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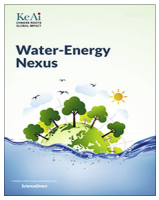

The food-water-energy nexus governance model: A case study for Iran

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ABSTRACT

As the world's population grows, food and energy supply will be one of the most important challenges. Agriculture, as the most important food producer, is not only a consumer of water and energy but also a major supplier of energy. Consequently, a balance must be struck between the harvest and utilization of production resources and the amount of agricultural production. The UN's Third Millennium Goals are on the agenda of achieving sustainable long-term development of human societies and ensuring food, water, and energy availability for future generations. To accomplish these goals, researchers have developed numerous interdisciplinary and specialized frameworks and approaches to achieve a dynamic and optimal balance of production and resource utilization, one of which being water, energy, and food. The water, energy and food Nexus approach is an overall vision of sustainability that strives to balance the various goals, interests, and needs of people and the environment by quantifying water, energy and food relationships through qualitative and quantitative modeling as well as advancing research for Integrate modeling and management to deliver important sustainable development strategies in today's dynamic and complex world. Given the environmental and water crises that threaten the Iranian nation's food and energy security, water, energy, and food, Nexus management can bring about change and balance in different sectors, depending on the needs and participation of all stakeholders. In this paper, a novel model for the Nexus approach governance model using the multi-layer visionary is being developed for the Iranian region for the water and food crisis the country is facing today.

1. Introduction

The agricultural sector, as the most important food producer in the country, is not only a consumer of energy but also a major supplier of energy (Böhringer et al., 2008). The agricultural sector is faced with a limited supply of production resources and, it is providing food security to the growing population, a balance must be struck between the harvest and utilization of the production resources and the amount of agricultural production (Endo et al. 2015). The process of using the resources of production must be sustainable and in line with sustainable development. Sustainable Development, as defined in the Year 1992 of the "Earth" Conference, is "meeting the needs of the present generation without compromising with future generations to meet their needs." According to FAO estimates, the agricultural sector needs to increase its production up to 60% to meet the need for population growth by the year 2050. Also, according to the International Energy Agency (IEA), energy consumption will increase by about 50% by the year 2035. It is also projected by the FAO that irrigation water use will increase by about 10% by the year 2050. As a result, as demand increases, competition for resources will increase (FAO, 2012). Guarantee of availability Water, Energy, and food security are key focal points for poverty alleviation by ensuring adequate resources to sustain and improve livelihoods in a fairway. Water, food, and energy and security in all three sectors without a reduction in natural resources is considered a major challenge in the Asian region, especially the Middle East and Iran. Since then, the United Nations has set out a set of goals, called the SDGs, from the year 2015 onwards to achieve sustainable long-term development of human societies and to ensure food, water, and energy availability for future generations (UN, 2015). To accomplish these goals, researchers have developed numerous interdisciplinary and specialized frameworks and approaches for achieving some sort of dynamic and optimal balance in the production and consumption of resources, one of the most important of which is the Nexus or

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interconnection of Water, Energy, and food (Fig. 1). Based on this approach, water, energy and food security are key focal points for poverty alleviation by ensuring sufficient resources to sustain and improve livelihoods in a fair way, while at the same time maintaining ecosystems by maintaining healthy natural environments and exploiting ecosystems by providing services directly or indirectly for livelihoods (MEA (Millennium Ecosystem Assessment), 2005). Given the environmental and water crises that endanger the country's food security and energy. It can be inferred that this approach can be a guide for sustainable development policy in the country. Accordingly, while explaining the status of the components of this approach, the necessity of considering the nexus approach as an appropriate policy strategy for sustainable development will be addressed (FAO, 2011a; FAO, 2011b).

Global trends show that due to population growth, economic development, technological advancement, urbanization, growing demand for food and diverse diets, climate change, resource depletion, and water scarcity, demand for freshwater, energy, and food will increase in the coming decades. Hoff, (2011a); Hoff (2011b). Currently, agriculture accounts for about 70% of the world's total freshwater resources as Egypt's largest water-consuming source. The food and agriculture supply chain is also used for the production, transportation, and use of all energy processes, while also producing and supplying chains. Food supplies also consume about 30% of total world energy (FAO 2014). This situation is expected to worsen shortly, as it is predicted that by 2050 due to more nutrients and quality differences (Feng et al., 2011). Better, 60 percent more food will be produced, and energy consumption in the world is on the rise, rising to nearly 50 percent by 2035 and 80 percent by 2050. It is projected that water costs will increase by the year. 2025 will increase by 50% in developing countries and 18% in developed countries (Flessa et al., 2002). With the increasing consumption pressure on resources and the complex relationships and interactions that resources have with each other, the need for a new approach to identify and analyze these relationships for the sustainability of valuable water, soil, energy, and so on resources is undeniable. WEFN Water and Energy Correlation (1 (an attitude that enables this)) Garcia and You, 2016 (You, Practically, Water, Energy, and Food Correlation) WEFN (can be used as an approach for evaluation, development and defined the implementation of policies that emphasize water, energy, and food security at the same time (HlPE, 2015).

