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URBAN DEVELOPMENT AND ITS RELATIONSHIP WITH THE WATER CRISIS OVER THE NEXT TWENTY YEARS (2042) IN THE CITY OF ZANJAN, IRAN

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ABSTRACT

Today, urban settlements are at risk of water shortage for various uses due to climate change and rapid population growth. Although this crisis has been considered in urban studies from different aspects, the future effects of urban development patterns on urban water shortage have rarely been investigated. This research aims to identify areas prone to the development of Zanjan city, emphasizing the indicators of the water crisis and the supply of drinking water to the city's population in the future. Currently, the underground water aquifers of Zanjan city supply 46% of its drinking water. In addition, due to the decrease in rainfall and increase in evaporation and air temperature (climate changes), the amount of surface water entering the Teham dam is decreasing. Consequently, Zanjan city becomes gradually dependent on underground water sources. In this research, the population growth trend was studied using the data obtained from the official reports of the Census Center of Iran. Also, the Canadian Water Quality Index (CWQI) method was used to analyze hadrochemical data, and interpolation methods were used in the GIS environment to draw quantitative and qualitative water maps. Based on the maps of the quality, depth, and direction of the underground water flow in the city and its surrounding areas, it is suggested that the western areas are the best place for the city's expansion. Moreover, the best place in the western regions, especially the northwest, was determined to be more suitable for the city's expansion. Overall, the region in the northwest and the model of linear city development were chosen as the optimal region and model, respectively. This decision was made according to the current direction of development and topographical conditions, the analyses performed, and issues related to the water crisis in Zanjan city.

Notably, basic studies are very important in planning water supply for urban populations. The results of these studies play an essential role as basic information in different parts of the project. Furthermore, in the research related to urban design, the most important method of designing the passages for collecting surface water is urban drainage and using the CVF system in collecting surface water.

Keywords: Urban development, population, water quality, water resources

INTRODUCTION

In 2008, the percentage of the urban population exceeded the rural population worldwide [1]. Based on the global urbanization perspective (2018), 55.7% of the world's population lived in urban settlements in 2019. This forecast for 2030 is about 60%. Regarding their nature, cities can greatly impact changing the global environment through social, economic, and biophysical interactions [2]-[3]-[4]-[5].

The dynamics and movements of urban areas affect the natural environment (Inoguchi et al., 1999). Accordingly, the hydrological cycle of urban settlements changes when buildings, asphalt, and concrete are developed instead of natural elements such as vegetation and soil on the ground surface [6]. Movement in urban areas is necessary because of using surface and underground water resources and even rainwater [7]. Urban activities and uses affect water quantity and quality (underground and surface). A noteworthy point in this regard is the direction of urban sewage into the environment, which spreads pollution in the surface and underground waters [8].

The correct management of water resources in urban areas is performed based on the impervious crust created on the city surface, following the surface runoff reduction by increasing the permeability of the soil and filling the phreatic aquifer. This method is highly important for the correct use of rainwater resources to minimize the flow speed due to the runoff and infiltration into the ground, which is caused by proper urban drainage [9].

Although urban settlements account for approximately 2.7% of the world's land area, these settlements use 75% of all materials/goods, services, and energy produced worldwide [10]-[11]. Regarding water consumption, in 2016, about 18% of all freshwater used was consumed in cities [12]. According to forecasts, in 2040, water demand will be 30% more than this amount [13].

Studies about water resources in urban areas focus on the analysis of water supply and quality [14], wastewater management [15], lack of water [16], and Sustainable water supply systems [17]. These cases are usually examined separately [17]. At the same time, cities and their immediate physical environment are part of a complex system with multiple interactions and conflicts [18]. In these systems, physical processes flow from outside to inside and from inside to outside the urban environment based on different interactions [19].

Conservation options for groundwater require understanding the hydrological characteristics of groundwater systems (e.g., scale, hydraulic conductivity, and effective porosity) to predict the transport of contaminants to these sources [20]. Achieving sustainable use of underground water resources in planning for the physical development and expansion of the cities and providing drinking water to the population requires a correct understanding of underground water resources [21]. Understanding this process will help supply water for future cities in both underground and surface water sources for efficient management and sustainable extraction. Moreover, to fulfill underground water stability and availability, we need to understand the characteristics of underground water resources and the contamination process of these water resources.

Such an understanding is required for urban physical development and predicting methods to prevent infiltration of these water resources in line with urban development and population growth [22].

Based on the mentioned points, different urban development patterns are among the indicators representing an increase in urban water demand [23]-[24]. Urban patterns of sparse development can lead to increased water consumption for open spaces, while urban patterns of high-density development led to reduced water consumption in open spaces [25]-[26].

Despite numerous studies regarding water scarcity at different spatial and temporal scales, the important role of different urban development patterns has been less discussed [27]-[28]-[29]. Most of the studies conducted mainly focused on the distribution of water, its availability, and the type of water use [30]-[31]-[32]-[33]. MacDonald et al. (2011) studied the relationship between population growth and climate change on water access for cities in developing countries and its effects [30]. In another study, Li et al. (2020) concluded that both urbanization level and type significantly affect water scarcity. In other words, increased built-up area due to increased water consumption by existing urban structures will deteriorate water scarcity [34].

In the United States, some researchers have examined the relationship between urban sprawl and urban water consumption [35]. Hummel (2020) considers the effects of these two indicators on each other to be more intense in the west and southwest of the United States [36]. For this reason, it is challenging to propose a sustainable approach to reduce future negative consequences on urban water resources [37]-[38].

