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Examining Drinking Water Security in Rural Areas of Iran: Perspectives from a Quantitative Analysis

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Abstract

Water is one of the basic needs of individuals and communities. In a way, without it, the growth and sustainability of societies is not possible. In recent decades, due to the effects of climate change and human activities, many parts of the world have faced water-related crises. Hence, this issue has jeopardized the sustainability of villages, especially in developing countries. Therefore, the purpose of this study is to quantify drinking water security in rural areas of Iran during the years 2013-2019. For this purpose, this paper has developed a rural water security assessment framework with four dimensions and ten indicators. The scale of the rural water security index is between 1 and 5. Based on findings, three dimensions: "availability", "accessibility" and "water health and sanitation", all show an upward trend, reflecting an overall improvement of water-related infrastructure in rural areas. Whereas the "economic value of water" dimension depicts a steady trend. Also, for the period of 2013-2019, the results show the improvement of rural drinking water security in Iran.

Keywords: Water Security, Rural Areas, Water Resource, Iran.

1. Introduction

Approximately 40% of the world's population suffers from water scarcity, so the need to manage water resources is essential (Larsen and Drews, 2019). Ensuring permanent access to water has become difficult due to global developments in today's economy, climate change and its consequences on the economies of communities (Hope et al., 2012). Water provides a wide range of production opportunities, so the use of water in agriculture and industry can be recognized as a driver of economic growth. But hydroclimatic events such as droughts and floods can lead to a reduction in GDP, and have significant economic and social effects on a country (Grey and Sadoff, 2006). Water is the center of human security. How to manage water will have an impact on almost every aspect of human security, which is why achieving adequate water security is one of the top priorities of governments around the world (Babel and Shinde, 2018).

Water security is a concept first introduced in the 1940s. Water security is not only directly related to food, energy, economic and environmental security, but also plays an important role in providing military security (Cook and Bakker, 2012; Bolognesi and Kluser, 2018). Water security is an emerging concept and there is still no single definition for it. Instead, there are different definitions that often follow the debate, and so its concept is evolving. For example, water security can be defined as access to sufficient water of suitable quality at all times to meet a variety of needs (Singh, 2017; Yomo et al., 2019). Also, (Grey and Sadoff, 2007) defined water security as “the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies.”

Iran is one of the developing countries experiencing serious water problems. Frequent droughts combined with over-exploitation of surface water and groundwater have raised the country's water situation to a critical level. This has been accompanied by the drying up of lakes, rivers and wetlands, declining groundwater levels, and land subsidence. Rapid population growth, followed by increased water demand, as well as climate change and drought, are among Iran's major water problems (Madani et al., 2016). Thus due to the problems related to Iran's water resources, water security analysis is considered important. Therefore, this article provides a quantitative assessment of drinking water security in rural areas of Iran for the period 2013-2019. Therefore, the structure of the paper is as follows. Section 2 contains a literature review. Section 3 discusses the data and methodology used for inferring ten indicators as well as an integrated index for rural water security. Results are shown and discussed in Section 4. Finally, Section 5 briefly summarizes the main findings of this study.

2. Literature review

Over the past twenty years, water security has received more attention as an important concept in studies and discussions. Therefore, several studies have examined and evaluated water security. Water security studies can be divided into three groups. The first group are studies that have examined water security at the regional or basin scale. For example, (Babel and Shinde, 2018) examined water security at the basin scale. To identify the dimensions and indicators of water security, the DPSIR framework (driving force-pressure-state-impact-response) has been used and five dimensions were introduced-water availability, water productivity, watershed health, water-induced disasters, and water governance. Li et al., assessed water security for 17 basins in the three regions of Gansu Province in China (Yellow River, Yangtze River, and inland rivers). In this study, researchers used multistage integrated water security assessment[1]. The findings indicate that the water security shifted from the security grade of the Yangtze River region to the insecure grade of the inland river region (Li et al., 2019). Layani and Bakhshoodeh simulated the behavior of the water resources system in Iran’s Kowsar Dam Basin using the system dynamics approach in the period 2018-2030. The research results show that the amount of available water resources will decrease during the simulation period. But the demand for water, which is directly affected by population growth, is increasing (Layani and Bakhshoodeh, 2019). In this study, the water security index is the ratio of water storage to water demand. Findings indicate that in the early years, the water security index is in a better condition, but it is expected to reach less than one in the final years. More related studies are (Wegerich et al., 2015; Li et al., 2017; Gong et al., 2017; Qin et al., 2019; D'ambrosio et al., 2020; Zhang et al., 2021).

The second group are studies that evaluate rural and urban water security. Bin et al., evaluated rural drinking water security in Yunnan Province. They built the fuzzy matter-element model based on the entropy weight, combining entropy theory with fuzzy matter-element. The results show that the rural drinking water security in Yunnan is low. (Bin et al., 2012). Khan et al., calculated the urban water security index in Islamabad, Pakistan. The introduced index has five dimensions (water supply, sanitation and health, water economy, environment and ecosystem, society and governance), eleven indicators and 22 variables. The water security scale introduced is from one to five. Findings show that Islamabad urban water security index is 2.8. This result shows that the city has a relatively satisfactory environment for water security (Khan et al., 2020). Babel et al., developed a water security assessment using an indicator-based approach in Bangkok, Thailand (Babel et al., 2020).

