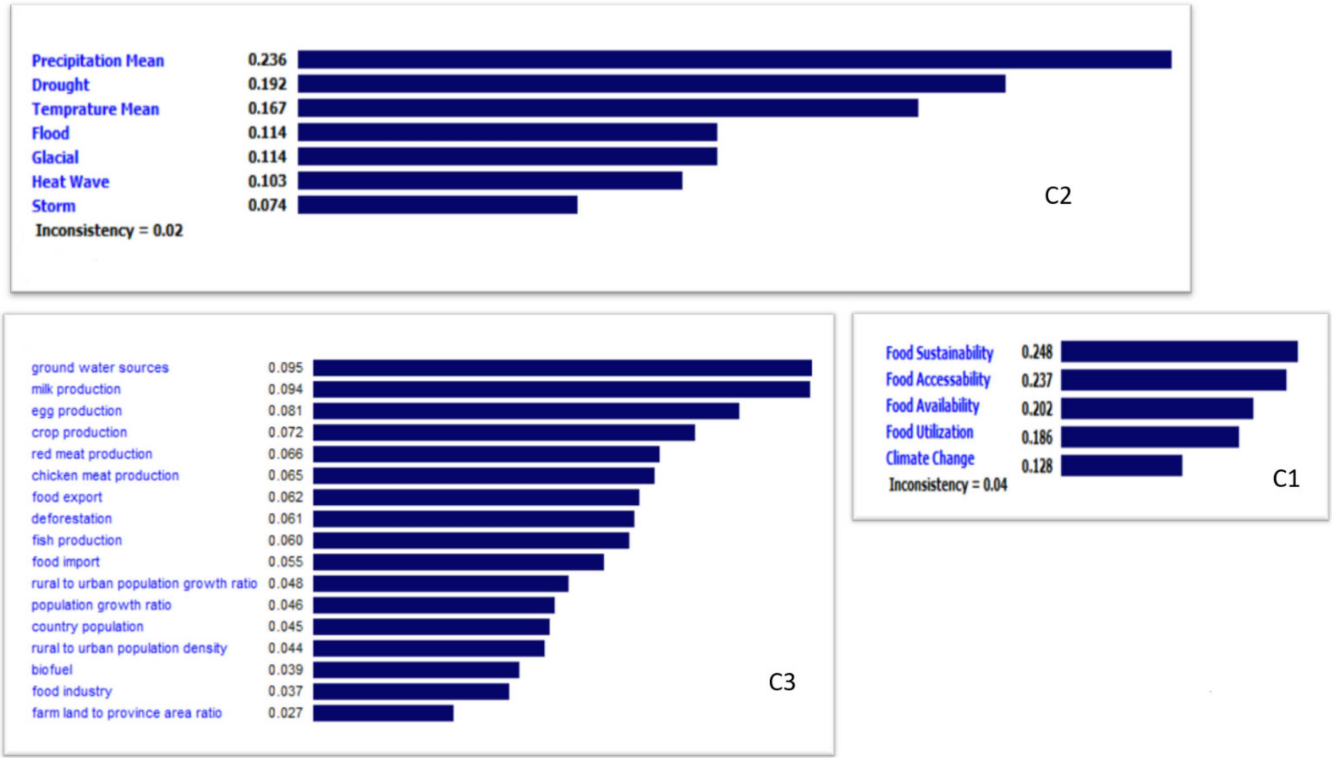

Figure 2. Relative Weights of Criteria and Sub-Criteria of Food Security under Climate Change by AHP Tool. **C1**: Criteria Weights of Food Security and Climate Change. **C2:** Indices' Weight of Climate Change. **C3**: Indices' Weight of Food Availability Criteria.