Therefore, the development and growth of urban areas affect the surrounding natural environment. The hydrological cycle of cities replaces natural elements such as vegetation and soil by changing buildings, asphalt, and concrete. In addition, urban activities lead to water abstraction from the surface and underground water sources and sometimes rainwater [7]. Urban use affects both the quantity and quality of water. For instance, untreated domestic wastewater is released back into the environment in many parts of the world.

Located in a semi-arid area, Iran always faces the risk of permanent water shortage. As a result, over a long time, various methods have been applied to optimize the use of water resources and combat water scarcity. The need for water is a major human need, and water scarcity is considered a serious crisis worldwide. Due to the growing world population, especially in developing countries, and the lack of control over the volume of withdrawals and irregular consumption, this crisis poses a serious threat to species society and people, especially in developing countries. It is not exaggerating to say that the war of the next century will be about water, not oil. On the other hand, one of the most important issues within urban planning concerns the spatial growth and development of cities and patterns. The resulting model of the spatial distribution of human activities in cities is represented in special forms or shapes. The city constantly evolves, depending on the dynamic and changing nature of urban areas. However, large-scale or horizontal expansion is the most unsustainable and unfavorable form of the city ever known. The main goal of this research is to analyze the quality of surface and underground water resources and their impact on urban development and water supply to the population of Zanjan (the capital of Zanjan province, Iran) until 2042.

2. METHODS

This study uses reliable reports from the Census Center to investigate the population growth trend. Canadian Water Quality Index (CWQI) method was used to analyze hydrochemical data. Also, interpolation methods are used in ArcGIS software to draw quantitative and qualitative water maps.

The increasing growth of population, cities, and industries in the last few decades has led to several factors in the field of water, including the increase in demand, the decrease in the amount of surface and underground water, and the increase in pollution of existing water resources. Therefore, estimating the impact of city expansion on the quality of existing water resources, especially in the field of drinking, is essential in making decisions and planning for sustainable development in the future. Currently, about 60% of the water consumed in Zanjan city is supplied from the underground water sources of Zanjan plain. Therefore, to determine the effect of the development of Zanjan city on the quality of underground water, it is tried to investigate the process of changes in the development of Zanjan city and the quality of underground water for drinking purposes simultaneously. Also, since the industries concentrated around the city of Zanjan supply more than 90% of their water needs from underground and drinkable water, the depth of underground water decreases by more than 1 m every year [39]. Canadian Water Quality Index (CWQI) has been used to estimate groundwater quality as one of the most widely used and reliable water quality index methods [40]. United Nations Environmental Program (UNEP) approves the CWQI index as a suitable model for rating the quality of drinking water in the world [41]. In the CWQI index, three factors should be calculated, each varying between 0 and 100. Factor 1 (scope) is expressed as follows:

$$F_1 = \left[\frac{\text{Number of failed variables}}{\text{Total number of variables}}\right] \times 100 \quad (1)$$

This formula produces values between zero and 100, with values close to zero indicating poor water quality and values close to 100 indicating excellent water quality. Water quality is classified as follows: 95-100 Excellent, 80-94 good, 65-79 average, 45-65 inadequate, and 0-44 poor (Lubm et al., 2011).

$$F_2 = \left[\frac{\text{Number of failed tests}}{\text{Total number of tests}}\right] \times 100 \quad (2)$$

And factor 3 (amplitude) is calculated in three steps, which are:

(a) The number of times in which a specific concentration is greater (or smaller, when the desired value is minimum) than the desired value, which is referred to as an excursion and is calculated as follows. When the test value should not be greater than the desired value:

$$\text{excursion}_\text{i} = \left[\frac{\text{Failed test value}_\text{i}}{\text{Objective}_\text{j}}\right] - 1 \quad (3)$$

When the test value should not be smaller than the desired value:

$$\text{excursion}_\text{i} = \left[\frac{\text{Objective}_\text{j}}{\text{Failed test value}_\text{i}}\right] - 1 \quad (4)$$

(b) the amount of the set in which certain tests are outside the optimal limit and is calculated as follows:

$$\text{nse} = \frac{\sum_{i=1}^{n} \text{excursion}_\text{i}}{\text{Total number of tests}} \quad (5)$$

(c) Then we calculate by the following asymptotic function that normalizes between zero and 100:

$$F_3 = \left[\frac{\text{nse}}{0.01\ \text{nse} + 0.01}\right] \quad (6)$$

Finally, the value of CQWI is calculated as follows:

$$\text{CWQI} = 100 - \left[\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right] \quad (7)$$

3. DISCUSSION

3.1. Separation of the share of surface and underground water consumption in Zanjan city

The analysis of the statistics related to the sources of water consumption in Zanjan city in the years 2020, 2021, and 2022 shows that 54% of the total water produced for consumption in Zanjan city comes from

Tehm Dam, and the remaining 46% comes from the plain's underground water (Figs. 1 and 2). Therefore, the role of underground water in the supply of drinking water in Zanjan city is very key and important. Further, to prevent a future water crisis in Zanjan, it is necessary to study the number of reserves of the mentioned resources and the process of their changes in recent years. Accordingly, more knowledge is gained about their condition to manage the city's water consumption more efficiently.

The interesting point of the graph shown in Fig. 1 is that in these three years, the amount of total produced water and the water produced by Teham Dam has decreased over time. On the other hand, some measures have been taken to be compensated by overtaking underground water. Therefore, there is no doubt that in the future, underground water will play a more important role as a source of drinking water in Zanjan city.