In this study, the introduced water security assessment framework has five dimensions (water supply and sanitation, water productivity, water-related disasters, water environment, water governance), twelve indicators and a number of variables to quantify the indicators. The water security scale is from one to five. According to results, water security index for Bangkok is 3.64 in 2015. This means that water security in this city is very good. In this regard, there are similar studies, such as (Romero-Lankao and Gnatz, 2016; Shrestha et al., 2018; Hoekstra et al., 2018; Jensen and Wu, 2018; Allan et al., 2018; Ray and Shaw, 2019; Yomo et al., 2019; Aboelnga et al., 2019; Chang and Zhu, 2020; Zhu and Chang, 2020).

Finally, the third group examined water security at the national level. Su et al., evaluated and simulated the

[1] Multistage Integrated Water Security Assessment (MIWSA)

scenarios of the water security system in Japan. Water security system consists of three subsystems of water resources, water environment and water disasters. In this study, a set pair analysis method is used to evaluate the water security system. The results show that the water security system in Japan is in good condition (Su et al., 2019). Wang et al., assessed water security in 5 Central Asian countries (Uzbekistan, Kyrgyzstan, Tajikistan, Kazakhstan and Turkmenistan). The results show that the degree of water security in Kazakhstan is high and water security in Kyrgyzstan, Tajikistan and Turkmenistan is at a safe level, but Uzbekistan is under pressure in terms of water security (Wang et al., 2020). Other studies in this group include (Jiang, 2015; Gain et al., 2016). According to previous studies, data related to urban and rural water security is collected from a city or village but the current study is the first to generalize and apply the described type of indicator-based approach to the national level. Also in this study, it is the first time that rural drinking water security is assessed for Iran as a whole.

3. Materials and Methods

3.1. Case study

Iran is a country in West Asia and is located between 44° to 63° East in longitude and 25° and 40° North in latitude and has a total area of 1648000 km^2 (Abbaspour et al., 2009) (Fig. 1). Iran has 31 provinces and the population of Iran was about 83 million in the year 2019 and it is the world's 17th most populous country. According to United Nations statistics, in 2018, about 75% of Iran's population is urbanist and 25% of the population lives in rural areas (Fig. 2).

Fig. 1. The map of Iran country

The climate of Iran is relatively heterogeneous. There are different types of climate in Iran, 35.5% hyper-arid, 29.3% arid, 20.2% semi-arid, 5% Mediterranean and 10% wet (of the cold mountainous type) (Amiri and Eslamian, 2010). So, Iran’s climate is mainly arid or semiarid (Sodoudi et al., 2010). Rainfall in Iran varies from less than 50 mm to more than 1000 mm per year and the average annual rainfall in Iran is 260 mm, so that the rainfall in most parts of the country is less than 100 mm. Therefore, due to lack of rainfall and frequent droughts, about 85% of Iran's soil is dry (Karimi et al., 2018; Madani et al., 2016).

3.2. Quantitative assessment of Iran’s rural water security

Fig. 3 shows how the indicators and variables relate to the rural drinking water security index in Iran. The framework is comprised of four dimensions, namely availability, accessibility, water health and sanitation, and economic value of water.

3.2.1. Availability

Availability is a dimension that indicates the availability of people’s access to different types of water available for daily activities. Hence, water availability includes both groundwater and surface water resources. It seems that the per capita water supply is perhaps the best and most accurate way to measure this dimension (Lawrence et al., 2002). So the more access to water resources, the better the water security situation (Hailu et al., 2020). In this paper Iran’s performance on the availability dimension is measured by the following three indicators:

- Rural population covered by water
- Volume of surface water
- Groundwater volume

The higher the rural population covered by water, the volume of surface water and the volume of groundwater, the higher the availability rank.

3.2.2. Accessibility

The second dimension is accessibility. This index shows the villagers' access to enough water, because there is sufficient water availability in many rural areas, but the residents of the area do not have enough water. When rural areas have water security, not only do residents have access to available water, but also, water reaches them through piping network (Aboelnga et al., 2019; Khan et al., 2020). In this study, Iran’s performance on the accessibility dimension is measured by the following two indicators:

- Number of household water subscribers
- The length of the water distribution network

3.2.3. Water health and sanitation

Water health and sanitation is the third dimension. The reason for choosing this index is that there is a relationship between water supply, water health and sanitation. For example, a rural area may have tap water but no sanitation, which can lead to outbreaks of water-borne diseases. One of the variables to measure this

