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Urban WEF Nexus: An Approach for the Use of Internal Resources under Climate Change

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Abstract: This study strives to utilize WEF resources for the sustainable development of the city, with respect to future climate change. Two diffusion scenarios of Rcp8.5 and Rcp2.6 from the 5th Assessment Report by the IPCC, with the output of the HADGEM2 model were used and the city of Borujerd, Iran was chosen as the case study. The urban morphological dataset was calculated using ArcGIS. Furthermore, the water requirement of some crops (apples, grapes, lettuce and vegetables with leaves) is estimated with the NETWAT and CROPWAT models. This output indicates that in the next period, an approximate 2.25 °C change will take place in the temperature and the rainfall will change between 20–40%. Adopting a WEF Nexus, this study suggests that an urban centralized agriculture will provide 21.3% of the local demand for fruit and a significant amount of the local demand for vegetables. The water reused for urban agricultural irrigation purposes and 3.6% of the freshwater resource demand and sewage cycling can be supplied by harvesting rainwater. Water treatment and recycling can also provide 60.74% of the city's current water demand. Furthermore, the production of biogas from human sewage and urban wastewater can save 32.4% of the current electricity, on a monthly basis.

Keywords: HADGEM2 model; climate change; urban agriculture; WEF nexus approach

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1. Introduction

With a view to economic growth, currently, the water energy demand is steadily increasing worldwide [1]. Within a 20-year time span, over 40% of the world's energy demand, is expected to experience a 40% increase. [There is a clear relationship between energy demand and economic growth. As economic growth increases, energy demand will increase as well. [2]. By 2050, food demand, as expected, will grow as much as 60% [3]. Specifically, urban areas abound with natural resources [4] and the urban population will account for 70% of the world's population, by 2050 [5]. This excessive consumption of natural resources has led to a dangerous mode of climate change [6]. A major obstacle to implementing economic alternatives for resources is to understand what the meaning of a limited planet life is [7]. Furthermore, in many cases, cities are limited in terms of efficiency and energy adaptation, in order to reduce climate change. Among these limitations, the total management of water resources is salient [8]. However, these two components have to be integrated in order to support urban flexibility [9] and their mutual positive correlations may raise the cost of productivity for the stake holders, particularly those in construction and urban infra structure sectors [10]. Recently, with climate change, resource constraints, economic and population growths, the provision of basic services and goods such as food, water and energy have become increasingly challenging for many cities. The combination of water, energy and food within cities are seen as key to the development of sustainable and resilient cities [11]. A wide array of concepts for the future of cities is directed at sustainable development. The concept of an eco-city focuses on energy-efficient buildings, the use of passive strategies and renewable energy sources, wastewater recycling, rainwater collection, sewage and waste recycling, access to green spaces and venues, walking and cycling throughout a city and social possibilities [12]. The water-energy-food approach is an urban integration plan, and it has grown rapidly over the past few years. This approach points to the connections between water, energy, and food [13], namely, that a large amount of energy is necessary for the freshwater supply and wastewater treatment and conveyance. Water is a requisite for food and energy generation [14]. This approach seeks to optimize traditional water and energy systems and aims for the optimized production of food products. The concept of sovereignty focuses on responsibility [15]. A new image of water is demanded, in relation to its significance [14]. In addition, for an effective adaptation, a WEF Nexus approach is important [16].

Compared to rural areas, the urban regions are exposed to climate change [17,18]. Furthermore, some types of urban change intensify the climate change effects, such as rain and warming [19]. So, understanding the interaction of water, energy, food, and waste within cities is essential to understanding the vulnerabilities, as well as finding the solutions that enhance urban sustainability and resilience at all scales [20]. The urban Nexus research in this field can be mentioned in the studies of Rasul and Sharma [16], Howartha and Monasterolo [21] and Gondhalekar and Ramseuer [22], who use a Nexus approach to water, food and energy security in order to adapt to climate change and their comprehensive decisions are expressed. In an article, Wa'el et al. [23] presented "an integrated model for evaluating the relationship between energy, water and food at the household scale." In this study, they used information about Duhok, an Iraqi city, and they used the WEF Nexus approach. The purpose of this paper was to investigate the seasonal effects on diversity in the demand for water, food and energy using the WEF model. Key findings included: seasonal variation and population growth, average annual per capita food demand and waste generated per season, water-related energy demand for recycling and the use of anaerobic digestion of food waste and sewage sludge for energy recovery [23]. Singh and Tayal [24], also addressed urban food management through the water-energy-food Nexus in India for sustainable development. This study examined urban area food systems (urban/suburban agriculture, green roof technology, urban farmers markets) and food waste management (reduction of food waste, compost from waste, waste energy). The results showed that urban food management in India is very effective in managing food waste through solid waste management strategies (compost and energy production) [24].

Given that climate change and its impacts on, notably, rainfall, water resources and its relation to energy and food resources, this study seeks to examine the potential for urban expansion in the future, using the application of the WEF Nexus in the city of Borujerd. It also aims to show the share of existing water resources and future climate changes, which shows the need to increase adaptation and productivity. The potential of the green space structure in this urban area was assessed by assuming that more green space structures would be completed as much as possible, within the existing constructions, which would be needed to effectively account for the impact of heat vapor and rain-induced flooding. If the potential for green areas is achieved in the urban agricultural model, the potential connection between energy efficiency and water resource management is the focus of the research. The main objective of the study is to introduce an option for an efficient application of the WEF Nexus by adopting a WEF Nexus approach and taking into consideration future climate change. The aim is to find out how it is possible, considering population growth and urban expansion, to overcome the Nexus problems and to meet the requirements for these resources so that a sustainable urban expansion could be achieved.