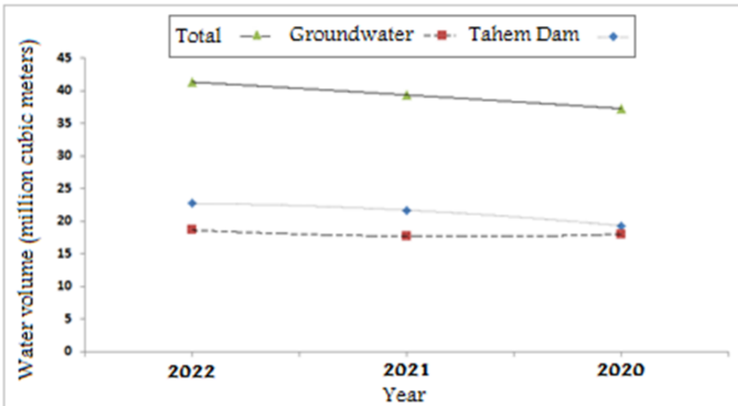

Figure. 1. The annual amount of underground water, surface water (from Tohtam dam), and total water production for Zanjan city

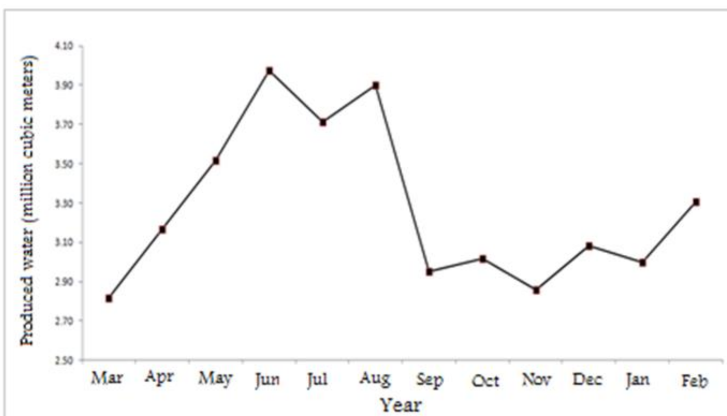

Figure. 2. The monthly average amount of total water production for Zanjan city in the years 2020 to 2022

The monthly water consumption in Zanjan city shows that the highest consumption is in three hot months, i.e., July, August, and September. Therefore, it is necessary to make more plans based on these three months because the water crisis will be severe during these months. On the other hand, the underground water level and the level of Teham dam in summer decreases due to lack of rain, a strong increase in evaporation and harvest. Now, it is necessary to find a balance between the increase in consumption in these months. In this respect, the decrease in available water resources in the same months requires studying how consumption increases and how the resources decrease. One of the important factors affecting water resources is climate change. Thus, how the precipitation and temperature changes in the region are studied in the following.

3.2. Climate changes in the region

Studying the extent of climate changes in the region requires investigating its trends of rainfall and temperature changes, as two important factors affecting water storage, consumption, and demand. Since the study area experiences severe climate changes, the annual precipitation shows a descending trend but the temperature and evaporation increase. For example, in Qara Bolag station, the trend of decreasing rainfall from 2018-2021 to 2020-2022 has a negative slope of 1.1. Also, in Sarmsaqlo station, the slope of this decreasing trend is negative (i.e., 0.28). As a result, it is inferred that severe droughts have occurred in the water years 2011-2015 and 2015-2020 in the region. It is of note that in these dry years, the evaporation rate, i.e., the loss of water, has been higher than what is available to humans, leading to an increase in the negative results of drought. Based on the data of Sarmsaqlo station, the evaporation rate is increasing with a slope of about 4. In addition to evaporation, the air temperature has also increased, which makes the situation worse. In Sarmsaqlo station, the minimum and maximum annual temperature increase with a slope of 0.008 and 0.11, respectively.

Therefore, climate change has worked to reduce the available water in the region (due to the decrease in precipitation and increase in evaporation) on the one hand and increase the need for water consumption (increase in temperature) on the other hand. Besides, the increase in population, especially the urban population, has caused a sharp increase in the need for water consumption. Therefore, the situation requires different specialists in water resources and urban planning to work together to manage and plan to control the optimal consumption of Zanjan city. To achieve this goal, here, the changes in water sources supplying water in Zanjan city are studied (Tahem Dam and underground water), followed by comparing water consumption per capita in Zanjan city with the standard values to identify water crises.

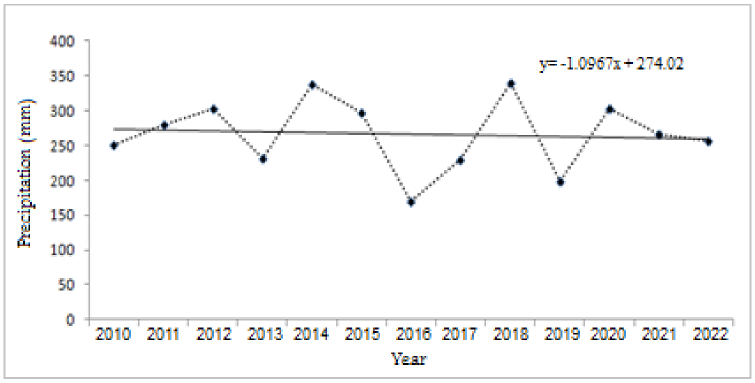

Figure. 3. Average annual rainfall of Qara-Balaghi station

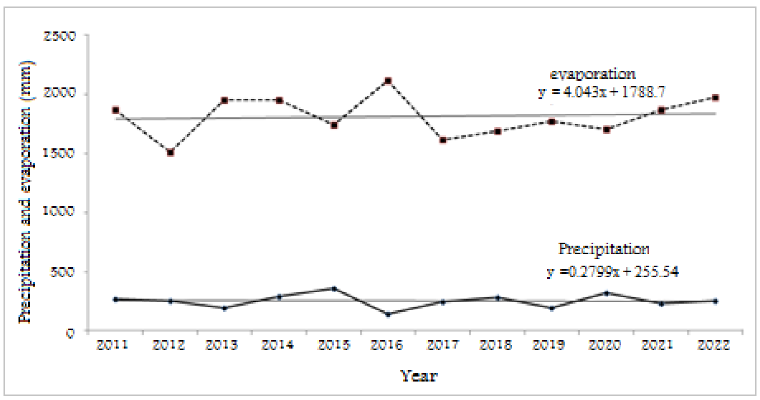

Figure. 4. Average annual precipitation and evaporation and transpiration for Sarmsaqlo station