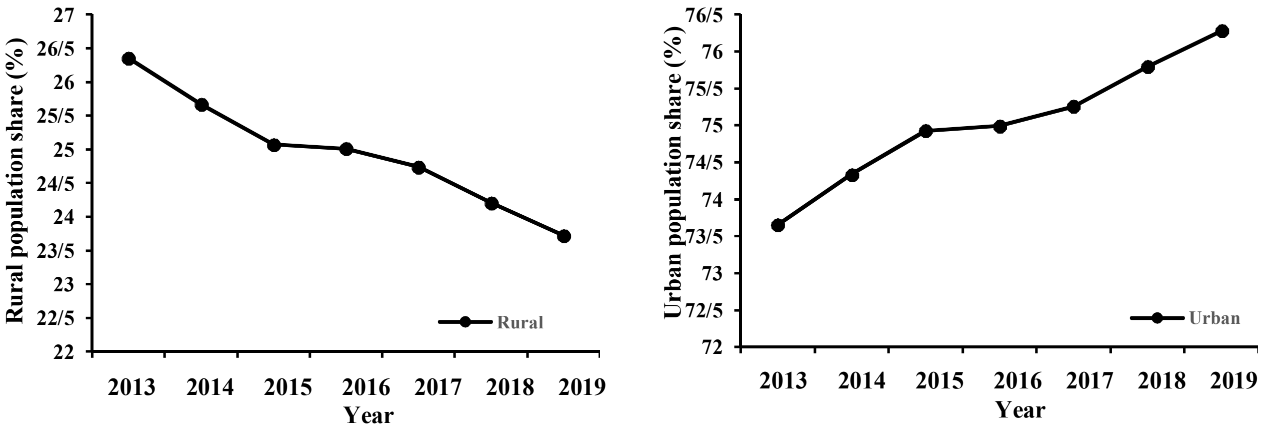

Fig. 2. The share of urban and rural population in the total population of Iran, Source: World Bank

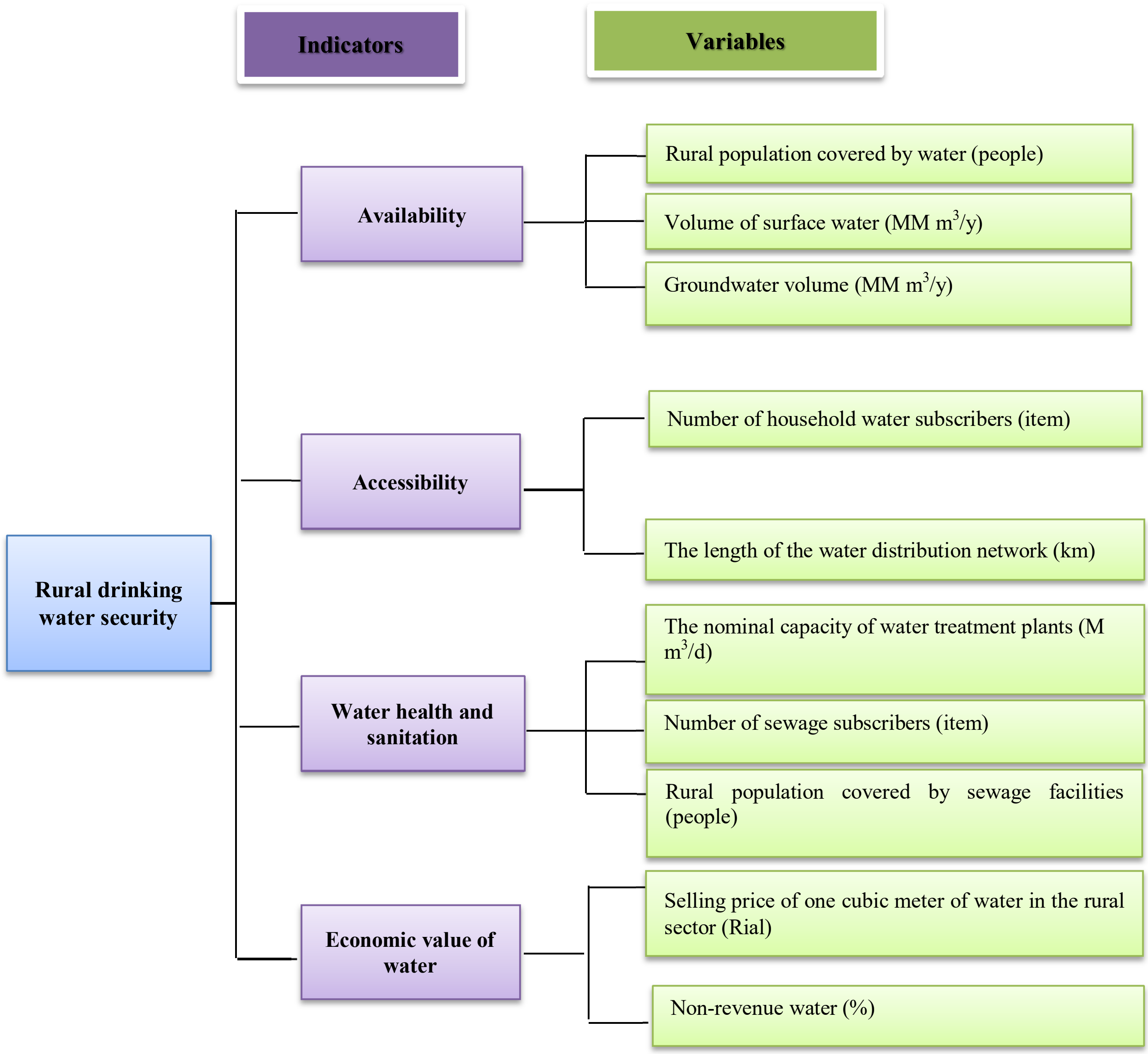

Fig. 3. Rural water security index framework. Source: authors' compilation

index is rural population covered by sewage facilities (Assefa et al., 2019; Jensen and Wu, 2018). The higher the rural population covered by sewage facilities, the greater the rural water security. In this paper, the other two indicators for measuring this dimension are as follows:
- The nominal capacity of water treatment plants
- Number of sewage subscribers

3.2.4. Economic value of water
The economic value of water dimensions reflects the economic aspect of water security and it should be considered an economic asset. Therefore, the selling price of one cubic meter of water and non-revenue water in the rural sector are used to calculate this dimension (Babel et al., 2020; Khan et al., 2020). Also, proceeds from the sale of water can also be used for water resources protection and infrastructure maintenance (Van Leeuwen, 2013; Koop and Van Leeuwen, 2015). It is noteworthy that values higher than the price of water indicate that water is better valued.