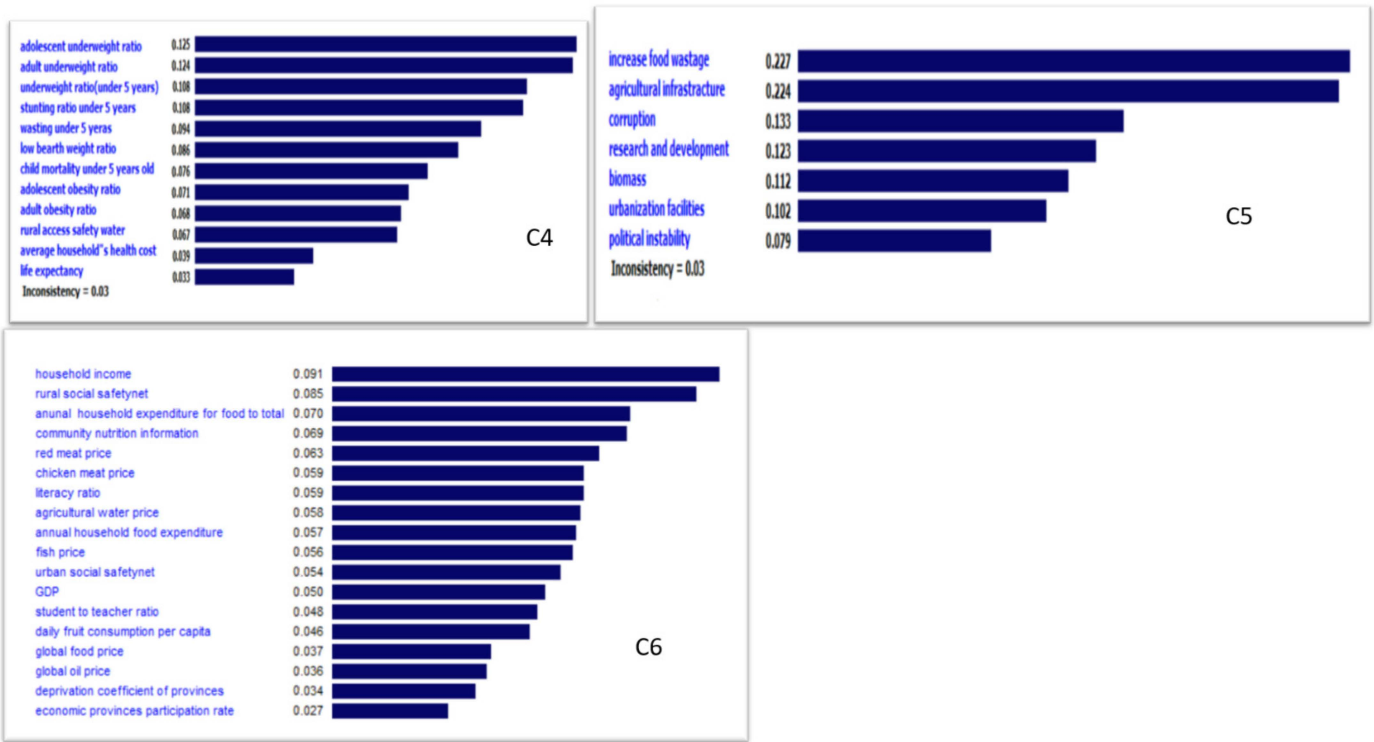

Figure 3. Relative Weights of Food Security under Climate Change Sub-Criteria by AHP Tool. **C4**: sub-criteria indices weight of food utilization. **C5**: indices' weight of food sustainability. **C6**: indices' weight of food accessibility criteria.