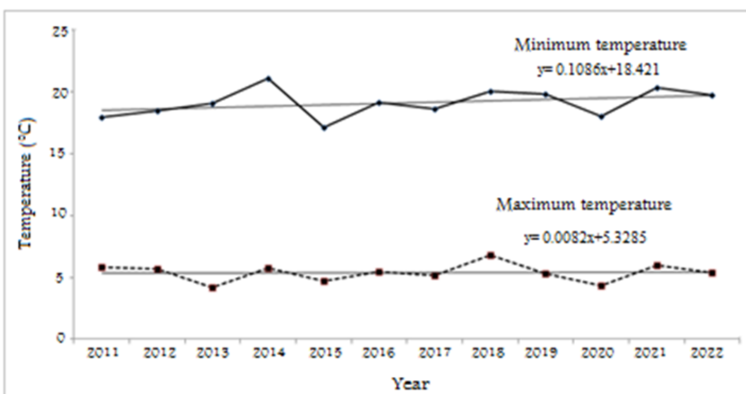

Figure. 5. Average annual minimum and maximum temperature for Sarmsaqlo station

3.3. Reduction of incoming water to Teham Dam

Teham dam acts as the only current source of surface water for Zanjan city's drinking water supply and provides about 56% of the city's drinking water. Therefore, the condition of the water entering it should be addressed to predict the available water for the future of the city. In this regard, due to climate change and a decrease in rainfall, the amount of flow entering the dam will definitely decrease in the future. To deal with this issue, we first investigate the trend of the changes in the flow entering the dam through the Tehm Chai River for the statistical period of 1980 to 2011. As shown in Fig. 6, the river discharge has a very strong decreasing trend, especially from 1998 until now. Accordingly, in this statistical period, the river discharge has decreased by about 47,000,000 m^3, indicating a water crisis can. Hence, proper planning should be provided for it; otherwise, the amount of inflow will greatly decline, and the dam will not be able to supply drinking water to the city. If this happens, it is necessary to think about other alternatives to supply the 54% provided by Teham dam.

Figure. 6. Location of Teham Dam and Zanjan River in relation to Zanjan city

Based on the mentioned points, the relevant authorities should make a proper plan to identify the factors affecting the flow of the Tehm Chai River. Some Solutions for this purpose are adequate drainage of the upstream areas of Teham Dam, preventing digging deep wells for agriculture, and preventing industries from using potable underground and surface water. Overall, this decreasing trend of the river flow must be stopped; otherwise, the city of Zanjan will be destroyed.

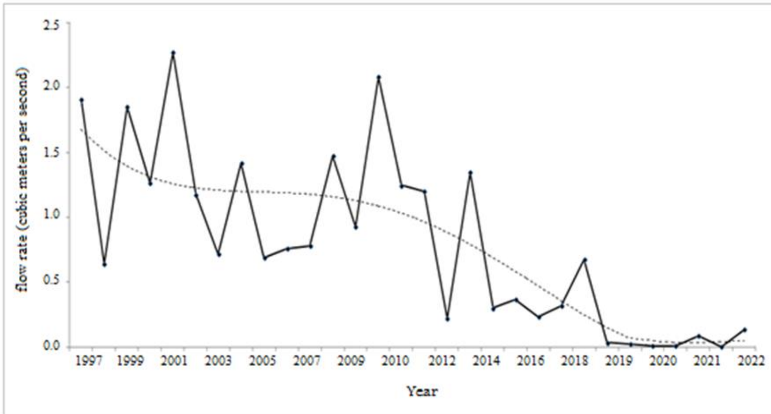

Figure. 7. Changes in Teham Chay river discharge from 1997 to 2022 (a 47,000,000 m^3 reduction in long-term river discharge) (Report of Zanjan Regional Water Company, 2022)

3.4. Reducing the volume of underground water in Zanjan plain aquifer

Currently, the underground water of Zanjan city provides an average of about 46% of the drinking water of Zanjan city. Besides, due to the decrease in precipitation and the increase in evaporation and air temperature, the amount of surface water entering the Teham dam is decreasing. These factors will intensify the dependence of Zanjan city on underground water resources.

Therefore, it is essential to know the amount of water available for the present and future to plan and deal with the water crisis properly. According to Fig. 8, the dynamic volume of the Zanjan Plain aquifer is decreasing drastically due to the decrease in rainfall in recent years and excessive harvesting by exploitation wells for agricultural, drinking, and industrial purposes. The amount of water table decrease from 2002 to 2022 (20-year return) was about 12.5 m. This value means that the underground water table level in Zanjan Plain has decreased by about 70 cm every year. Thus, in the coming years, the amount of underground water available for drinking will decrease unless serious and regular decisions are taken to restore it and reduce its extraction. Fig. 9 shows the trend of water level changes in the piezometer of Zakir lands in the middle of Zanjan Plain. The curve has a strong decreasing trend with a negative slope of 0.18. It is noteworthy that the reduction of the underground water level and the reduction of the volume of available water will cause the extraction of underground water from deeper depths. For this purpose, it is required to dig the wells deeper, thereby consuming more energy to extract and transport water.