For this purpose, in this research, according to the climate model, the precipitation and temperature of the urban area with the HADGEM2 model under two climate scenarios are considered. In the continuation of the urban morphological dataset, the features of the surfaces, including the yard and roof surfaces, the façade and the length of the facade are calculated using ArcGIS. Furthermore, the water requirement of some crops (apples, grapes, lettuce, and vegetables with leaves) is estimated with the NETWAT and CROPWAT models. Then, by calculating the spatial volumes and rainfall of the region and the cultivable area for urban agriculture, the estimation of food demand from urban agriculture is obtained. Moreover, the performance of the energy sector is examined through the production of biogas from sewage and urban waste.

The rest of the paper is organized as follows. Section 2 describes the WEF Nexus, climate change, the NETWAT software, the CROPWAT software and the study area. Section 3 demonstrates the results in an organized order, while Section 4 entails the discussion of the results. In Section 5, the conclusions are presented.

2. Materials and Methods

2.1. WEF Nexus

2.1.1. The Relations among Water, Energy and Food Security

The water-energy-food in security cans indicate that certainly water security, energy security and food security are interconnected and the initiatives in one area usually affects those in the other two. Given the fact that the world population is approaching 8 billion, as the demand for basic services and the propensity for higher living standards increase, the requirements for the protection of critical resources, needed for the achievement of services and expectations, are explicitly compulsory [1,25].

- In the millennium development goals, water security is defined as access to healthy and fresh water, both of which have recently become a human right while access to water for the other human uses and ecosystems, is highly significant from view point of communications, despite the fact that a major part of the conceptualization of water security is unavailable [26].
- Energy security is defined as access to clean, reliable and economical services for making food, heating, illumination, communications and production purposes. It is also meant as physical access, with respect to economical environmental concerns [27].
- Based on the FAO′s definition, food supply is defined as access to sufficient and healthy food for the fulfillment of food needs and the regulation of food for an active and healthy life. Furthermore, proper food is defined as a human right [28].

2.1.2. The Interactions between Water, Energy and Food Security

A remarkable interaction exists between water, energy, and food. Water is used for the extraction, mining, processing, treatment and disposal of the waste from fossil fuels, growing raw materials for biofuels and power generation. In the energy sector, the intensity of water is different where compared to the biofuels and sands used for oil production, much less water is used for producing oil and gas. An accurate coordination needs to be made of the preferences, to choose or identify the biofuels for energy production because the water used for producing raw materials for biofuels might also be used to grow food products.

Many energy production farms using fossil are highly contaminated while they have a great deal of water extracted notably from sand and through hydraulic fracturing. Moreover, the return of water flowing from plants to rivers is warmer. This water is highly contaminated in the air and thus may endanger the downstream alternative uses including the ecosystems.

Conversely, water is required for the extraction, transmission, distribution, and treatment. In order to have access to 1 m^3 water, different intensities of energy are required. Logically, access to local water requires less energy compared to underground pumping, wastewater recycling or the disposal of seawater. Compared to farming and precipitation, more energy is required for irrigation while still drop irrigation systems need much more than when water is distributed under pressure.

Food production is the largest consumer of fresh water. Agriculture, at its global level, is responsible for, on average, 70% of the fresh water consumption. This amounts to

80–90% in some countries. This agricultural use of fresh water also exceeds its utilization levels. In terms of water resources, food production has affected other areas, such as natural settlements through soil degradation, run-off change, dysfunctional discharge of underground water, water quality and access to water and soil. The increased production that led to mechanization and other modern initiatives, is the product of high energy costs because food and supply chains account for an almost 30% of the total world demand. Energy involves soil preparation, fertilizer production, irrigation, cultivation, harvesting and transportation of agricultural products. In recent years, there exists a discernible relationship between energy and food products because the increase in oil price brings with it the rise in the price of food products. Another negative impact on food products may come from the energy industry when mining for fossil fuels and deforestation for biofuels reduce the land for agricultural, ecosystems and other uses [29].

2.2. Climate Change

The prediction of the future climate relies on digital models, known as general circulation models (GCMs), which simulate the climate of the Earth. Currently, the most reliable model for developing climate scenarios is the Atmosphere-Ocean General Circulation Model, known as AOGCM [30]. The HADGEM2 model was used under two scenarios of the fifth assessment report. In its formulation, it is the assessment report on the representative concentration pathways scenarios adopted by the IPCC.

The RCP scenarios for the year 2010, were offered by a scientific group under the supervision of the IPCC to provide the data that may help identify the main factors of climate change and may be applied to climate models. These models employ such resets to capture the data for the concentration and release levels of greenhouse gases, as well as the extent of pollution and land reuses. Two scenarios have been used in this research. In RCP2.6, the concentration effect is, by 2100, estimated to be 490 ppm and 2.6 W/m^2, respectively. In RCP8.5, the concentration of CO_2, by 2100, will reach 1370 ppm and will continue to increase. In RCP8.5, the climate will remain the same if no mitigation policies are adopted and no effort to combat the climate effects is taken [31].

Downscaling with the LARS-WG Model

LARS-WG is a random climate generator that may be used in a station under the present or future climate conditions, in order to simulate the atmospheric data. In 1990, the first version of this model was developed in Budapest as a part of the agricultural risk assessment in Hungary [32]. Then, in 1998, it was reconsidered by Semenov and reduced by Barrow [33]. This model produces daily time series for the minimum temperature, the maximum temperature, rainfall, and sun radiation. A random climate generator uses the climate observed in one station to calculate a set of parameters for distributing the probability of the meteorological variables and their relationships [34].