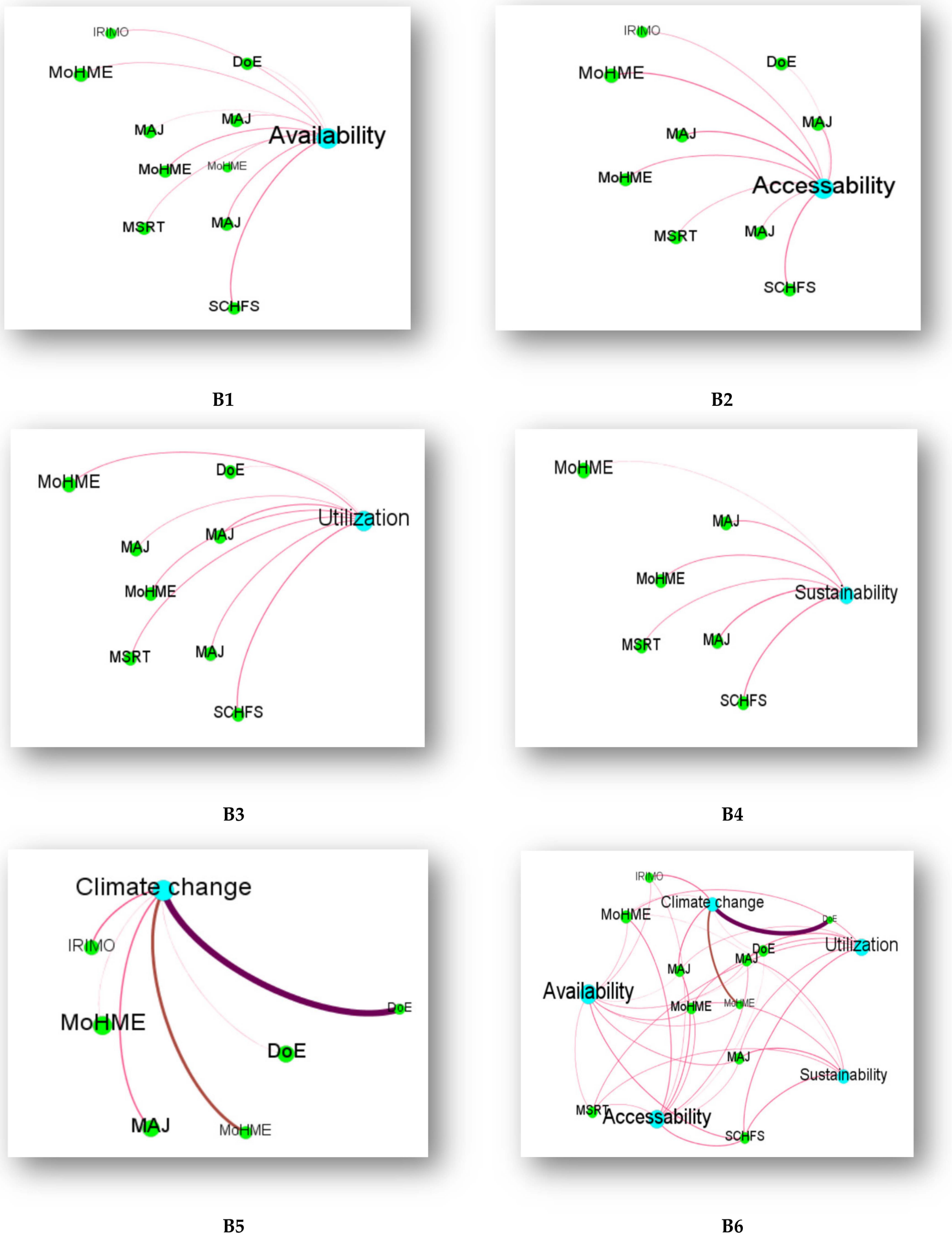

Figure 4. Social network analysis of food security and climate change experts' decisions according to their organizations (institute), parts **B1**–**B6**. Categories and colors: blue, food security components and climate change index; green, organizations. Note: MoHME (Ministry of Health and Medical Education), IRIMO (Islamic Republic of Iran Meteorological Organization), MSRT (Ministry of Science, Research and Technology), MAJ (Ministry of Agriculture Jihad), DoE (Department of Environment), SCHFS (Supreme Council for Health and Food Security). Authors' contribution.

Relative Weights of Indicators

The first category of indicators in the hierarchical framework (the criteria level in the matrix) and relative weights for food security components and climate change are depicted in Figure 2-part C-1. The second category in the hierarchical framework (the sub-criteria level in the matrix) and the relative weights of climate change and the four sub-criteria of food security (availability, accessibility, sustainability and utilization) are presented in Figure 2-part C2–C3 and Figure 3-part C4–C6. Figure 2, part C1—show the weight of the criteria (climate change, availability, accessibility, sustainability and utilization), and the highest weight was assigned to food sustainability (24.8%). Figure 2-part C2—shows that the mean precipitation and drought had the highest relative weights among the sub-criteria (indices) of climate change. Figure 2-part C3 indicates the sub-criteria indices' weight of the food availability criteria, with the highest index's weight on groundwater sources.

Figure 3-part-C4 presents the relative weights of the sub-criteria indices' weight of food utilization, with the highest rank of adolescent undernutrition ratio. Furthermore, Figure 3-part C5—shows the sustainability sub-criteria indices' weight with the first rank of increased food wastage (22.7%). In Figure 3-part C3, the indices' weight of the food accessibility criteria is showed, and the household income indicator was on the first rank with a weight of 9.1%.