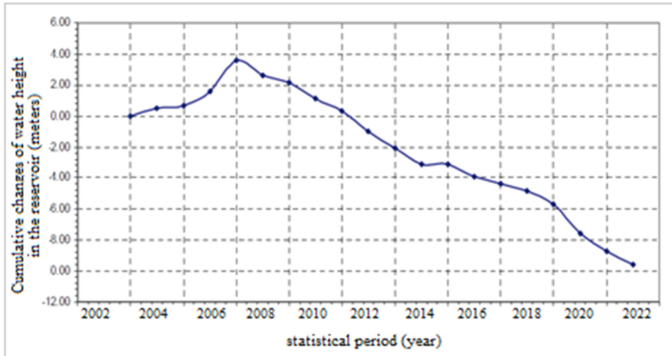

Figure. 8. Hydrograph of the underground water unit of Zanjan Plain from 2002 to 2022

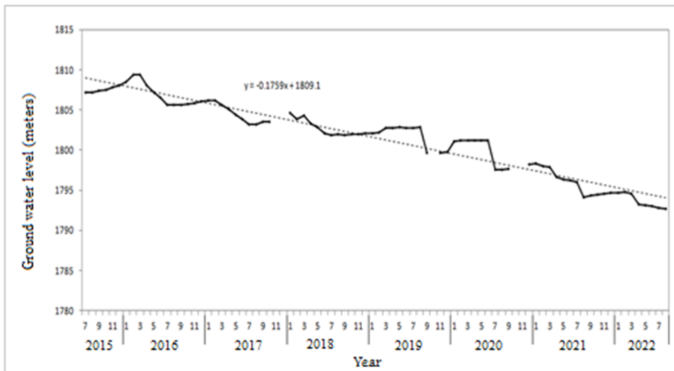

Figure. 9. Water level changes in one of the piezometers of plain Zanjan

3.5. Forecasting the amount of water consumption in Zanjan until 2042 based on the standard

To have proper and optimal planning and to prevent the creation of a water crisis in Zanjan city, we used the standards of water consumption in different household sectors (Table 1), the amount of green space in Zanjan city, and the amount of water consumed in Zanjan city until 2042. For the amount of general, commercial, and industrial consumption and water losses, the per capita consumption table values approved by Zanjan city were used. As Fig. 10 shows, if water is consumed according to the standard table in Zanjan city, without considering the green space, the amount of water needed in 2015 will be around 30,000,000 m^3. Besides, if we consider the green space, this amount will reach 35,000,000 m^3. Due to population growth, these values increase to 32,000,000 m^3 and 46,000,000 m^3, respectively, without considering the green space and with the inclusion of the green space in 2042. Currently, the volume of water consumed in Zanjan city is about 39,000,000 m^3 annually, which is 9,000,000 m^3 more than the city's water consumption in 2015 in accordance with the standard conditions. In other words, the citizens of Zanjani consume about 33% more than the standard amount of water per year (Regional Water Company of Zanjan Report, 2022). Notably, since the region's climate is cold, water consumption should be reduced compared to the standard because using cooling devices in Zanjan city is required for a limited period of the year.

Table 1. The standard for different domestic uses of water

type	*consumption (liters per day per person)*
bathing	43
wash basin	26
Cleaning and watering the garden	8.5
Cooler and ventilation	4.5
laundry	17.5
drinking	4.5
Cooking	13
dish washing	13
Total	130

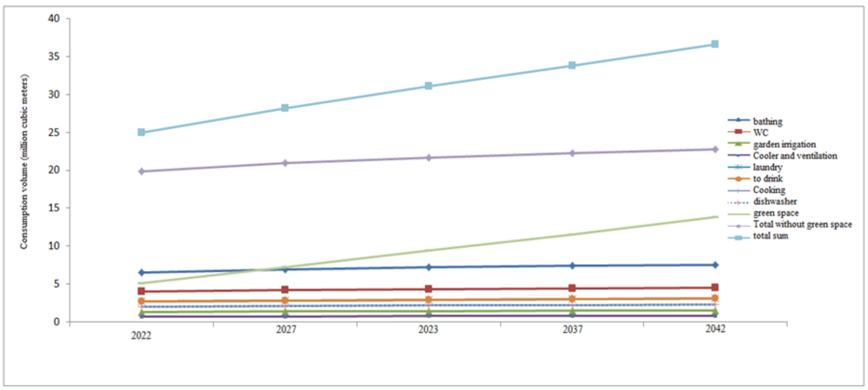

Figure. 10. The amount of different expenses for the city of Zanjan based on the standard of household expenses and the area of green spaces of the city until 2042

3.6. Suggested scenarios to reduce water

To reduce water consumption in Zanjan city, two scenarios are presented to reduce water consumption based on the standard tables mentioned. In this way, it is possible to achieve the most optimal areas for urban development and planning in comprehensive and detailed plans.

The scenario of recycling water used for bathing (scenario 1):

In urban studies, it is essential to determine the consumption in different categories to know the volume of water consumption due to the crisis created by this resource at national and provincial levels. As it is clear in the standard table, 43 liters (33%) of water consumed daily is dedicated to bathing. Now, if part or all of the water consumed for bathing is recycled or reused, the consumption per capita will decrease sharply. Accordingly, the first scenario to reduce water consumption is dedicated to reusing bathing water. Therefore, it is suggested to take 26 liters of water needed for the washroom and toilet from the bath water during the first scenario. As a result, the water required for daily consumption can be reduced from 130 to 104 liters per day. Now, considering the annual population of Zanjan and implementing this scenario, the amount of water consumed in Zanjan will decrease by about 4.5,000,000 m^3. Therefore, implementing this scenario will give the planners a general view that urban development is closely related to the densities and development of different urban areas. Hence, this scenario might be very effective in this field.