3.3. Data
Iran's National Water and Wastewater Engineering Company is responsible for collecting information on water and sanitation in rural areas of Iran. Therefore, data on rural water supply and sewerage from 2013 to 2019 were obtained from Iran's National Water and Wastewater Engineering Company. The reference values of the 10 indicators are detailed in Table 1.

Table 1. Reference values of 10 indicators

	Unit	Raw values						
		2013	2014	2015	2016	2017	2018	2019
Availability								
Rural population covered by water	people	16347560	16427570	16630122	16667291	16817558	16897556	16902659
Volume of surface water	MM m^3/y	178	194	177	197	218	231	250
Groundwater volume	MM m^3/y	1134	1203	1214	1185	1223	1258	1351
Accessibility								
Number of household water subscribers	item	4587792	4728108	4819487	4812293	4967731	5110503	5197439
The length of the water distribution network	km	162781	167320	171609	173297	178847	181638	194229
Water health and sanitation								
The nominal capacity of water treatment plants	M m^3/d	283944	425231	432530	358034	472105	471334	319220
Number of sewage subscribers	item	12318	12327	15904	18703	18961	20055	22474
Rural population covered by sewage facilities	people	62326	73823	72308	72251	88112	98142	99865
Economic value of water								
Selling price of one cubic meter of water in the rural sector	Rial	1201	1487	1919	2576	2684	3615	3997
Non-revenue water	%	30.38	31	30.72	31	32.27	33.3	34.11

Source: authors' compilation

3.4. Normalization

As shown in Table 1, the available data were measured at different scales and did not have the same units. So the reference values were then transformed to normalized values with a range of 1-5. 1 represents the lowest level of drinking water security, while 5 illustrates the highest level of drinking water security. In the study, normalization was performed using the following equation

$$X_i' = 1 + \frac{X_i - X_{imin}}{X_{imax} - X_{imin}} \times (5-1) \qquad (1)$$

Where

X_i^': Normalized Indicator,
X_i: Reference Indicator,
i: Data range of X,
X_imin: Minimum values in i,
X_imax: Maximum values in i.

Some indicators are inversely related to scale, meaning that the smaller is the better (Huang et al., 2015). For example, increasing non-revenue water indicates lower drinking water security. The Eq. (1) in this case is modified to the following equation

$$X_i' = 1 + \frac{X_i - X_{imax}}{X_{imin} - X_{imax}} \times (5-1) \qquad (2)$$

3.5. Calculation of rural water security index

Finally, the following formulas are used to calculate the rural water security index

$$I_J = \frac{\sum_{i=1}^{n} X_i' * w_i}{\sum_{i=1}^{n} w_i} \qquad (3)$$

$$D_k = \frac{\sum_{j=1}^{m} I_J * w_j}{\sum_{j=1}^{m} w_j} \qquad (4)$$

Where

wi and wj are weights given to variables and indicators, respectively. Thus it is important that equal weight is given to all variables and indicators, since their relative importance to urban water security is generally unknown. This follows from the principle of maximum entropy (Chaves, 2014), so w_i= 1⁄n and w_j= 1⁄m. Finally, the following equation is used to calculate drinking water security in rural areas of Iran

$$\text{Rural Drinking Water Security} = \frac{\sum_{k=1}^{4} D_k}{4} \qquad (5)$$

4. Results and Discussion

The normalized values of 10 indices as well as the average of each dimension are shown in Table 2.

4.1. Results analysis

Fig. 4 shows the average of the indicators in the availability dimension in the period 2013-2019. Availability of water in rural areas of Iran has improved in all of the years, but the trend of increasing the availability dimension in 2016-2019 compared to 2014-2016 is associated with a steeper slope. Accordingly, villagers' access to water availability in rural areas of Iran has increased.

The accessibility dimension shows citizens access to sufficient water through piping network. In this study, Iran's performance on this dimension is evaluated by trend number of household water subscribers and the length of the water distribution network. Fig. 5 shows the average of these indicators during the years 2013-2019. As can be seen in Fig. 5, the accessibility dimension has increased in the seven-year period under review, in other words, this result shows that the number of households covered by tap water has increased in rural areas. Also in these areas, the length of the water distribution network has increased, indicating stable investments and improvements of the water sector in Iran.