Bizikova et al., (2014) more precisely, WEFN provides a conceptual and analytical approach to socio-ecological systems and proposes a framework for coordinated management and use of natural resources in all sectors and sectors (2014), FAO Highlighting various sources of WEFN concepts that vary in scope, goals, and understanding of the driving and influencing factors. Fig. 2) shows the multidimensional correlational aspects. Hand expanded the domain and added other issues related to his particular concerns, but in this context, it is worth noting that despite the addition of disruptive tools for Correlation between water, energy, and food/land remains at the core of the conceptual framework (El Costa 2015).Fig. 3.

Considering the rapid population growth in Iran, which increase from 35 million people in 1979 to 86 million in 2020 and it is predicted to reach 100 million by 2050. Moreover, the water shortage of the country which caused the water per capita to decrease from 4800 liters in 1928 to 1380 liters per capita and predicted to decrease to 700 liters per capita by 2050 (IEA, 2010). All these enhancements and reductions caused the climate system in Iran to lose its productivity, and the severe food shortages happen in the country. The 280% inflation in the main food resources during the past five years is a witness for this crisis. The food, water, and energy crisis in Iran state the necessity of the Nexus concept view and perspective implementation in the Iranian governance and policymaking process. The main gap in this field is the lack of a native governance method for the country, which can be implemented to face the coming crisis and issues. Thus this paper is aimed to model the Nexus governance for Iran's future (MEA (Millennium Ecosystem Assessment), 2005).

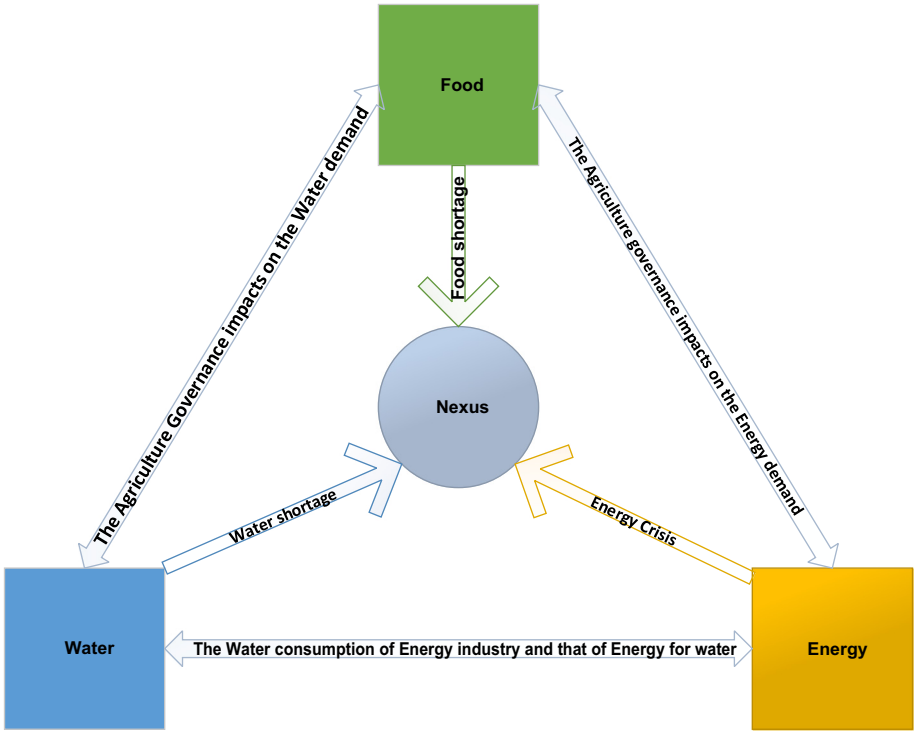

Fig. 1. Water, Food, Energy Nexus (source: the authors).

Fig. 2. Different concepts and models of the Nexus (Source: various Sources noted in each diagram).

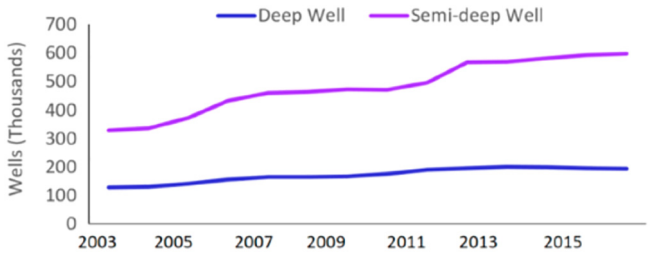

Fig. 3. Number of water wells (source: Mirzaei et al., 2019).