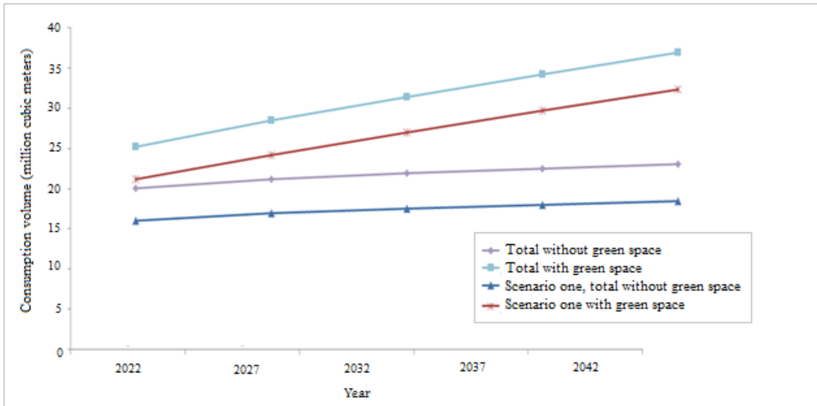

Figure. 11. The scenario of recycling water used for bathing (Scenario 1)

The scenario of using runoff to clean and irrigate the garden (scenario 2)

In the standard table, the daily amount of water required for cleaning and watering the garden is 8.5 liters per person. In Scenario 2, it is suggested to supply this water by collecting runoff from the roofs and streets of the city. According to the average annual rainfall of Zanjan city (about 300 mm), the area of residential areas (which have impermeable roofs), and the runoff coefficient of 50%, the annual runoff production of Zanjan city was determined to be about 1.5,000,000 m^3. Storing this amount of water in special tankers or underground ponds in the yards of houses and using it for watering and cleaning the garden, the per capita consumption of the city can be reduced by 1.5,000,000 m^3 annually. Therefore, this scenario can also be useful.

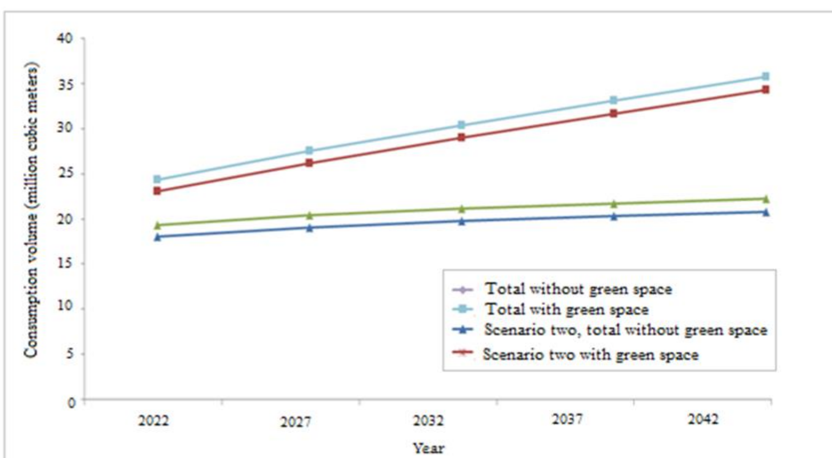

Figure. 12. The scenario of using runoff to clean and irrigate the garden (Scenario 2)

3.7. The sum of scenario one and two

According to the above information, if it is possible to use both methods in Zanjan, water consumption will be reduced by about 6,000,000 m^3 annually. In the long term (e.g., a 20-year period), this figure will be very large (about 120,000,000 m^3). For example, for the year 2042, when the consumption is based on the standard, the saving rate will decrease by 24% by implementing these scenarios, which can be a good key to eliminating the urban water crisis

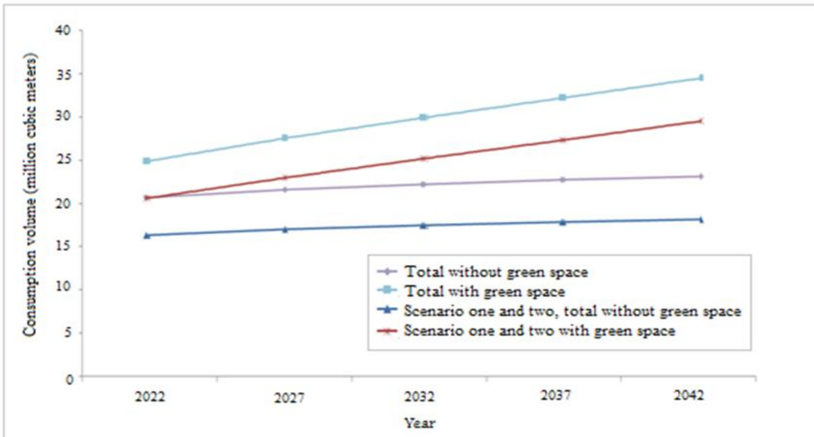

Figure. 13. Diagram of water consumption volume of Zanjan city until 1415 according to global consumption standard