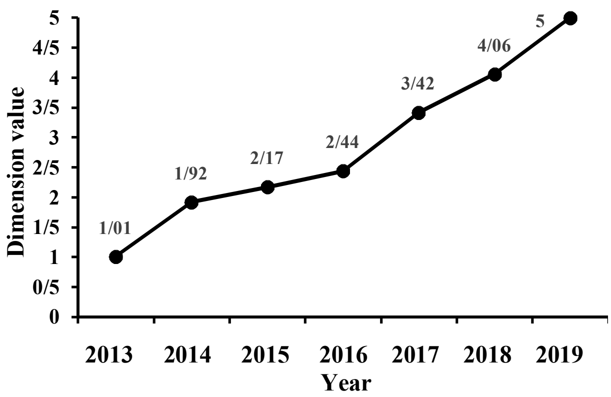

Fig. 4. Availability dimension

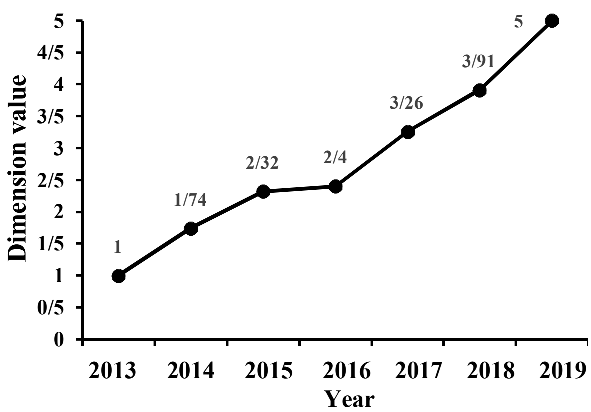

Fig. 5. Accessibility dimension

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Table 2. Normalized values of 10 indicators

	Normalized values						
	2013	2014	2015	2016	2017	2018	2019
Availability							
Rural population covered by water	1	1.57	3.03	3.30	4.38	4.96	5
Volume of surface water	1.05	1.93	1	2.09	3.24	3.95	5
Groundwater volume	1	2.27	2.47	1.94	2.64	3.28	5
Average availability	1.01	1.92	2.17	2.44	3.42	4.06	5
Accessibility							
Number of household water subscribers	1	1.92	2.52	2.47	3.49	4.42	5
The length of the water distribution network	1	1.57	2.12	2.33	3.04	3.39	5
Average accessibility	1	1.74	2.32	2.40	3.26	3.91	5
Water health and sanitation							
The nominal capacity of water treatment plants	1	4	4.15	2.57	5	4.98	1.74
Number of sewage subscribers	1	1.003	2.41	3.51	3.61	4.04	5
Rural population covered by sewage facilities	1	2.22	2.06	2.05	3.74	4.81	5
Average water health and sanitation	1	2.41	2.87	2.71	4.12	4.61	3.91
Economic value of water							
Selling price of one cubic meter of water in the rural sector	1	1.40	2.02	2.96	3.12	4.45	5
Non-revenue water	5	4.33	4.63	4.33	2.97	1.86	1
Average economic value of water	3	2.87	3.33	3.65	3.04	3.16	5

Fig. 6 depicts the third dimension of rural drinking water security in Iran. This dimension is obtained from the average of the nominal capacity of water treatment plants, number of sewage subscribers and rural population covered by sewage facilities. According to Fig. 6, the water health and sanitation dimension has increased in all the studied years except 2016 and 2019.

But in general, it can be seen that the status of water health and sanitation in rural areas of Iran has improved and a greater population of rural households have benefited from these services.

Economic value of water dimension displays the economic aspect of water security. According to Fig. 7 the economic value of water has had a steady trend, so that the highest and lowest values for this dimension are found in 2016 and 2014, respectively. This index is obtained from the average selling price of water in rural areas of Iran and non-revenue water.

4.2. Assessment of rural water security

Fig. 8 presents the status and trend of Iran’s rural drinking water security by plotting the indicators on a four-point radar chart. Table 3 below shows drinking water security in rural areas of Iran.

Iran's rural water security is measured by four dimensions, availability, accessibility, water health and sanitation, and economic value of water. Iran's rural water security, which is measured by an average of four dimensions, has improved in all years of the period under review. So according to Fig. 9, rural water security in 2014 compared to 2013 and in 2017 compared to 2016 is associated with significant growth compared to other years. In 2019, rural drinking water security reached a maximum in the period under study, which was due to the improvement of availability and accessibility indicators.