The details of the priorities and weights are indicated in Table 5, presenting the relative weights of the criteria and sub-criteria (indicators). In each of the five categories, the values introduce the weight of each indicator which is relative to other indicators. In the definition column in this table, all national indicators are described and the international (well-known) indicators are addressed by reference. In another column, the priorities of each indicator according to its weight are presented. The last column shows the inconsistency ratio; the inconsistency ratios for all pairwise matrixes were less than 0.1.

The social network analysis (SNA) is used to understand: who choose which criteria, or which criteria is necessary for whom? This network showed the informants' decisions for prioritizing criteria according to their organization's positions on food security and climate change policy making in Iran. These are displayed in Figure 4 and Supplementary Figure S1.

Table 5. Relative weights, priorities by weights of criteria and sub-criteria (indicators) in AHP tool.

Criteria	Definition/Source	Of Criteria and Sub-Criteria	Weight	Priority	Inconsistency
Food sustainability		[72]	0.248	1	0.04
Food accessibility		[72]	0.237	2	
Food availability		[72]	0.202	3	
Food utilization		[72]	0.186	4	
Climate change		[73]	0.128	5	

Criteria	Sub-Criteria	Definition/Source	Weight	Priority	Inconsistency
Food Sustainability	Food wastage ratio	Percentage of national food waste in 12 months [73].	0.227	1	0.03
	Agricultural infrastructure	This is a composite indicator that measures the ability to store and transport crops to market [73].	0.224	2	
	Corruption ratio	[74]	0.133	3	
	Agricultural research and development	[73]	0.123	4	
	Biomass	Percentage of plant-based material used as fuel to produce heat or electricity.	0.112	5	
	Urbanization facilities (urban absorption capacity)	This indicator measures the capacity of a country to absorb the stresses placed on it by urban growth and still ensure food security [73].	0.102	6	
	Political instability	[74]	0.079	7	
Food Accessibility	Household income	[72]	0.091	1	Less than <0.1
	Rural social safety net	[72]	0.085	2	
	Annual household food expenditure over to total household expenditure ratio	[73]	0.07	3	
	Community nutrition information	Percentage of the knowledge of food and nutrition consumption that is monitored annually in Iran by the ministry of health.	0.069	4	
	Red meat price	Mean red meat price (national currency/Kg) a year.	0.063	5	
	Chicken meat price	Mean fish price (national currency/Kg) a year.	0.059	6	
	Literacy ratio	[73]	0.059	7	
	Agricultural water price	[73]	0.058	8	
	Annual household food expenditure	[72]	0.057	9	
	Fish price	Mean fish price (national currency/Kg) in a year.	0.056	10	
	Urban social safety net	Presence of urban food safety-net programs [73].	0.054	11	
	GDP	Gross domestic production.	0.05	12	
	Student/teacher ratio	The number of students over teachers number nationally.	0.048	13	
	Daily fruit consumption per capita	Percentage of daily fruit consumption per capita (national survey).	0.046	14	
	Global food price	[73]	0.037	15	
	Global oil price	USD for one barrel. Based on Organization of the Petroleum Exporting Countries (OPEC)	0.036	16	
	Deprivation coefficient of provinces	Estimated by the Gini coefficient [73].	0.034	17	
	Economic participation rate of provinces (workforce)	The proportion of the older 10-years-old population over to total population of the country that works and makes money in each province according to the national statistic center of Iran [73].	0.027	18	