2.3. NETWAT Software

Known as the national document, this software is applied to fulfill the demands and needs for farming and horticultural plants. This software is, in fact, the output and product of the plan "the net demand for the irrigation of farming and horticultural products", conducted by the Agriculture Ministry and Meteorological Organization [35]. This software provides the data on the transpiration and evaporation of the plants grown in 620 fields in Iran. With a correct estimation of such evaporation and transpiration, it is possible to manage effectively these farming and horticultural practices in each field. Generally, the meteorological data for a reformed 60-year period has been included in this software to estimate the two aspirations and evaporations. The calculation models, in this software, are based on the FAO's Penman–Monteith method [35].

2.4. CROPWAT Software

The most basic needs for devising irrigation systems and water supply structures and conveyance are empowered in an examination of the levels of evaporation and transpiration. Such an examination is an effective and important practice in promoting the productivity of water resources in agriculture. Furthermore, evaporation and transpiration are commonly dependent on the determination of the potential evaporation and transpiration. Over the past 50 years, therefore, many practices for assessing these two processes in plants have been introduced in different regions [36]. Any fault in this process is likely to negatively affect the performance of plants or the output of irrigation, especially in Iran where there is insufficient water resources and the correct assessment of water needs as well as their identification is unavoidable. This assessment is carried out with the referent evaporation and transpiration values. Since these time processes are under the influence of a multitude of factors, many methods have been proposed, among them notably is the Penman–Monteith method. Penman, in 1949, introduced his first mixed method that was a combination of the theory of energy balance and the functions of aerodynamics [37]. Monteith (1965) included, in Penman's method, the parameters pertaining to the resistance of pores in the head of a plant and its aerodynamic resistance. As a combination of the relationships concerning aerodynamic resistance and the resistance of pores in the head of plants, the early Penman–Monteith equation became the FAO Penman–Monteith equation [38]. In FAO Review 56, this method was introduced by Allen et al (1998) as a world standard practice [38].

CROPWAT was designed by the Land and Water Development Division of the FAO [39]. This program is used with the FAO Penman–Monteith method to plan irrigation systems and account for the water evaporation of plants. The latest version of this program can evaluate the water demand of over 30 different plans and provide an irrigation plan for each. If the soil moisture data is present, it serves as a helpful method to manage the moisture insufficiency [38].

2.5. Study Area

The plateau of Iran is an elevated and mountainous terrain in the South Western Asia. With an area of 1,648,195 km^2, it is widely covered by the territory of Iran. These features are shared by the province of Lorestan, located in close proximity to the Zagros internal hills, with a diversity of climate, wild rivers and a number of areas suitable for farming, such as the Silakhore plain. Borujerd, the second largest city of the province, is responsible for about 5.7% of the total area of Lorestan. Located in northern Lorestan, it is located at 48°, 45′ longitude and 33°, 53′ latitude. Within these boundaries, of over 3550.28 ha, it is home to more than 240,654, as determined by the local census figures obtained by Emco Counseling Ltd, in 2012. That same year, the statistics for the urban population density, was approximately 65.05 p/h, based on the population distribution over the defined area. It means that such a density is low, and the city has grown and expanded horizontally (housing and population official census, Tran's statistics bureau, 2012). For the same reason, the city of Borujerd was selected as the location for study.

3. Results

3.1. Results of the Climate Models

In this study, under the two scenarios of RCP2.6 and RCP8.5, related to the 5th Assessment report on climate change provided by the intergovernmental panel on climate change, the output of the HADGEM2 model was used. These data are freely accessible through a center for data distribution established by the IPCC in 1998. (www.TPCC-data.com, accessed on 21 January 2022). In order to see the data on the area under study within the basic and future periods of 20 years, the spatial coordinates of the given location and the required statistical length, the time series of temperature and precipitation during the basic period (1986–2005) and the future period (2020–2039), should be input in order to have access to the monthly output of the parameters within these two periods. Once the downscaling of the temperature and precipitation data in the LARS-WG model is completed, the climatic results were analyzed. Figure 1 shows the comparison of the relative changes in precipitation, the maximum and minimum temperature under RCP8.5 and RCP2.6 scenarios within the base period.