3.8. Zanjan plain underground water quality zoning

Since about 46% of the water consumed in Zanjan city is supplied from the underground water of the Zanjan Plain, and on the other hand, the dependence on this resource is increasing day by day. In this study, the quality of underground water in Zanjan city was mapped based on the quality data. To this end, the underground water of Zanjan regional water should be investigated from 2002 to 2022. Canadian water quality index, EC, pH, and calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and potassium ions were used to calculate the quality of underground water. After calculating the Canadian index of water quality at the sampling points, a zonal map of the underground water quality was prepared in the GIS software using the inverse distance weighting (IDW) interpolation method (Fig. 14). As shown in Fig. 15, the quality of underground water in the drinking wells of Zanjan city, which supplies the water needed by the citizens, has an inappropriate class in the western area of Zanjan city and an acceptable class in the central and eastern areas of the city. Therefore, based on this map, the expansion of Zanjan city to the east should be avoided to prevent the destruction of the good quality underground water in the eastern areas of Zanjan city. The explanation is that the city's expansion will destroy the water quality due to the production of sewage and its infiltration into the underground water. Therefore, it is recommended to expand the city to areas with the worst possible quality in terms of hydrochemistry to prevent further damage to the existing water sources. Hence, it is recommended to expand the city to the west, which has poor-quality underground water. However, this proposal will not be accepted unless the underground water in these areas has a greater depth. For this purpose, it was tried to prepare the depth of the underground water in the next part of the map (Fig. 14).

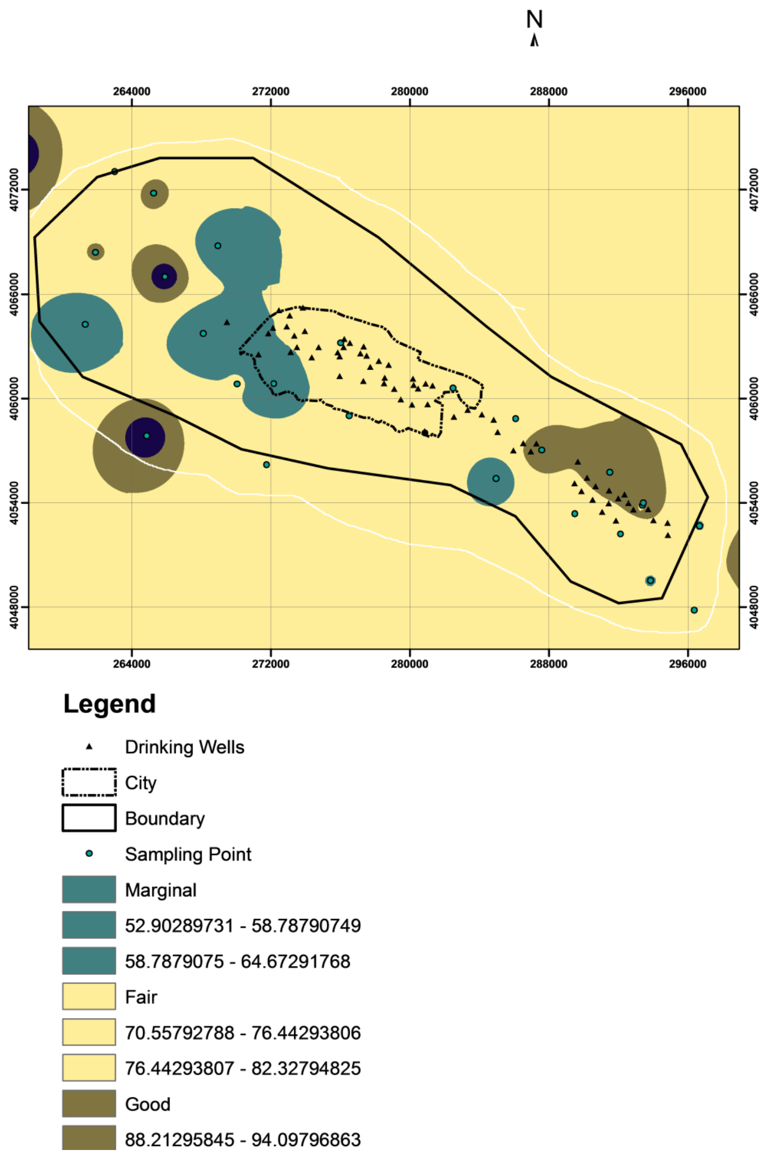

Figure. 14. Zoning of underground water quality in Zanjan Plain

3.9. Zanjan plain underground water depth map zoning

The greater the depth of the underground water in the cities, the more appropriate it is to be immune from the destructive role of the city on the quality of the underground water. The reason is that when the water is deeper, a smaller amount of urban pollutants enter it. In this study, the data of the water depth measured in Zanjan plain piezometers for June 2021 were used to determine whether the depth of underground water in Zanjan city and its surrounding areas is deep enough. The water depth was interpolated using the IDW method in the GIS environment. The resulting map (Fig. 15) shows that the water depth is greater in the blue areas, and the water is closer to the ground in the red areas. Fortunately, the depth of underground water in the western areas is deeper, especially in the northwest of Zanjan, which was found to be of poor quality in the water quality section. This higher depth confirms that expanding the city toward the western, especially the northwestern areas, will play a destructive role and has less impact on groundwater quality. Therefore, this area is suitable for developing the city and the industrial units that might produce more wastewater