Table 5. *Cont.*

Criteria	Sub-Criteria	Definition/Source	Weight	Priority	Inconsistency
Food Availability	Groundwater sources	[73]	0.095	1	Less than <0.1
	Milk production	Average national milk production (tones/year).	0.094	2	
	Egg production	Average national egg production (tones/year).	0.081	3	
	Crop production	Average national crop production (tones/year).	0.072	4	
	Read meat production	Average national red meat production (tones/year).	0.066	5	
	Chicken meat production	Average national chicken meat production (tones/year).	0.065	6	
	Food export	[73]	0.062	7	
	Deforestation	[73]	0.061	8	
	Fish production	Average national fish production (tones/year).	0.06	9	
	Food import	[73]	0.055	10	
	Rural–urban population ratio	Proportion of rural population over urban population in country.	0.048	11	
	Population growth rate	[73]	0.046	12	
	Country population	Total amount of population living in country + refugees and immigrants.	0.045	13	
	Rural–urban population density	[73]	0.044	14	
	Biofuel	Percentage of national biofuel production annually [72].	0.039	15	
	Food industry	Total national industrial food production annually. Tones/year.	0.037	16	
	Farmland-to-province area ratio	Proportion of farmland over total land in country.	0.027	17	
Food Utilization	Adolescent's underweight ratio	[72]	0.125	1	0.03
	Adult underweight ratio	[72]	0.124	2	
	Underweight ratio (under 5 years old)	[72]	0.108	3	
	Stunting ratio (under 5 years old)	[72]	0.108	4	
	Wasting (under 5 years)	[72]	0.094	5	
	Low birth weight (under 2500 g)	[72]	0.086	6	
	Child mortality under 5 years	[72]	0.076	7	
	Adolescent obesity ratio	[72]	0.071	8	
	Adult obesity ratio	[72]	0.068	9	
	Rural accessibility to safe drinking water	Access to potable water is the proportion of people using improved drinking water sources: household connection; public standpipe; borehole; protected dug well; protected spring; rainwater [73].	0.067	10	
	Average household's health costs	[73]	0.039	11	
	Life expectancy	[72]	0.033	12	
climate change	Annual average precipitation	Mean precipitation during 12 months [73].	0.236	1	0.02
	Drought	[73]	0.192	2	
	Annual average temperature	Mean temperature during 12 months [73].	0.167	3	
	Flood	[73]	0.114	4	
	Glacial	[73]	0.114	5	
	Heatwave	[73]	0.103	6	
	Storm	[73]	0.074	7	

4. Discussion

The results of this study clearly showed that the AHP is a credible tool to prioritize the criteria and indicators of food security under climate change in the context of Iran. This is because the AHP technique as a multidisciplinary approach enables us to identify the most important factors that play a role in food security under extreme weather events in this country. Moreover, the social network analysis helps us to reveal that the technique allowed for confidence indicator selection; this is because the experts' point of view did not relate to their roles in the organization or the position of their institutes. Our efforts to present the evidence led us to understand that in the second level of the hierarchy matrix, the highest weight was assigned to food sustainability (0.248), among the other four food security and climate change criteria. Zarei et al. [42] pay attention to food sustainability and the prioritization of the indicators by applying the AHP; however, in that research, food security was categorized in the sub-criteria level with weight (0.034) and the weight was not noticeable. Likewise, other researchers have made efforts to distinguish the essential indicators of food security in Iran, although they did not define the sustainable component of food security in their AHP hierarchical matrix [40,41].

It is necessary to explain that researchers employed the results of food security prioritizing and weights in their modeling of food security in Iran, and they proposed that the area in central parts of Iran has the higher food security score [75]. However, there is the most food-insecure area in the central parts of Iran, and it faces drought, water stress and other socio-economic impacts of extreme weather events [41]. Hence, what we aimed to indicate was the proper criteria and indicator selection and a credible weighting method that are indispensable for future food security under climate change estimation or prediction. It would be more comprehensive when paying attention to the FAO, the Paris Agreement (PA) and the 2030 Agenda for Sustainable Development announcement in which there was call for a produce policy framework to understand: (1) how disasters impact food systems and (2) what is the extent of extreme weather events on food and agriculture sectors. Consequently, identifying the most important factors that threaten food sustainability was highlighted. In other words, climate change places food sustainability at risk, not only by damaging agricultural products and increasing food loss and waste but also indirectly by soil erosion, decreased precipitation, farmers' economic damage and an increase in political instability and crisis [76]. The other evidence to raise the power of the indicator selection in this study is the sub-criteria regarding food sustainability: agricultural infrastructure, food waste, agricultural research and development, corruption ratio and political instability.

Ardakani Z. et al. [39] applied another MCDA approach named the TOPSIS technique, aiming to calculate a dynamic quantitative index of food and nutrition security in Iran. Interestingly, food stability reveals a higher weight among the four dimensions of food security in the context of Iran. This result from Ardakani Z. et al.'s study is in line with our research outcome [39], which is precisely revealed by employing the AHP technique and was further evidence for the power of the AHP method to prioritize the food security criteria in Iran.