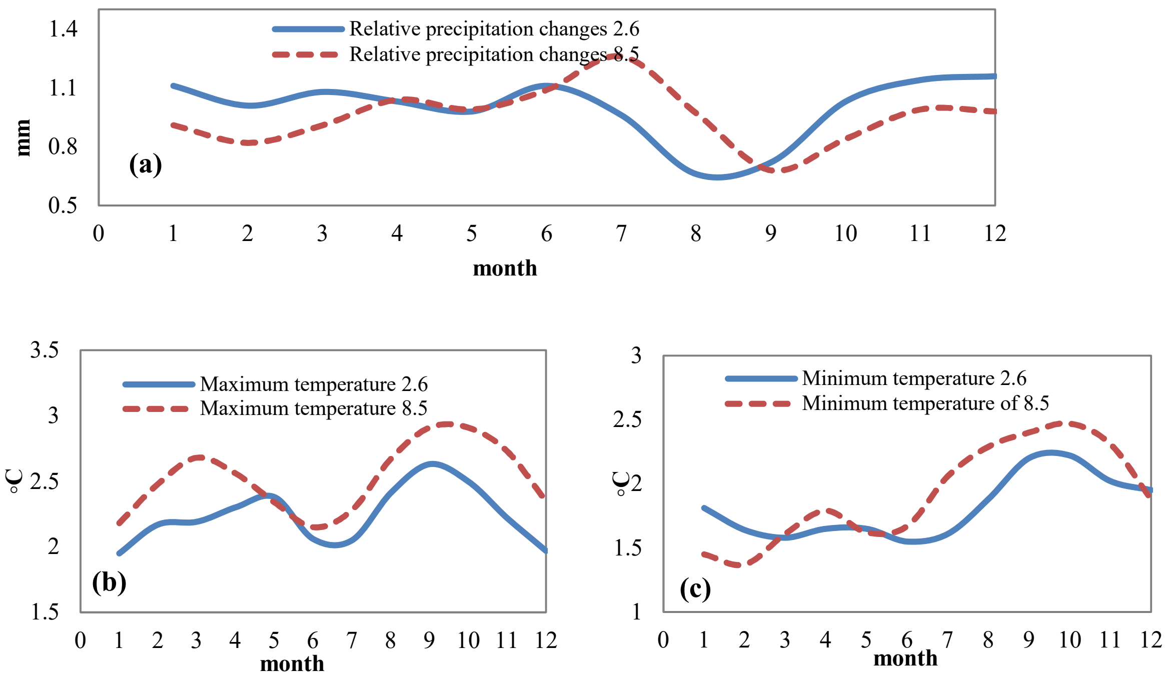

Figure 1. Comparison of the relative changes in (**a**) precipitation, (**b**) maximum and (**c**) minimum temperature under the RCP8.5 & RCP2.6 scenarios within the base period.

According to Figure 1a, given the changes in the precipitation patterns, it was observed that during winter time, from January to March, in the RCP2.6 scenario, evidence of climate change increases. However, in RCP8.5, evidence of climate change decreases, by as much as 20%.

In spring, these two scenarios have similar changes and experience relatively equal conditions during the base period. In summer, they experience some changes by 40%. While in autumn, a 20% increase in rainfall is observed in RCP2.6 and an increase of 10% in RCP8.5.

The changes in the maximum temperature is illustrative of at least a 2 °C increase in the temperature in both scenarios. In RCP8.5, during winter, more than a 2.5 °C increase in the temperature is observed and in autumn, an approximate 3 °C increase is indicated (Figure 1b).

Figure 1c shows the changes in the minimum temperature. In both scenarios, given the changes in the minimum temperature, at least a 1.5 °C rise in temperature will happen. The highest rise takes place in autumn, so that in October, as much as a 2.5 °C increase will occur. On average, in RCP2.6, a 0.5 °C increase in the temperature is predicted, which is less than that in RCP8.5.

3.2. Results of the GIS Model

The planning and management organization in Lorestan province, Iran and the local government of the city of Borujerd have supplied a set of data on the urban morphological features. The demographic tabular figures within each block and throughout the entire city were provided by the statistics division of this organization. The sampling figures include the census taken for different age groups and during a 5 year period, the age of the buildings, their features, the quantitative figures and the use of the ground. By the same token, the density of the buildings and population density were measured. ArcGIS, the geographical information system, was used to collect the data. The spatial and tabular data, coupled together though the indexing of the blocks and houses in ArcGIS, were provided in terms of an integrated approach, as well as the principles of all the existing data. As a standard in ArcGIS, the surface areas of the yards and roofs of the blocks were calculated. In order to calculate the area of the facade, the length of the façade was multiplied by the number of floors, each with a 3.20 m height. Flanging systems, the most suitable option for a green covering of the facades, have to be analyzed in terms of the low technologies compared to the diversities of the facades.

To exclude the polygonal edges among the buildings directly attached to each other, the polygonal edges have been spatially combined on the surface of the blocks by dissolving and reversing the lines. The flexible lines on the top have been separated to form the edges of the building for the different heights of the adjacent buildings. The front appearance of each building was measure based on the area surface and the internal direction. Such measurements were taken using a GIS medium, based on a 3D model of the city of Borujerd. The front appearance was removed from these measurements because no changes were allowed in these parts.

For the purpose of the analysis, 13% of the one-story buildings were residential, and the rest of them were garages, etc. Fifteen percent of two storied buildings were measured and the remainder that were workshops, etc., were non-residential and therefore excluded from the study.

- Three-storied buildings were taken as residential.
- Most of the enclosed surfaces inside the blocks are parting lots that might be the aerobically used if their personal ownership is reduced.
- Smooth roofs and those with a 15-degree gradient are suited to agricultural purposes with no particular reformation.
- Roofs with a more than 15-degree gradient are suitable for rain harvesting and fifteen percent of the roofs were estimated as gable roofs.
- Facades, except the front part of the buildings, are suitable for vertical urban agriculture.
- Around 30% of the urban buildings with parking spaces are 2.5 m high and the dimensions of the garages are ten meters.
- As far as the constructions are allowed, the increase in green infrastructure is allowed as well.

For this reason, as noted above, the model maps of the city, based on the data obtained from the bodies concerned, were designed to calculate the areas under consideration. Following the design of the spaces in a GIS media, the occupied spaces were each illustrated separately, in Table 1. For the convenience of calculation.

Table 1. Table areas and number of land uses in the City of Borujerd.