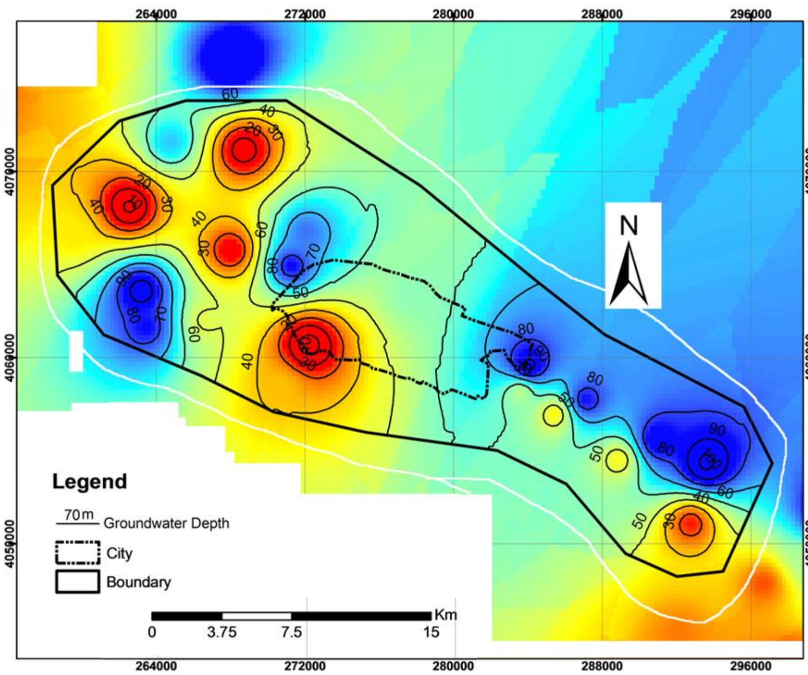

Figure. 15. Zanjan plain underground water depth map zoning

3.10. General water flow direction map of Zanjan Plain underground water

The direction of the underground water flow is also effective in designing suitable places for the expansion of the city because if the upstream is polluted, the underground water flow can cause the said pollution to be transferred to other areas. Therefore, it is necessary to consider the areas downstream of the underground water to expand the city. In this study, a flow direction map was drawn based on water level data and their interpolation in GIS using the kriging method. Fortunately, the contaminated areas of the underground water in Zanjan Plain and the area around the city of Zanjan are located downstream of the underground water. In this respect, comparing the map of underground water quality and flow direction reveals that the eastern areas of the plain (which have good quality water) are in the upper reaches, and the western areas (which have poor quality water) are in the western area. Accordingly, concerning the direction of the underground water flow, the city should be expanded toward the west to reduce the pollution caused by water on the underground water resources.

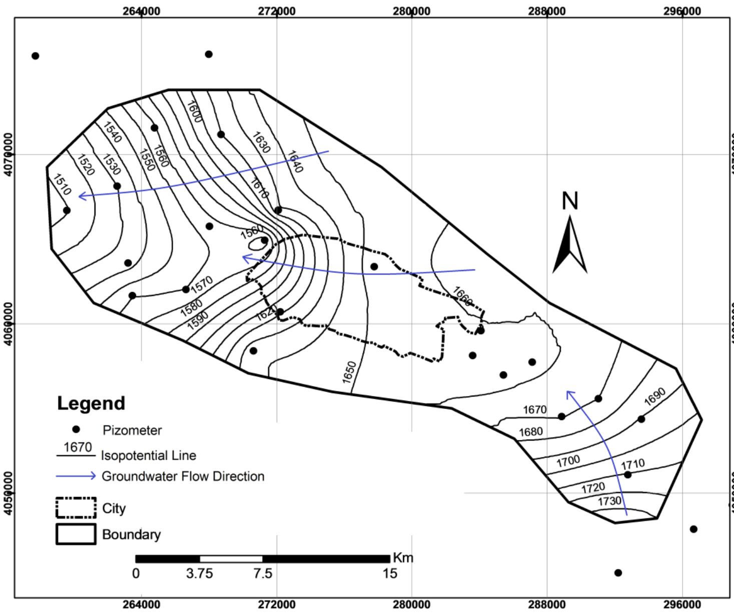

Figure. 16. Map of the direction of the general water flow of Zanjan plain underground water

3.11. Conclusion

In this article, the main themes of urban water sustainability from 2000 to 2042 were identified. Considering the speed of urbanization and population growth, urban planning and sustainable management of water resources seem to be more critical. This study was conducted to investigate the relationship between urban development and the water crisis in the future in Zanjan city and introduce the urban development path. After the surveys conducted on water resources, water quality, urban population, and water consumption in Zanjan city, we determined the development paths for the expansion of Zanjan city in the western parts. Based on the obtained results, a better understanding of the factors that reduce water scarcity conditions in the future can help local and regional planners identify policy solutions that lead to more efficient water use.

Focusing on water resources reveals an interplay between key issues related to the natural water cycle, ecosystem services, and water quantity and quality. These issues describe the conditions of water resources and their environment. Urban water flow represents the interaction relationship between water supply, water use, and water quantity and quality. These factors show the pressure on water resources due to all human activities' increasing demand for water. Water equity represents the interplay between water supply, sanitation, service costs, and water-related conflicts. They are linked to the quality of life of citizens and their surroundings. In addition, water governance and financing represent the interplay between water management, investment in water issues, water service costs, and water-related conflicts and tie with the actors responsible for it.

Our approach contributes to informed decisions about water resources at the urban level by understanding that every decision made in cities directly impacts many issues. Our new operational approach presents six challenges to urban water management that stakeholders must address in the pursuit of urban sustainability:

1) Make informed and equitable decisions about water management at the urban level, 2) Recognize and integrate and/or restore water-related ecosystem services at the urban level, 3) Ensure the quality and quantity of water resources and water supplied and used, 4) Maintain and improve supporting green and green spaces, 5) Ensure public and social health and welfare of the people, and 6) Prevent and manage conflicts over water resources.

The results show that urban development in the western parts can be the best option for expanding the city. Since this area has low-quality underground water, it prevents the contamination of underground potable water in the northern and eastern parts of Qazar city. Also, this area has more suitable conditions in terms of surface water drainage.

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