2. Iran's three head chaos dragon

According to the narrative of the Third Water Crisis Report, governance is essential for crisis mitigation, and societies face social, economic, and political challenges to how to govern more effectively (UN World Water Development, 2009; Sadoff et al., 2015). Governance of water, Energy, and food is the controlling behavior that is exercised through managerial or regulatory measures across a wide range of political, social, environmental, economic, and administrative systems, ultimately leading to "allocation" and improvement of conditions. "Exploitation" comes from three components (Summit, 1992; FAO, 2011a; FAO, 2011b). Good governance can, as an essential tool for sustainable development in the energy sector, absorb the capacity of developing countries to attract foreign direct investment and promote economic development (USAID, International Development Agency) (World Economic Forum WEF, 2011). The issue of governance in the energy sector has been studied by the International Energy Agency (IEA, 2010) from the three aspects of empowerment, structures, coordination, and coordination process (IEA 2010). Each of the three sections includes sub-sections that cover the concept of governance in the Nexus field. Given the current pattern of development with the sustainability of natural resources, especially water and energy resources and its widespread dimensions in most countries of the world, including Iran and other Developing countries, reforming or rebuilding governance in most countries to address this conflict as a fundamental and radical solution to resolving the crisis it is imperative for executives and policymakers. In this regard, the approach of water, energy, and food Nexus as a new and emerging concept seeks to express to us the complexities and interdependencies of global resource systems (Bizikova et al., 2014). In this emerging approach, the issue of water security is linked to energy security, which calls for the continued availability of energy physically at an affordable cost and respect for environmental concerns. It can be concluded, therefore, that much of inappropriate governance is related to the lack of a dynamic and dynamic relationship between the amount, manner, and method of water use in food production and energy production. Therefore, a mechanism and approach are needed to achieve this dynamic (FAO, 2014).

The main Groundwater extraction methods in Iran are the deep well (>50 m), semi-deep wells (<50 m), ancient Qanats, and the springs (see Fig. 4). The trends of water withdrawal show that the springs and Qanats are gaining lesser water each year (spring and Qanats share decreased by 42% and 47%). The trend shows that the deep wells increased from 2003 to 2015. This fact notes the groundwater decline trend (See Fig. 5) (Nima, 2017).

Although Iran's last decade, food production did not present a stable decline trend because of the various other uncertainties (Norouzi et al., 2020). However, the renewable water usage in many arid and semi-arid counties caused the venerability of those regions toward the water crisis, and the lack of firm governance in the matter of water can cause severe food shortages similar to that of the year 2008. Also, land management is an important and effective adaptation for the water shortage mitigation in the arid

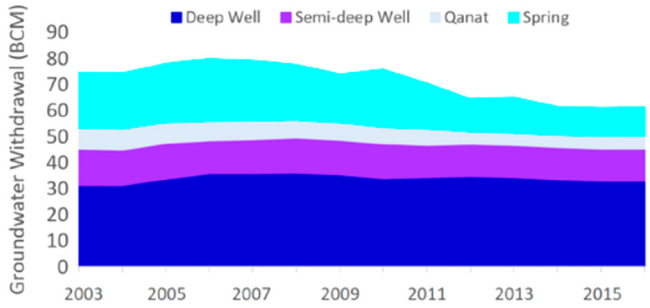

Fig. 4. The Groundwater Withdrawn by the method (source: Mirzaei et al., 2019).

regions, which can help the energy and energy policymakers to manage the consumption and the energy price. Although in the Iranian region, the subsidies, cheap power supply for agriculture, and other miss management plans caused the removal of the energy pricing control pressure from the agriculture deep groundwater withdrawal. The rapid energy consumption increasing trend shows this fact that the energy policymakers in Iran need a renewal of their perspective toward the climate system with the nexus approach (Norouzi, 2020).

Severe groundwater withdrawal in most of the Iranian regions is an important trend that will lead to the water bankruptcy of the country in the future. Considering the GEF policies for long-term water security, if the current trend continues, it means the growing water scarcity and reduction of groundwater availability. Fig. 6 shows the vulnerability of the Iranian provinces toward the water crisis (Nima, 2018).