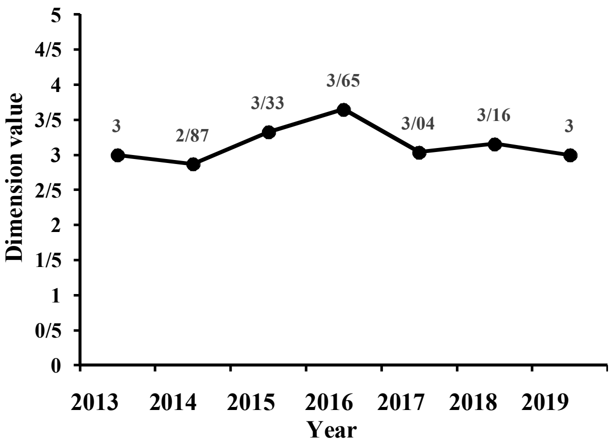

Fig. 7. Economic value of water dimension

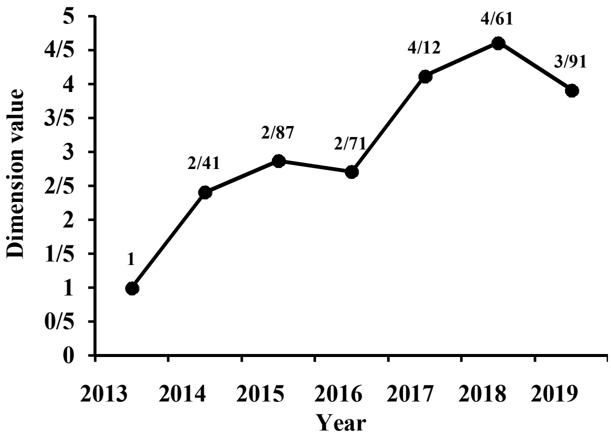

Fig. 6. Water health and sanitation dimension

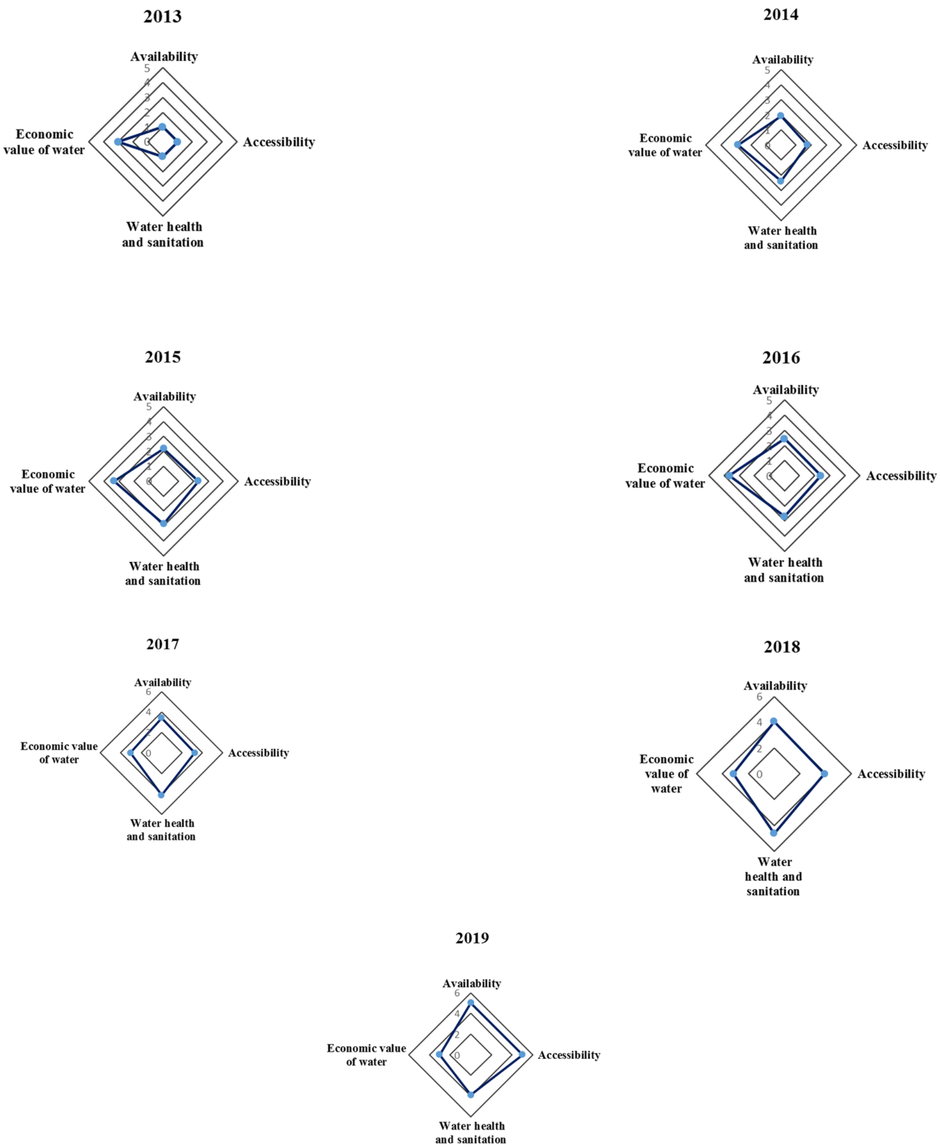

Fig. 8. Trend of Iran's rural water security. Source: authors' compilation

Table 3. Drinking water security in rural areas of Iran

Summary of average indicator values and rural drinking water security					
	Availability	Accessibility	Water health and sanitation	Economic value of water	Rural water security
2013	1.01	1	1	3	1.50
2014	1.92	1.74	2.41	2.87	2.23
2015	2.17	2.32	2.87	3.33	2.67
2016	2.44	2.40	2.71	3.65	2.80
2017	3.42	3.26	4.12	3.04	3.46
2018	4.06	3.91	4.61	3.16	3.94
2019	5	5	3.91	3	4.22