Land Use	Area (m^2)	Share of Area	Number	Population Per Capita
Residential	6,253,069	17.36	3533	25.98365
Higher education	83,178	0.23	15	0.345633
Educational	319,420	0.89	158	1.3273
Office-military	207,340	0.58	67	0.861569
Commercial	432,411	1.20	5048	1.796816
Sports	184,251	0.51	35	0.765626
Health care	125,373	0.35	92	0.520968
Cultural art	20,484	0.06	17	0.085118
Historical	38,441	0.11	51	0.159736
Green held	1,048,415	2.91	143	4.356524
Farming and gardening	9,001,664	25.00	134	37.405
Industrial workshops	793,063	2.20	115	3.295449
Urban machineries	218,784	0.61	44	0.909123
Warehouse and transportation	286,748	0.80	62	1.191536
Cemetery	507,031	1.41	1	2.106888
Ranching and husbandry	35,880	0.10	9	0.149094
Barren landscape	10,398,987	28.88	2330	-
Pathway	6,059,002	16.82	-	-

Furthermore, the total number of building blocks and other 3D and land use data on the existing prop leaf of the city, with the aim of separating and sorting out the existing spaces throughout the city, are given in Figures 2 and 3.

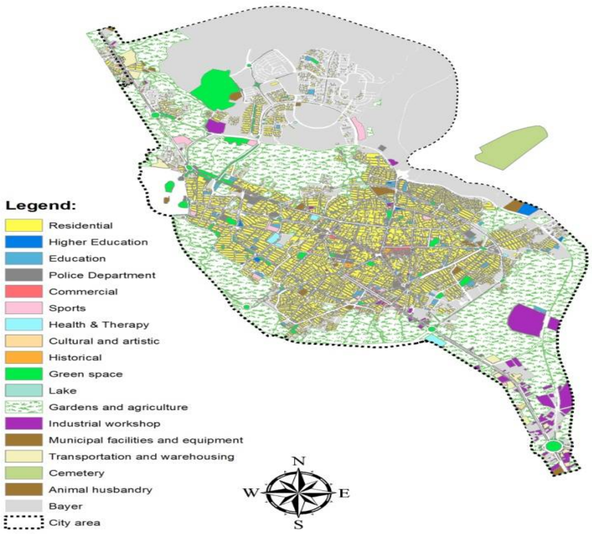

Figure 2. The maps of the land use in Borujerd, as divided by spaces.

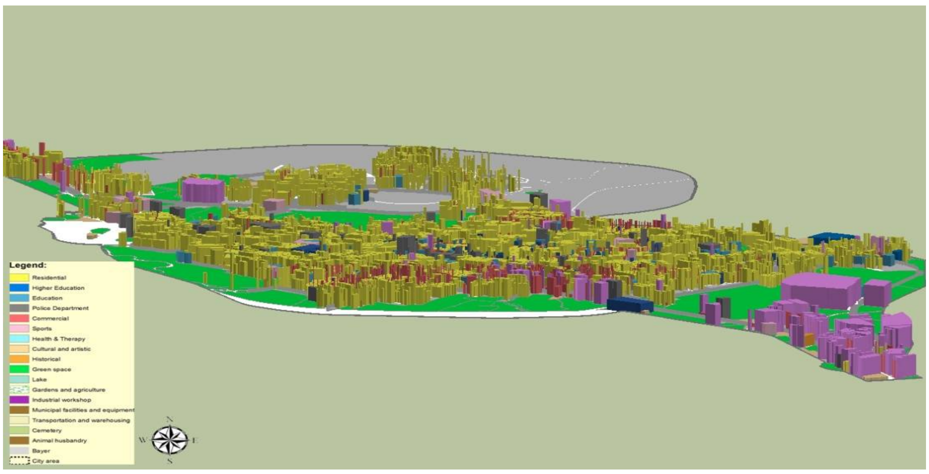

Figure 3. The 3D model of the urban buildings in Borujerd.

With an analysis of the above data, Table 2 gives a tabular representation of the buildings.

Table 2. The data on the floors of the residential buildings and their usable areas.

Number of Floors	The Total Number of Buildings	The Number of Residential Blocks	The Number of Other Buildings	The Vertical Area Other Than the Fabric (m^2)	The Number of Buildings with Garage
One-storied	12,110.25	274	1836	350,720	-
Two-storied	9569	385	2184	985,600	-
Three-storied	10,559.75	1200	360	4,608,000	-
Four-storied	6592.75	720	472	3,686,400	483
Five-storied	3009.25	520	490	3,328,000	879
Six-storied and more	1734	434	300	3,333,120	1512
Total	43,573	3533	5642	16,291,840	2874

Furthermore, in Table 3, ceilings with a gradient of 15° or more have been identified for measurement in the subsequent sections:

Table 3. The area of ceilings required and the volume of garages.

The Number of Residential Blocks with a Gable Roof	The Total Area of Gable Roofs (m^2) ($s < 15°$)	The Total Area of Non-Gable Roofs ($s > 15°$)	The Total Volume of Garages (m^2)
530	1,361,361	7,314,453	718,500

3.3. Implementation of the WEF Nexus Approach

3.3.1. Water

Because of the abundance of underground water and suitable ground in Borujerd, there exists no systematic mechanism for the entire irrigation system. In Borujerd, apple trees and grape vines need water. For this reason, the total water demand for grapes is 9270 m^3/h, for apples is 11,350 m^3/ha, for vegetables with leaves is 7300 m^3/ha and for lettuce is 7200 m^3/ha, during the growing season. with respect to the length of this season or the period for such products, the requirements are to some extent supplied with rainwater. However, if the wet season ends and the heat increases, fruits and vegetables need to be regularly irrigated. In the following years, the increasing pattern of temperature and the decreased rainfall would result in a reconsideration of traditional irrigational mechanisms and serious attention to the application of mechanized irrigation schemes would be made. The total water demand of these plants, in an urban environment and during the growing period, is illustrated in Table 4.

Table 4. An analysis of the water requirements for plants using the NETWAT & CROPWAT approaches in the software model of Borujerd.