3. Models and materials

The GWP Global Water Partnership was established in 1996 in coordination with several national and global organizations to support comprehensive water management. It was introduced to maximize economic and social prosperity without harming the sustainability of our ecosystems and the environment. The purpose of the IWRM approach is to reconcile the diverse needs of different stakeholders in resources, which may not include the food and energy sectors. Water and Sustainable Development 146, No. 1, 2019, which primarily includes food and Energy WEFN, and secondly, its focus on the inter-relationships of these resources with each other. Even intercontinental portability is a relatively more local resource. The IWRM approach plays an effective role in water-related activities in a catchment, on the other hand, the boundaries of a WEFN study can vary depending on the study

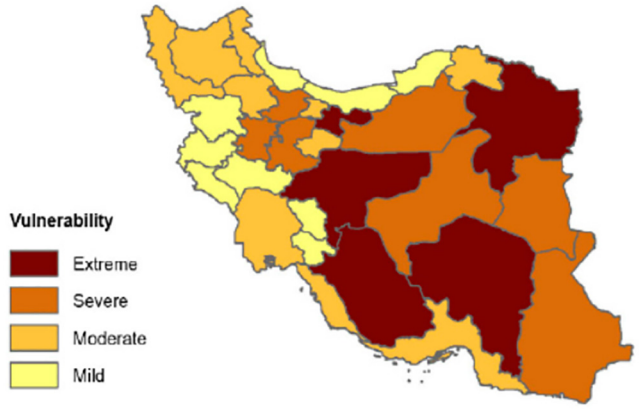

Fig. 6. The vulnerability of each Iranian province toward the water crisis(source: Mirzaei et al., 2019).

focus: regional, national, Provincial and even local. Also, depending on the type of problem, the WEFN approach can focus on a specific part of the system, while the IWRM focuses on water resources (Mohtar and Lawford, 2016).

There are two widely available methods for calculating water, energy and food bond traces. These methods are named bottom-up and top-down, respectively (Böhringer and Rutherford, 2008). The bottom-up approach takes into account the quantity of product footprint as well as the analysis of key processes to reduce the footprint of critical products. However, the bottom-up process-based approach does not distinguish between average and end-users in terms of water consumption, so it cannot provide a comprehensive explanation of supply chains. (Feng et al., 2011). Low-energy models also represent partial equilibrium in the energy sector. These models are used to replace the energy carriers at the initial and final levels of energy to process the replacement or improve system performance. (Böhringer and, Rutherford 2008). The bottom-up approach, by estimating the water footprint by calculating the virtual water content of international commercial goods and services by careful data processing, is one of the most popular methods of water tracking studies.

In contrast, the top-down approach uses the "big picture" approach by modeling the share of resources and flow of water, energy and food systems in an economic system; in fact, by modeling the flow of materials and breaking them down into smaller units, potentially reducing the water footprint in energy and food. Top-down models adopt an economic perspective based on the initial market turbulence, financial weaknesses, and income impacts

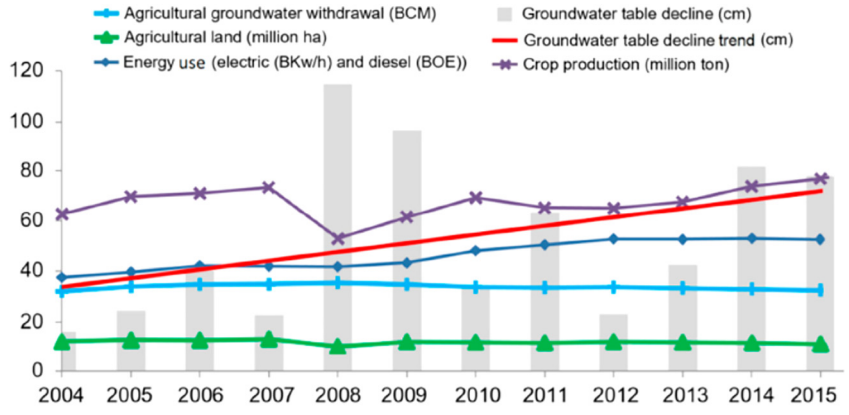

Fig. 5. The Groundwater Withdrawn by the method (source: Mirzaei et al., 2019).

on various economic factors such as households or governments (Norouzi, 2020). Top-down models usually take into account the exact details of current and future technological options, so the two above methods tend to diverge one from the top down, at the macro and national levels, and the other at smaller studies and product levels. Specific is used. It is worth noting that bottom-up and top-down approaches have their strengths and limitations in estimating various performance studies so that the gap between some results on food security and water can sometimes reach up to 48% (Feng et al., 2011; Nima, 2018).

> "The water crisis is essentially a governance crisis, and societies face social, economic, and political challenges to how to govern more effectively (Kaveh Madani, 2019; Fani et al., 2019)."

3.1. Sum model governance process

Considering the importance of governance in the field of crisis mitigation plans. Iran, due to its current weak governance and management form, is greatly vulnerable to climate change, food, and water crisis. Thus a more developed governance model using the nexus perspective is very useful for the Iranian policymaking system (Norouzi, 2020). The model shows the governance system of resource management which is made based on the Documents, options, and scenarios and then the draft policies made during the Governance system are used in the sun model with the driving forces to develop the strategies and paradigms implementable in the Water, Food, and Energy nexus government. This model is named the Sun nexus model after the sun as the source of all three aspects of the model (water, energy, and food) (Mohtar et al., 2016).