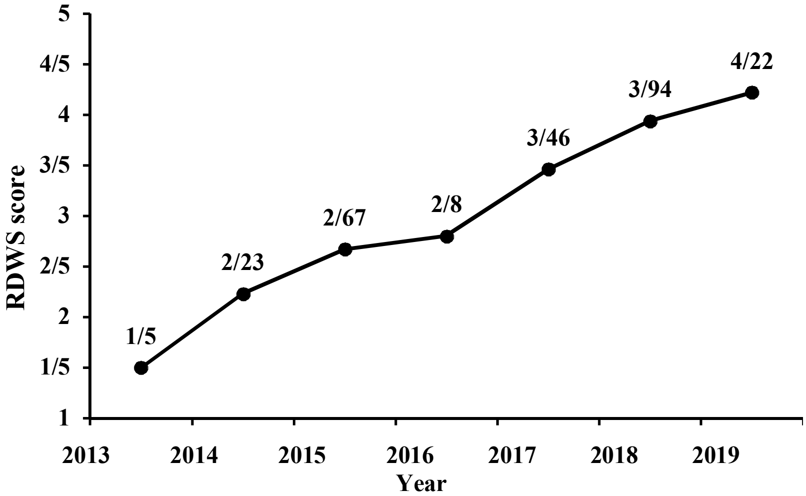

Fig. 9. Rural drinking water security (RDWS) in Iran. Source: authors' compilation

5. Conclusion

This study appraises the drinking water security condition of Iran's rural areas during 2013-2019. This study provides insight into rural water security of Iran from different perspectives, including availability, accessibility, water health and sanitation, and economic value of water. Several interesting results have been obtained from this study:

The first is about the drinking water security assessment framework in Iran's rural areas. This framework is unique in that it is designed to examine and enhance water security in rural areas, but can be adapted and used for city or village-scale analyses within Iran and beyond. The framework has two levels- indicators and variables, and the variables are determined depending on the type of villages or rural areas of each country.

The results also show that drinking water security in rural areas has improved during the period under review. Therefore, the government seems to have been very efficient in ensuring continued investment in rural water systems, which can be inferred from the dimensions of availability, accessibility and water health and sanitation. According to the results, availability dimension of water security has increased from 1.01 to 5 (based on the introduced scale) in an ascending trend. For accessibility dimension, we also can see the upward trend of the water security. As, it is becoming more intensive in recent years from 1 to 5. Also, water health and sanitation dimension increased from 1 to 3.91 during 2019-2013.

Although Iran has experienced high inflation in recent years, it is believed that the increase in the selling price of water has been used to improve the infrastructure of the water network in rural areas. Research results can be effective for policymakers and planners to improve water security. Also, the developed framework is generally usable and can be considered for other rural or urban areas around the world. Future studies can focus on the use of this framework in different socio-economic, institutional, and climatic conditions.

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References

Abbaspour, K. C., Faramarzi, M., Ghasemi, S. S. & Yang, H. 2009. Assessing the impact of climate change on water resources in Iran. *Water Resources Research*, 45, W10434.

Aboelnga, H. T., Ribbe, L., Frechen, F. B. & Saghir, J. 2019. Urban water security: definition and assessment framework. *Resources*, 8(4), 178.

Allan, J. V., Kenway, S. J. & Head, B. W. 2018. Urban water security-what does it mean? *Urban Water Journal*, 15, 899-910.

Amiri, M. & Eslamian, S. 2010. Investigation of climate change in Iran. *Journal of Environmental Science and Technology*, 3, 208-216.

Assefa, Y. T., Babel, M. S., Sušnik, J. & Shinde, V. R. 2019. Development of a generic domestic water security index, and its application in Addis Ababa, Ethiopia. *Water*, 11, 37.

Babel, M. & Shinde, V. R. 2018. A framework for water security assessment at basin scale. *APN Science Bulletin*, 8, 27-32.

Babel, M. S., Shinde, V. R., Sharma, D. & Dang, N. M. 2020. Measuring water security: a vital step for climate change adaptation. *Environmental Research*, 185, 109400.

Bin, O., Shuyan, F., Yu, W. & Liping, W. 2012. The comprehensive evaluation of rural drinking water security in Yunnan Province. *Procedia Earth Planetary Science*, 5, 155-158.

Bolognesi, T. & Kluser, S. 2018. *Water security as a normative goal or as a structural principle for water* governance. *a critical approach to international water management trends*. Palgrave Macmillan, London, UK.

Chang, Y. J. & Zhu, D. 2020. Urban water security of China's municipalities: comparison, features and challenges. *Journal of Hydrology*, 587, 125023.

Chaves, H. 2014. Assessing water security with appropriate indicators: challenges and recommendations. *Proceedings from the GWP Workshop: Assessing Water Security with Appropriate Indicators*. Stochholm, Sweden.

Cook, C. & Bakker, K. 2012. Water security: debating an emerging paradigm. *Global Environmental Change*, 22, 94-102.

D'ambrosio, E., Ricci, G. F., Gentile, F. & De Girolamo, A. M. 2020. Using water footprint concepts for water security assessment of a basin under anthropogenic pressures. *Science of the Total Environment*, 748, 141356.

Gain, A. K., Giupponi, C. & Wada, Y. 2016. Measuring global water security towards sustainable development goals. *Environmental Research Letters*, 11, 124015.

Gong, L., Jin, C., Li, Y. & Zhou, Z. 2017. A novel water poverty index model for evaluation of Chinese regional water security. *IOP Conference Series: Earth and Environmental Science*, IOP Publishing, 82(1), 012029.

Grey, D. & Sadoff, C. W. 2006. Water for growth and development. *Thematic Documents of the IV World Water Forum. Comision Nacional del Agua.* Mexico City. Mexico.

Grey, D. & Sadoff, C. W. 2007. Sink or swim? water security for growth and development. *Water Policy*, 9, 545-571.