According to the findings of this study, mean precipitation and drought take the higher importance weight, 0.236 and 0.192, among the climate change sub-criteria. It is reasonable to score higher for precipitation and drought in Iran because, during the last two decades, the average annual precipitation diminished and drought occurred with high frequency [31,38,77]. Again, Cheng J. et al. [78] employed the AHP to determine the weights of various relevant factors in the agricultural drought vulnerability in the Hubei Province of China. In fact, they investigated the indicators that contributed in regard to three aspects: the economic, social and political systems, on one hand, and on the other hand, the indicators that related to impacts of these aspects. Some of the indicators in that study looked like findings in this research, e.g., per capita GDP, infant mortality rate, the proportion of health care expenditure to total financial expenditure, the population natural growth rate and annual net income. Then, the drought evaluation with these indicators' weights shows the validity of this weight to find the most vulnerable county. These outcomes might show evidence of the suitable indicator selection in our study and increase our validity method. Also, the application of the Markov chain and Fuzzy modeling AHP to identify the linkage between climate change and food security in drought-sensitive agro-ecological zones in Ghana help us to understand that some indicators in our study related to drought factors or impacts are properly selected [49]. However, our hierarchy matrix is different from the Ghanaian study.

Further, researchers tried to document the climate change vulnerability assessment for agriculture by performing the AHP method in Vietnam. They constructed a hierarchy matrix with 3 primary indicators and 22 secondary indicators, whereas 6 climatic indicators were selected, including high temperature (0.153), heavy rain, meteorological drought (0.0157), hydrological drought (0.0166), flood (0.0221) and saline intrusion (0.0186), to determine the exposure of the agriculture sector. Moreover, they carried out consultations with ten experts to collect data and use the AHP technique for the analysis. The method and the number of experts were the same as in our study; we interviewed eleven informants. Likewise, the climate change indicators were almost similar to what we found in this study, albeit they categorized drought into two indicators: meteorological drought (0.0157) and hydrological drought (0.0166) [49]. This evidence proved that the AHP method would be a credible tool to prioritize climate change and food security indicators if the design is context-specific.

In the present study, among the 17 food availability indicators, the groundwater source with a weight of (0.095) was an important indicator. This evidence presented the validity of the informant's indicator prioritization by the AHP questionnaire because it is one of Iran's most essential elements for agricultural production [32–34]. Other researchers in the Middle East region documented the same results [19]. They applied the compound AHP-GIS model to evaluate the agriculture's suitability to achieve food security in an arid area; the water resource was the main criterion, with weight (0.314), and groundwater availability, weight (0.354). These results are in line with the present study findings and Li, Xiao et al.'s outcome [79] with a groundwater weight of (0.23) that prioritized water–energy–food indicators with the AHP technique in China.

The AHP questionnaire in the present study identified the highest weight for the increased food wastage (0.227) indicator in the context of Iran in the food sustainability criteria. It is reasonable, because the ratio of this index in the world and Iran is very high, according to scientific kinds of the literature, with approximately one-third of food production, with the highest 45% for fruit and vegetables and 20% for dairy products and meat production [80–82].

Social Network Analysis (SNA)

We tried to produce an overview of the connection between professionals or main stakeholders and their points of view to select the most important indicators by applying the social network analysis method. SNA can provide a perspective of collaboration among diverse informants and sectors of food security and climate change (e.g., researchers, knowledge producers and decisionmakers) [26,66,67].

In Iran, these issues experienced interdisciplinary challenges. Hence, giving a neutral opinion by experts without respect to their role or positions is valuable [68,83]. We indicated that all informants believe in the importance of food availability. The academics (MoHME, SCHFS and MSRT) selected sustainability criteria. Nevertheless, this component of food security was more important for the MAJ as the most responsible institute of food production in Iran. In addition, climate change was the most important threat to agricultural production in Iran, selected by the DOE and MOHME, who work in the disaster part in these organizations, and the IRIMO, responsible for estimating weather in Iran. In summary, utilization was the priority for food production (MAJ) and the MOHME. It is reasonable that the MOHME selected this component, but the higher weight by the MAJ shows that they understand the importance of food availability in health. In this study, we pay attention to the gender of professionals; a total of 2 out of 11 experts were female. They work at the SCHFS and DoE in decision-making positions. Their job revealed that, in Iran, women play a role as a food producer in rural areas and farms similar to other parts of the world [76]. They are also considered active as food security and climate change policymakers.