To combine the three introduced concepts, including ideas, theories and drivers, and strategic elements of the environment that took place in a layered manner, environmental challenges, strategic priorities, and strategic change took place in the governance process to develop more accurate and useful strategies and paradigms (Ali Raza Kalair, 2019).

Of the strategic priorities, the direction of theories and drivers, and the environment of the strategic elements of the environment, environmental challenges are achieved. On the integration stage, the combination of the results from the three sections is achieved by strategic challenges. The basis of the outlook document is based on this model (Shu-Yuan et al., 2018). A vision statement is arranged in a few tips, but transparent, clear and explicit terms, including environmental data, changes in attitudes, values and social aspirations, intellectual creativity of strategists and social leaders, and the public (Radcliffe, 2018). This statement is arranged in the way that the strategic challenges and the qualitative objectives set in the document, have direct and meaningful connections, and homogenize the needs of the society in the future and present time, using ideal, achievable, valuable and sacred phrases and words for documentation of this outlook. In every modeling method, systematic thinking and the importance of feedback must be taken into account (Norouzi, 2020). In this model, there is a feedback, review, and correction process. This means that when the environment is analyzed, and the future is evaluated, estimated, and designed. These events have not existed in the internal and external society, and their effects and consequences it has not been perceived and evaluated by people in the past and the future, and it creates related events that may affect all parts and layers of the model. Finally, an integrated model consists of three sectors in Fig. 8 below (see Fig. 8).

In the sun model, the environmental data and evaluation of them is performed with formal, analytical, systematic processes, and intuitive and unstructured creativity, and looks at the creation of the future as a designing method. In this paper, the perspective consists of three categories: data derived from the fundamental aspirations and values of the nation, data from the analysis of the environment, and the data from analysis of trends and the recognition of futuristic proponents. Each of these categories includes the layers described in detail in the previous section, and finally, the relationships between them and how they are linked together, and how the general model is described (see Table 1).

4. Results and discussion

The inherent solidarity of the three sectors requires stakeholder engagement and belief in the public and private sectors to model and manage sustainability issues systematically and comprehensively (Norouzi, 2020). Accordingly, one of the suggested institutional development strategies for policy and discourse in the various sectors involved is to achieve a common consensus. Meanwhile, the ministries of energy, agriculture, and industry, mining, and trade play a major role. Coordination between the three departments of Deputy of Planning and Economics, Deputy of Water Affairs and Deputy of Electricity and Energy of the Ministry of Energy and involvement of the Office of Strategic and Integrated Planning to develop development and organization plans related to affairs, as well as coordination with the Deputy Director of Watershed Affairs to improve water efficiency. Moreover, it is necessary to regulate water use in agriculture (Nima, 2017). Monitoring food production and monitoring the country's industries should also be considered to optimally use the country's energy and water resources (Fani, 2019). The development of the country's industries based on the green economy and sanitary goods is also effective. The Islamic Consultative Assembly plays an important role in the formulation of upstream laws in the field of industrial development, the use of energy and water resources, as well as the coordination between the responsible bodies and the determination of the role of each entity in achieving sustainable development (see Table 2).

4.1. Policy implementation

Food and water are essential to human existence, and energy is the key to human development. Water, energy, and food are strongly linked and play an important role in achieving sustainable development goals. The declining water level is a threat to agricultural sustainability, food production, health, and the environment, and access to these resources, and their sustainable management is the basis for sustainable development. Therefore efficient use of these limited resources is essential for sustainable development. At the Rio 20 conference in 2012 under the heading "The Future,

Table 1
Characteristics of the Sun Model.

	Realistic	Idealistic	Structured analysis	Semi-structured innovation	Interacting	layer
Aims	-	*	-	*	*	*
Driving forces	*	*	*	*	*	*
Strategic indicators of environment	*	-	*	*	*	*

Table 2
the main role players and the impact of each one in the sun model.

Main Role player	Organization	Operations
Ministries	Ministry of Energy	The executor of water and electricity projects of the country
	Ministry of Agriculture	The administrator of Agriculture and Improvement of Soil Affairs
	Ministry of Economy	Food production as well as monitoring of industrial and environmental measures
Other executives and policymakers	Ministry of health	Financing and funding
	Association of the environment protection	Pay attention to water quality and food safety
		Conservation of natural resources
	Parliament	Legislation on water, energy and food security of the country based on sustainable development
Academic and associations	Academies	public education
	NGOs	Offer designs and suggestions
	Scientific AssociationGuilds	Getting involved in the implementation
		Fundraising