Crop	Area (ha)	Water Requirements per Hectare (m^3) (NETWAT)	The Urban Software Model Requirements (m^3)	Water Requirements in Each Phase (mm/dec) (CROPWAT)	The Length of Growth Period (Day)
Grapes	88	9270	815,760	412	165
Apples	104	11,350	1,180,400	460	175
Vegetables with leaves	331	7300	2,416,300	142.5	103
Lettuce	400	7200	2,880,000	142.7	107

With a population of 240,654 people, Borujerd produces 22 mm^3 annually, of which around 17 mm^3 are made accessible and the remaining 5 mm^3 is wasted. The average fresh water consumption per capita per day is 196.22 lit, of which approximately 75% is consumed for flush, sink, etc. If black and gray water is consumable, the water that remains for reuse after treatment, is around 75% of the sewage. In the urban software model, the daily wastewater is 35,416.6 m^3/day. In the same model for Borujerd, the total wastewater produced per year is 12,750,000 m^3. The watering needs of trees and vegetables, in the city, are theoretically provided by the daily wastewater produced.

Urban wastewater is rarely possible to be recycled and locally sourced. Therefore, since the city, in the coming years, would face a reduced rainfall that resulted from climate change, urban wastewater may be potentially a source of plant irrigation. In Borujerd, another important source which remains unused, is rainfall. As noted above, the surface of the roofs with a gradient of 15° or more and thus not suitable for farming if not modified, might be used for rain harvesting. For the same purposes, the street floors and other surfaces not used for agricultural applications are likely to be used. In the urban model, the total area of the roofs, for this purpose, is 136.13 ha. Considering the predicted rainfall in the past years, and the limited changes in annual rainfall, the amount of rainfall varies between 0.4 and 0.5 m and the value of 0.45 m is presumed. The volume of rain water is measured by the amount of rainfall multiplied by the area of gable roofs.

The volume of rainfall achieved annually is 612,612.45 m^3, it means that the total volume of the existing rain water in the urban model is sufficient to supply the current urban freshwater demands. As a default, this reduces the freshwater source by as much as 3.6%. As noted in Table 3, underground parking spaces are likely to be used as water reservoirs to keep rain water. The volume of water in the reservoirs is 718,500 m^3 and the capacity to keep the existing water is less than what has been calculated. Thus, there is no obstacle to store the rainwater. Based on the calculations, if the rainwater cannot be stored in the urban infrastructure, as shown in Figure 4, new infrastructure may be created in the crossing points and the output channels throughout the city so that the utmost utilization of this fresh water source can be achieved in Borujerd.

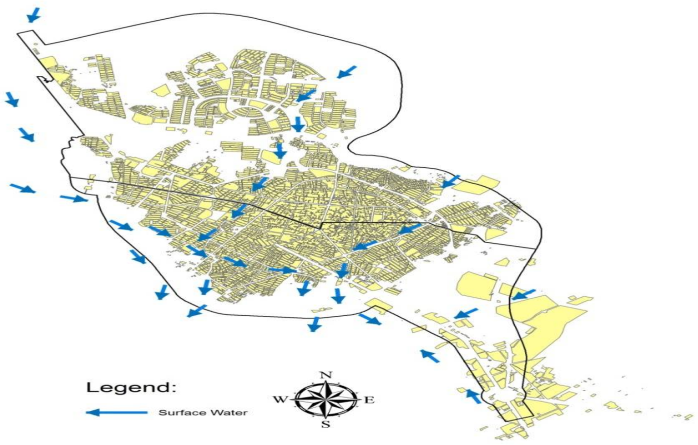

Figure 4. The map of the movement of Surface water.

3.3.2. Food

Within the blocks in the software model of Borujerd, urban agriculture can be measured. If the ground surface and the operative and old-fashioned buildings are excluded, and the enclosed surfaces, such as parking spaces are added, the total area left is equal to 21 ha. If the green landscape is considered in the entire city and inside the blocks, their total area would be 104 ha. As a result, in the afore-mentioned urban model, a 125 ha area is totally available for urban agriculture. In addition, the total area of the roofs with a gradient of less than 15°, would be as much as 731 ha. Finally, the fabric of the buildings (except the frontage) was included and the southern, south western and western sides of these buildings were viewed as the most suitable. A 307 ha of their areas may be used for windows, doors and the structures required for the plants. Concerning the following equation, it can be argued that there is a 488 ha area, in the entire city, for urban vertical farming:

$$S_T = 30\% \, (S_V) \quad (1)$$

where S_V is the usable vertical area and S_T is the total area for the vertical views of the buildings. In the urban software model, the total areas in Borujerd, for urban farming is 1448 ha. Some of these areas are shown in Figure 3. Since it is unlikely to effectively grow foods such as corn on small surfaces within the urban blocks, planting corn was cancelled but it is still possible to grow a great deal of vegetables and fruits. To assess the potential for growing plants in the urban blocks, based on the urban model, it is assumed that there is suitable land for growing crops, but roofs are more proper for growing vegetables. Therefore, all the areas in the city were divided, roofs for vegetables and other surfaces for planting trees. Furthermore, in this study, a number of fruits and vegetables were analyzed in each urban planting on vertical and horizontal surfaces so that a maximum yield is obtained for each hectare. Around 20 types of vegetables from the gourd family and commonly grown in Borujerd, were studied to identify the best plant for urban farming, which saves water, has a shorter statistical growth period and more potential. For this reason, CROPWAT and NETWAT were used. The net demand of watering crops in each phase using CROPWAT & NETWAT have been shown in Table 4.