Hailu, R., Tolossa, D. & Alemu, G. 2020. Household water security index: development and application in the Awash Basin of Ethiopia. *International Journal of River Basin Management*, doi: 10.1080/15715124.2020. 1755300.

Hoekstra, A. Y., Buurman, J. & Van Ginkel, K. C. 2018. Urban water security: a review. *Environmental Research Letters*, 13, 053002.

Hope, R., Hansen, K., Mutembwa, M. & Schlessinger, S. 2012. *Water security, risk and society–key issues and research priorities for international development*. Key Issues and Research Priorities for International Development. Oxford, UK.

Huang, Y., Xu, L. & Yin, H. 2015. Dual-level material and psychological assessment of urban water security in a water-stressed coastal city. *Sustainability*, 7**,** 3900-3918.

Jensen, O. & Wu, H. 2018. Urban water security indicators: development and pilot. *Environmental Science Policy*, 83**,** 33-45.

Jiang, Y. 2015. China's water security: current status, emerging challenges and future prospects. *Environmental Science and Policy*, 54**,** 106-125.

Karimi, V., Karami, E. & Keshavarz, M. 2018. Climate change and agriculture: impacts and adaptive responses in Iran. *Journal of Integrative Agriculture*, 17(1)**,** 1-15.

Khan, S., Guan, Y., Khan, F. & Khan, Z. 2020. A comprehensive index for measuring water security in an urbanizing world: the case of Pakistan's capital. *Water*, 12**,** 166.

Koop, S. H. & Van Leeuwen, C. J. 2015. Application of the improved city blueprint framework in 45 municipalities and regions. *Water Resources Management*, 29**,** 4629-4647.

Larsen, M. A. D. & Drews, M. 2019. Water use in electricity generation for water-energy nexus analyses: the European case. *Science of the Total Environment*, 651**,** 2044-2058.

Lawrence, P. R., Meigh, J. & Sullivan, C. 2002. *The water poverty index: an international comparison*, Department of Economics, Keele University, Citeseer. Straffordshire, UK.

Layani, G. & Bakhshoodeh, M. 2019. Water security in Kowsar dam basin under climate variability: application of system dynamics approach. *Agricultural Economics*, 13**,** 47-72. (In Persian)

Li, D., Wu, S., Liu, L., Liang, Z. & Li, S. 2017. Evaluating regional water security through a freshwater ecosystem service flow model: a case study in Beijing-Tianjian-Hebei region, China. *Ecological Indicators*, 81**,** 159-170.

Li, X., Su, X. & Wei, Y. 2019. Multistage integrated water security assessment in a typical region of Northwestern China. *Journal of Cleaner Production*, 220**,** 732-744.

Madani, K., Aghakouchak, A. & Mirchi, A. 2016. Iran's socio-economic drought: challenges of a water-bankrupt nation. *Iranian Studies*, 49**,** 997-1016.

Qin, K., Liu, J., Yan, L. & Huang, H. 2019. Integrating ecosystem services flows into water security simulations in water scarce areas: present and future. *Science of the Total Environment*, 670**,** 1037-1048.

Ray, B. & Shaw, R. 2019. *Developing water security index for urban areas*. *In Urban Drought*, 53-68. Springer, Singapore.

Romero-Lankao, P. & Gnatz, D. M. 2016. Conceptualizing urban water security in an urbanizing world. *Current Opinion in Environmental Sustainability*, 21**,** 45-51.

Shrestha, S., Aihara, Y., Bhattarai, A. P., Bista, N., Kondo, N., Futaba, K., Nishida, K. & Shindo, J. 2018. Development of an objective water security index and assessment of its association with quality of life in urban areas of developing countries. *SSM-Population Health*, 6**,** 276-285.

Singh, V. P. 2017. Challenges in meeting water security and resilience. *Water International*, 42**,** 349-359.

Sodoudi, S., Noorian, A., Geb, M. & Reimer, E. 2010. Daily precipitation forecast of ECMWF verified over Iran. *Theoretical Applied Climatology*, 99**,** 39-51.

Su, Y., Gao, W. & Guan, D. 2019. Integrated assessment and scenarios simulation of water security system in Japan. *Science of the Total Environment*, 671**,** 1269-1281.

Van Leeuwen, C. 2013. City blueprints: baseline assessments of sustainable water management in 11 cities of the future. *Water Resources Management*, 27**,** 5191-5206.

Wang, X., Chen, Y., Li, Z., Fang, G. & Wang, Y. 2020. Development and utilization of water resources and assessment of water security in central Asia. *Agricultural Water Management*, 240**,** 106297.

Wegerich, K., Van Rooijen, D., Soliev, I. & Mukhamedova, N. 2015. Water security in the Syr Darya basin. *Water*, 7**,** 4657-4684.

Yomo, M., Mourad, K. A. & Gnazou, M. D. 2019. Examining water security in the challenging environment in Togo, West Africa. *Water*, 11**,** 231.

Zhang, C., Li, J., Zhou, Z. & Sun, Y. 2021. Application of ecosystem service flows model in water security assessment: a case study in Weihe River Basin, China. *Ecological Indicators*, 120**,** 106974.

Zhu, D. & Chang, Y. J. 2020. Urban water security assessment in the context of sustainability and urban water management transitions: an empirical study in Shanghai. *Journal of Cleaner Production*, 275**,** 122968.