We Want," a set of 17 clauses was presented by the United Nations as a sustainable development objective. The subject of water, energy, and food are, directly and indirectly, related to the 12 clauses. To achieve the 17 goals of poverty alleviation, food security, gender equality, health, sustainable consumption, and biodiversity conservation, we need to understand their complex metabolism and work together. Nexus thinking or "system thinking" addresses individual, kidney, feedback and communication, rather than individual components, and can change systems through targeted interventions in "critical" events, Alcamo (2015) The Nexus approach deals with a wide range of issues related to health, social and economic policies and covers a wide range of engineering ponds. Spending water and energy is one of the most important sustainable development areas around spending energy that can reduce the pressure on water resources because the water needed to generate energy can be stored or reallocated. The birth of a water harvester can also reduce the amount of energy used to transport, heat, and purify water, so the existence of Nexus thinking can be considered a key to sustainable development. FEW ($ 50 million to advance research on Food, Energy, and water transplantation) released such research funding that Nexus has become a powerful metaphor for transcending interdependencies between society and natural systems. The key to Nexus thinking is the interaction between FEW securities. From 2011 to 2015, 291 organizations, from political, business to scientific institutions, participated in FEW security activities (Norouzi, 2019).

water-energy-food systems are so interconnected that one action often affects the other. Therefore, to reduce exchanges and increase cooperation, integrated approaches for analysis, planning, and decision making should be employed. A strong correlation between water-energy-food resources and their close relationship to environmental issues, climate change, economic, social, political, and other needs requires stakeholder cooperation so that systematic management among the sectors is essential for the achievement of the Nexus goals and sustainable development. The Harris program and the policymaking between the parties and the mechanisms involved to reach a common point require the discourse among stakeholders and the organization of conflicting goals to create cooperation and reduce interventions.

4.2. Regional strategies

By definition (Gray and Sadoff, 2007), water security is "an acceptable quantity and quality of water for health, livelihoods, acceptable production, and ecosystems with an acceptable level of water hazards to people, the environment and the economy" Ideally, water allocation should be economically efficient, technically, practically as well as socially just. The World Economic Forum highlights the problem of water, food, and energy security as high population growth and economic growth puts unbearable pressures on resources. Demand for energy and food water is expected to increase by 30% to 50% in the next two decades, while economic inequalities and encouraging short-term response to production and consumption will undermine long-term sustainability. Lack of resources can create social and political instability, geopolitical conflict, and irreparable environmental damage. Focusing on one part of the relationship between water, energy, and food, without considering the relationships between them, will have serious risks and unintended consequences (World Economic, 2011; Hoff, 2011a; Hoff, 2011b). The concept of food energy water web (WEF) has emerged in the international community in response to climate change and social change, including population growth, globalization, economic growth, urbanization, growing inequality, and social discontent (Hoff, 2011a; Hoff, 2011b). The approach of Water, Energy, and food is an overarching vision of sustainability that strives to balance the various goals, interests, and needs of people and the environment. The results of the Sun nexus model recommended for the climate change issue mitigation process:

All-Seunger's approach to spatial development in a spatial development approach seeks to tackle the phenomenon of valid inequalities and present the appropriate tools for achieving balanced, equilibrium, and sustainable development at the regional level. Water caretakers have always had a mission and concern, and caretakers of the consumer sector certainly have no effort but to consume it. In these two organizational missions, "Development and Supply," "Integrated Water Resources and Consumption Management" have been overlooked. Therefore, any organization, whether popular or not, takes a different, and necessarily infinite, approach to the limited resources available, and the reign of each of these weak niches will bring more catastrophes. It is expected that policymakers, decision-makers, planners, thinkers and all development stakeholders and relevant stakeholders in constructive interaction with each other, within the framework of national development and in a grand program, can prepare the country plan in the form of a "humanitarian program with Water centrality" Redefine, compile and implement, following the conditions and capabilities of the country's development.

A. Modifying the water management structure through the integration of related entities

In this approach, and for the legal management of water, various responsibilities for the provision and protection and, ultimately, the sustainability of water resources, from watershed to re-rotation, are defined in a separate instrument. Merging and reviewing its responsibilities and monitoring, and most importantly, the concrete involvement of social institutions and effective public participation, are restructured and integrated (Nima, 2020a, Nima, 2020b).