For the convenience of the calculations, in this study, the total horizontal area for farming was used. Corn was chosen for vertical growing on the fabric surfaces of the buildings. Due to the moderate hot weather in summer, these crops can grow well in Borujerd. However, the presumption is that some certain types of crops are grown in this region. While the green roofs used for urban farming in this study, can sense the heat effects, the temperature in summer, affected by the local climate change, is still high and thus suitable for growing corn. There is no available data on growing corn on urban vertical surfaces. Therefore, as the average yield for the corn crop grown in Borujerd, the yield of 8 t/ha was considered.

With the data and suggestions given above, the total area available for vegetables (roof area) is 731 ha, of which 331 ha is for vegetables with leaves and 400 ha for lettuce. The green areas and some of the enclosed surfaces in the parking spaces of the blocks are used to plant trees (80 ha), Some part of the green area is also used for growing grape (45 ha). The remaining 488 ha area is used to grow corn on vertical surfaces. In the urban software model, the general account of the yield of fruits and vegetables is illustrated in Table 5.

Table 5. The potential yield of fruits and vegetables in the software model.

Crop		Area (ha)	Yield (t/ha)	Potential Yield (t/Year)
Vegetables	Vegetables with leaves	331	30	29,790
	lettuce	400	45	18,000
Fruits	grapes	45	12	540
	apples	80	40	3200

By adding the yield of lettuce and vegetables with leaves, the total annual yield of vegetables, in the software model, is 47,790 t. Furthermore, adding the yield of black figs, grapes and apples, the total potential of fruits in the software model, will be 3740 t. The World Health Organization [40] suggests that each person at least consumes 400 g of fruits and vegetables per day for a healthy diet or 200 g of each separately. Of the total population of 240,654, living in the urban blocks in Borujerd, 16,925 children are under the age of 15 (in 2012) and consume a great deal of food products. Their healthy diet includes both fruits and vegetables, accordingly, the diet required for the population is achieved through equation 2 as follows:

$$F_D = 0.4\ (p) \tag{2}$$

where F_D refers to the daily demand of fruits and vegetables (kg), p is the population of the city, the coefficient 0.4 is the consumed value per capita per day (kg). To achieve the annual values, F_D multiplied by 365 days:

$$F_Y = F_D * 365 \tag{3}$$

where F_Y is the requirement of fruits and vegetables consumed for a single year (kg), F_D is the daily requirement of fruits and vegetables and 365 is the number of the days in a single year. In the software model, the values for consumption and production of fruits and vegetables are given separately, in Figure 5.

According to Table 5, the separate demands for fruits and vegetables are each 17,567.74 t/y. In terms of the urban agricultural products, it seems that the yield in the software model, can supply 21.3% of the annual demand of fruits and 272% of the annual demand of vegetables, locally. In order to offset the 78.71% lack of fruits, the additional production of vegetables with leaves are used for sale and purchase. Furthermore, green roofs can contribute to the cooling down of the temperature during the warm season.

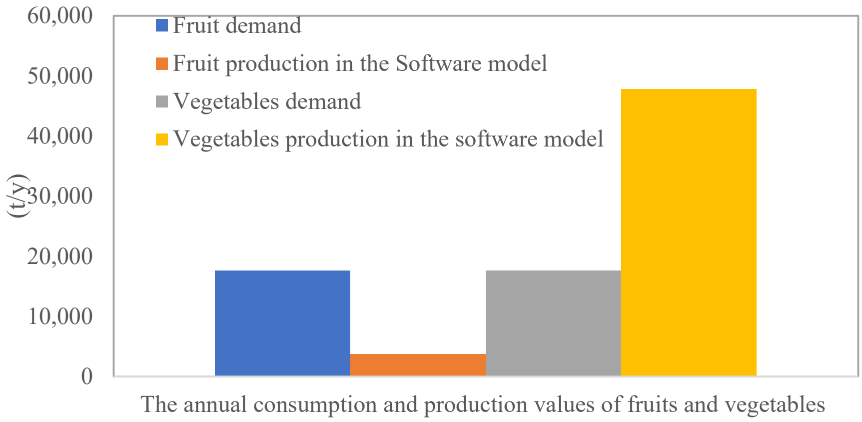

Figure 5. The annual consumption and production values of fruits and vegetables in the urban model of Borujerd for a population of 240,654.

3.3.3. Energy

The annual power consumption, for Borujerd, is 208,321.64 mw/h. It means that on average 116,720 subscribers consume 1.78 MG/h. These values are used for such home applications as hot water supply, freezing, lighting and others. Similar to other cities, as noted earlier, good practice here is the generation of power and biogas from gray silt and urban waste. As presumed, if each person, in the software model of Borujerd, consumes energy as much as what he/she currently uses, it is likely, to some extent, to generate power and energy for the city from the urban waste values. The total urban waste produced in Borujerd is approximately 250 t/day. In other words, the production per capita is 1.03 kg/day. The energy generated from a system for the transformation of waste was estimated to be 250 t/day, the estimated amount of energy produced from the waste is 11,781.1 kj/kg. The amount was measured in two ways: (1) a system combined of fluid-based gas generation, internal combustion system, electrical generator and (2) a system consisting of a combination of urban waste burner, boiler, turbine and electrical generator. With respect to the observations, in these two methods, 6.2 and 5 MW electrical energy was generated, respectively. Given the total electrical energy consumption of 570.7 MW/h in the urban model, it is concluded that around 1.08% of the urban daily energy is likely to be generated from the urban waste.