Finally, these results indicated that experts selected the food security component despite their responsibility in their institutes (Supplementary Figure S1). Therefore, this method might help the validity of indices weighting by the AHP.

5. Limitation

This AHP questionnaire is designed for prioritized food security with 61 indices, including 4 food security dimensions and extreme climatic weather events in the criteria level and 56 sub-criteria by our team. We had to provide a pairwise design for all indices. This means that the questionnaire was lengthy and time-consuming to answer. Furthermore, we could not receive an expert's viewpoint on food security and extreme climate change events weighting indices from other countries.

There might be mentioned some strengths of this research. Our team succeeded in distinguishing 11 knowledgeable professionals in different aspects, e.g., economic, health, agriculture, social and environment. These experts worked in different governmental organizations with acceptable diversity in responsibilities and experiences. Additionally, we supported their viewpoint by analyzing their position and roles in employing SNA. This method enabled us to improve the validity of the informants' opinions to score the AHP questionnaire.

6. Conclusions

Food security is endangered by extreme climate events because both climate change and food security have a multidimensional nature. Therefore, researchers should focus on employing the multidisciplinary approach (MCA) to understand the factors most related to these issues. In this study, we focused on the AHP technique, which is one of the multidisciplinary approaches aimed to design tools for identifying the essential indicators that contribute to food security under extreme climate change events in the context of Iran. Further, we conducted the SNA to support the robustness of the informants' decisions about indictor prioritization. The potential property of the AHP to measure the essential criteria helped us to provide the set of important indices of extreme climate change events that contribute to food security in Iran. Our finding addressed the 61 priority indicators and the relative weight of the criteria from various subjects, e.g., socioeconomic, health, political and environment.

In addition, the dominant indicator among food security components in this study was food sustainability. This result shows that informants look out for the instability impacts of climate change on food security because the dominant indicator among the climate change criteria was the annual mean precipitation in Iran, and the second index was drought. These two weather and extreme events recognized the remarkable risk for agricultural food production in Iran [31,37,45]. Also, the expert's point of view in the SNA revealed that they selected and prioritized indicators without being biased to their job or organizational position because, for instance, academic informants have given the higher score to climate change compared to experts of agriculture institutes or environment organizations. In summary, we demonstrated that the AHP questionnaire could be a helpful tool to highlight the important indicators.

Furthermore, we provide insight into various indicators with different weights for policymakers to focus on various factors when making decisions about food security in their national context that might be vulnerable to extreme weather events. These causing factors are context-based. In addition, according to our survey, we have recommended the SNA technique to support and enhance the reliance on criteria prioritizations by the AHP tool.

7. Suggestions for Future Research

The authors offer the following recommendations to improve the situation of food security under extreme climate weather and attract the attention of academics and policymakers toward indicators that have previously received less consideration.

1. Applying the same questionnaire in other countries with different political, social and economic contexts to understand the most essential national indices contributing to their food security under climate change.
2. Reviewing and revising the food security indices, especially under extreme weather events, to develop an AHP questionnaire at the provincial level in Iran.
3. Developing such studies in other countries to explore methods like the SNA with aims to improve the validity of indices' weights.
4. These indicator weights might be helpful in models that were conducted to predict the risk of food security under extreme weather event uncertainty in the national context.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14148494/s1, Supplementary Figure S1—Network analysis of food security and climate change actors according to their roles show in G1–G6 parts. Categories and colors: Purple: food security components and climate change index. Red: Responsible role, Green: Supportive role, Blue: Cooperative role. Note: MoHME (Ministry of Health and Medical Education), IRIMO (Islamic Republic of Iran Meteorological Organization), MSRT (Ministry of Science, Research and Technology), MAJ (Ministry of Agriculture Jihad), DoE (Department of Environment), SCHFS (Supreme Council for Health and Food Security). Supplementary File S1, AHP Questionnaire. The prioritization of effective factors for prospecting the relationship between climate change and food security in Iran.

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