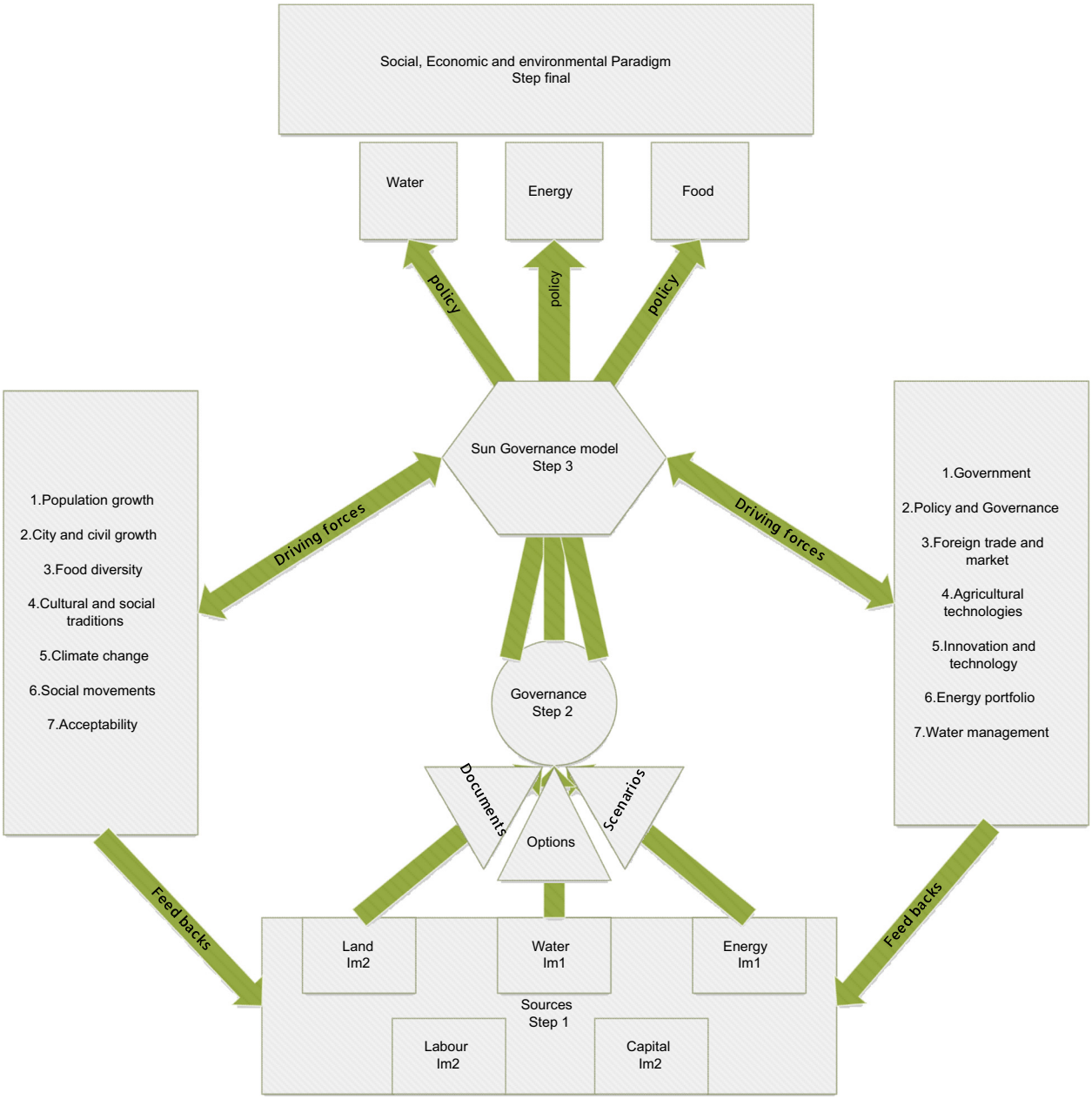

Fig. 7. The nexus governance model for Iranian region (in step 1 Im is the importance tier, and one is the most and two is the least which is used for ranking of the Driving forces) (source: by the authors).

B. Defining the entrepreneurial plan and defining institution agencies

The second approach, which is practically partially consistent with previous experiences, merely combines the various entities into one grand plan and, following their goals, mandates the different institution's Data, and their outputs are also monitored. In this approach, the Transnational Plan establishes an integrated and collaborative water resources management framework in a way that, in the form of a joint project and a description of specific tasks and tasks, all institutions are involved. Certainly, the impetus for this partnership will be the wide perspective of the people and the consensus and consensus on the current and desirable situation. Then the roadmaps can be implemented and monitored (Maryam and Nima, 2019; Pan et al., 2018; Norouzi, 2019).

5. Conclusion

The Water-energy-food nexus has been getting a significant amount of attention among researchers and policymakers since 2009. Although much of this research was conceptual and not directly applied or industrial, this field still requires more development in the concepts and the main theories of the topic to improve the framework and the structural basis of the method. This trait of the Nexus is great because of its regional nature. In this paper, a novel governance framework is being implemented to improve the conceptual framework of the Nexus and also to help further researches to evolve into the more quantitative and applied fields using the nexus structure. The output of this model is an environmental analysis study that organizes the economic, political, energy,