In this study, a WEF Nexus approach was adopted to investigate the possible connections between water, food, and energy resources in Borujerd, Iran, where the local demand for these resources is increasing because of the growing population. In view of the future climate change, the changing precipitation patterns, and the rise in temperature, the LARS-WG model was used to analyze the future changes. A WEF Nexus approach was taken to study the relations between water, food, and energy. Furthermore, once the two international and national tools of CROPWAT and NETWAT were used to prevent any potential errors and for more precision in doing the tasks, no considerable error was observed, and the margin was tiny.

4. Discussion

In fact, the issue of agriculture is widely acknowledged as a good way to protect food security and resources [41]. Urban agriculture is a kind of harmony and consensus, because green roofs can protect the energy efficiency of the buildings by adding thermal mass, storing rainwater and partially cooling the environment. Moreover, green roofs have a higher life cycle than conventional roofs [42].

According to the above results, it can be concluded that the predicted changes indicate water and temperature changes in the next 20 years and changes in precipitation and temperature can affect water, food and energy sources. Therefore, the necessary measures should be taken to deal with these changes for the coming years so as not to face the problem of a water shortage. In Borujerd, due to the abundance of surface and underground water

(Dasht Silakhor aquifer), there is no new and systematic way to irrigate gardens and crops. Borujerd Water and Sewerage Company collects 22 million cubic meters of water for 240,654 people living in this city. Of this amount of water, 5 million cubic meters are wasted, and the rest is available to citizens. It can be said that each person in Borujerd consumes 196.22 L of water daily, 75% of which is used for siphons, sinks, bathrooms, cooking, etc. If measures are taken to treat black and gray water, the daily wastewater of Borujerd, which is 6.35416 cubic meters per day, can be returned to the water cycle. The total wastewater of the city is 1,275,000 cubic meters per year, and according to its treatment, it is possible to prevent the withdrawal of underground water.

Furthermore, another important resource in Borujerd that has not been exploited is rain. It is possible to consider gable roofs and roofs with a slope angle that is more than 15° to collect rainwater during the rainy season. The total area of these roofs is 136.13 ha and according to the variable average rainfall, which is 0.454 m, this resource can be used to the fullest. The amount of precipitation obtained per year for the city is 612,612.45 cubic meters, which is significant. Hypothetically, it can supply 3.6% of the fresh water supply. Moreover, if the volume of wastewater is considered for treatment, the amount of the available water source reaches 13,362,612.45 cubic meters, which can provide 60.74% of the current water demand.

Using the rainwater means it is treated to become available. In Borujerd, because of the fresh water from the runoff (accounting for 30% of drinking water) and appropriate ground water (supplying around 70% of the urban drinking water), much energy is consumed. Additionally, the urban recycled wastewater is reused for irrigating urban farming after it is treated. Although, in Silakhore plain, Borujerd, aquifers with sufficient water resources are noteworthy because the amount of ground water is adequately high, it should be noted that protecting such resources for a future water shortage is necessary, as concerned with the changes noted earlier and the decreased rainfall.

Moreover, in this city, wastewater is not used as a particular resource while human waste is likely to be used for the generation of biogas and can be stored. In contrast, renewable energy resources such as solar energy, wind, etc., are not storable. Yet, there is no plant, in Borujerd, with the potential of generating biogas. Finally, the concept of the WEF Nexus as an advanced agenda for developing cities and economies is widely applicable to the cities that have advanced contexts, are susceptible and have many potentials.

5. Conclusions

The correlation between water, food, and energy represents, to some extent the complexities, opportunities, and challenges across the different disciplines and sectors. These complexities are not limited to just one sector but the reliance of food, water and energy on the relevant natural resources, makes it necessary to supply human resources for a better human and economic growth. As a result, one or more of the other sectors is affected by the interactions between these resources or affected by even just one of them. A communication approach makes the knowledge investment, the sharing of skills and the expertise relevant for the development of innovative solutions to international complications.

As the heat rises in summer and the temperature increases, green yards may play well with cooling down the air and improving public health, as an adaptation to climate change. As noted earlier, crops need to be planted into integrated networks if urban farming is to be practiced in urban blocks in Borujerd. To do so, it is necessary to conduct bio studies to ensure that crops receive sufficient light, rain, etc. Furthermore, it is possible to absorb rainwater and prevent flooding with an appropriate management of urban agriculture.

In this study, a WEF Nexus approach was adopted to investigate the possible connections between water, food, and energy resources in Borujerd, Iran where the local demand for these resources is increasing, because of the growing population. In view of future climate change, the changing precipitation patterns, and the rise in temperature, the LARS-WG model was used to analyze the future changes. A WEF Nexus approach was taken to study the relations between water, food, and energy. Moreover, once the two international and national tools of CROPWAT and NETWAT were used to prevent any potential error and for more precision in completing the tasks, no considerable error was observed, and the margin was tiny.

Generally, if the approach of the WEF Nexus can be conducted within neighborhoods and blocks, it may be argued that such an approach is extendable to the other cities in the same province or even to the entire country. Although many lessons may be attainable through the present study, this approach is likely to be adopted as a means of determining guidelines, policies, compatibility strategies, fighting climate change and mitigating its impacts in the other cities across the country. Such measures are even capable of reducing or even reversing the impacts of climate change, including local warming and local thermal vapor.

For example, urban agriculture is often formed as a social movement for sustainable communities, in which producers supply organic food and social networks based on the sympathy in the society and the common spirit of nature. Receiving official institutional support, these networks may turn into integrated urban planning initiatives as a movement for sustainable urban development. So, it can help not only to face economic and social problems but also to assist their growing population patterns.

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