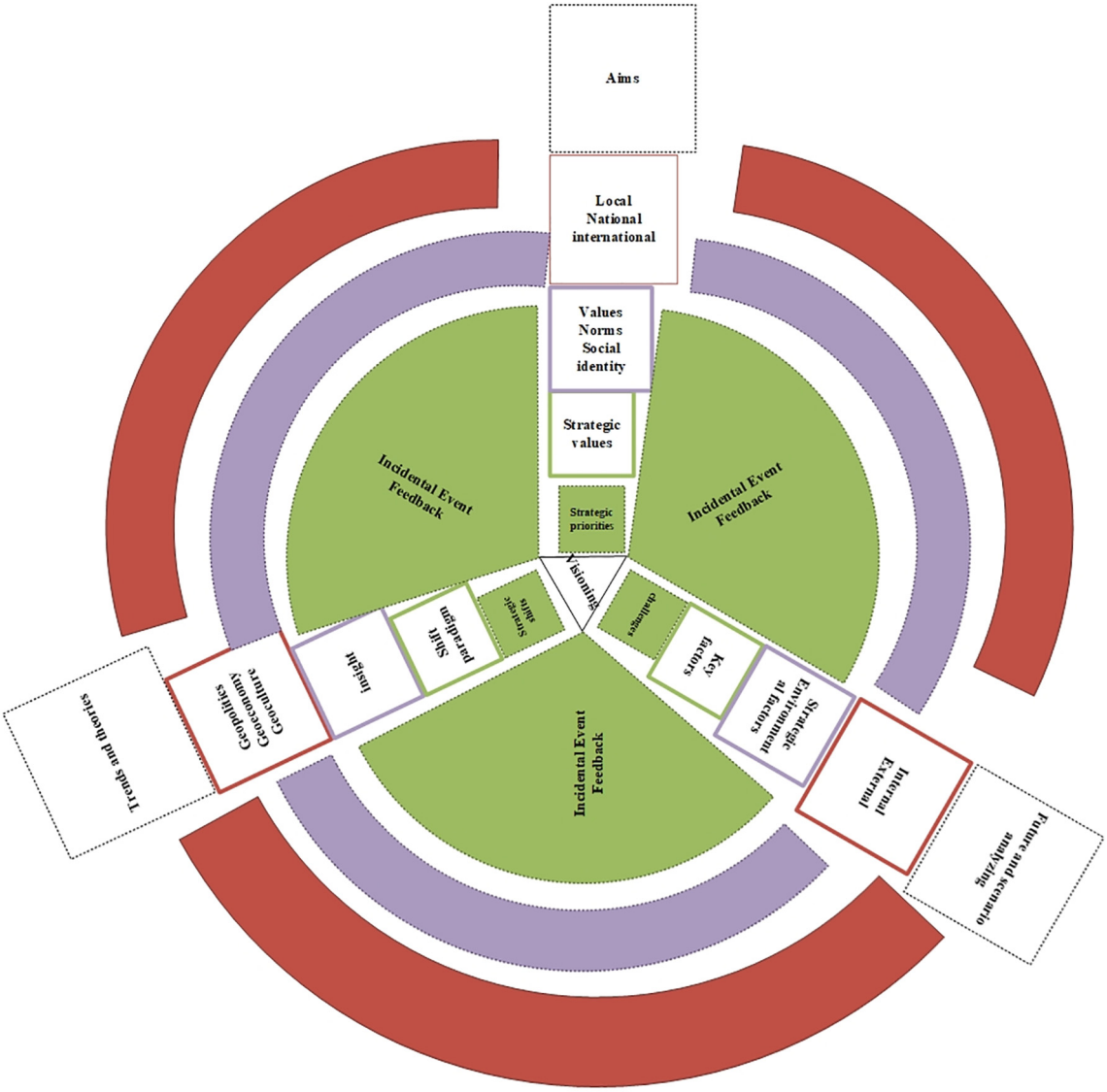

Fig. 8. The Sun Governance model used in the sun nexus model (source: by the authors).

environmental, and governance ambient of a region and helps the researcher to model the complex social systems. In this study, this model is being implemented for the Iranian region in the term of its water shortages and possible future food problems. The result as it was shown in Table 2 and the Figs. 7 and 8, noted that the main reason of Iran's problems in the water and food management is the governance shortages and in the discussion section (4.2) some strategies were recommended for the governance improvement process. In the end, the main recommendation of the Sun governance model for Iran was to improve the cooperation between Iranian effective organizations and roleplayers in the water, food, and energy management. The fragile and limited cooperation between the organizations and parts of the government and private sector in Iran is the bottleneck of the Nexus approach and its implementation for Iranian water and food problems. The results of this model are being compared with the other references in this literature, and nearly most of the references (Böhringer, 2015; Feng, 2018; Nima, 2018) stated the importance of cooperation and Transparency of information to be the two most important factors of a nexus-friendly governance system and policymaking body.

Credit authorship contribution statement

Nima Norouzi: Conceptualization, Methodology, Software, Writing - review & editing, Supervision. **Ghazal Kalantari:** Data curation, Writing - original draft, Visualization, Investigation.

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.

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