Water Poverty Index: a Tool for Water Resources Management in Jordan

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Abstract In terms of water resources, Jordan is considered one of the poorest countries in the world. Water resources management is one of the available options to decrease the gap between demand and resources. Water resources management requires optimum use of the available water resources taking into consideration resources availability, resources reliability, water use pattern, in addition to the socio-economic issues. One of the most important aspects is human behaviour which has a strong impact on water management and on the ecosystem. Therefore, there is a need to follow a sustainable approach to improve the management and the understanding of the difficulties of water issues by integrating the physical, social, economic, and environmental aspects, as well as linking water issues to poverty indicator. In this paper, Water Poverty Index (WPI) will be used as a tool for water resources management. WPI was calculated based on five parameters: resources, access to water, capacity, use, and the environment. The Jordanian water strategy targets will be used to forecast the water situation in 2025 and calculate WPI. In 2002, the WPI was calculated and found at 46.3%, in comparison with higher figures for other countries. WPI was calculated for the year 2018, and the results showed a value of 50.7%. If the national water strategy targets and improvements will be successfully implemented, by 2025, the value is expected to be increased to 56.38%. Water resources are the most sensitive component of WPI. COVID-19 increased the rate of unemployment and poverty ratio which will affect WPI negatively. It's concluded that WPI could be used as a valuable indicator to help evaluate the running plans and monitor the management performance.

Keywords Water Poverty Index · Jordan · Water budget · Consumption · Water scarcity

1 Introduction

Jordan is located in the middle east covering an area of about 89,342 km^2 with a population of 11 million. Jordan's economy resources depend on tourism, phosphate, potash, fertilizers, remittances, and agriculture [DOS, 2022]. Jordan is classified as a middle-income country with a Gross Domestic Product (GDP) of 43.7 billion $ in 2020. As a result of the Syrian war, more than 1.3 million of Syrian refugees posed heavy load on all socioeconomic sectors especially the economic, infrastructure, water, employment and the environment. Recent reports indicated unemployment

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rate of 23.3% (2022), − 8.7 billion annual trade balance (2021), with economic growth rate of 1.6% in 2020 [DOS, 2022, Word bank, 2022]. Regarding the ecology, there are 2545, 436, 82, and 99 species of flora, bird, mammal and reptiles respectively. Fauna species include but not limited to *Canis aureus*, Caracal caracal, Rana bedriagae, Red fox, Rock hyrax, wolf, and *Vulpes cana* [RSCN, 2022].

Water management requires optimum use of the available water resources taking into consideration several factors, particularly; resources availability, resources reliability, water use pattern, in addition to demand characteristics. In terms of water resources, Jordan is considered among the poorest countries in the world. Limited water resources, high population growth rate, low rainfall, high evaporation rate, depletion of groundwater aquifers, high rate of unaccounted water, mismanagement, transboundary nature of surface water, and industrial pollution are the main causes of the water crisis in Jordan [Mohammad et al., 2020, AL-Ananzeh et al., 2012]. The annual water budget for 2017 indicated that the gap between renewable resources and demand reached more than 559 million cubic meters (MCM) that resulted in per capita share of 85 m^3/capita. year with an average daily water supply of 130 l/c.d [MWI, 2020]. Ministry of Water and Irrigation of Jordan set "National Water Strategy (2016–2025)" and "Water Sector Capital Investment Program (2016)" in order to summarize the recent successes, water sector challenges, and targets. The main targets of these proposals are; improvement of the current water resources by increasing the storage capacity of dams from 325 to 400 MCM, raising the efficiency of the water distribution system for domestic, industrial, commercial, and agricultural sectors by reducing the non-revenue water (NRW) from 52 to 25%. Also, it aims to improve the efficiency of operating and water supply system and improving the energy efficiency in the water sector through reducing the energy consumption by about 15%, which will increase the share of renewable energy to 10% of the overall national power supply. According to the mentioned strategy, sanitation services will be developed by increasing the percentage of wastewater service coverage from 63 to 80% [MWIa, 2016, MWIb 2016].

Three companies manage the water supply in Jordan under the Ministry of Water and Irrigation (MWI) umbrella: Miyahuna, Aqaba Water Company, and Yarmouk Water Company. The safe drinking water coverage in Jordan is 94%, with microbiological compliance that exceeds 99% [MWIa, 2016]. Because of these shinning figures, most of the communities receive water once a week with limited amount (< 100 L/c.d) which is very low in comparison with other countries [Al-kharabshah and Alzboon, 2021].

Due to the high stress of water challenges, there is a need to build a sustainable approach to improve the management and understand the difficulties concerning water issues by integrating the physical, social, economic, and environmental aspects. This could be achieved by linking water issues to poverty [Anju et al., 2017;].

There is a strong relationship between the water poverty and economic poverty and both parameters are considered as sustainability indicators [Liu and Liu, 2021]. Water Poverty Index (WPI) is used as a tool to determine many indicators that relate to water resources sustainability and their impacts on people [Sullivan, 2002; Sullivan et al., 2006]. Sullivan (2002) developed the WPI to reflect five components: Resource (R), Access (A), Capacity (C), Use (U), and Environment (E). Song, 2021, developed a water management index consisting of 24 indicators in 7 main areas and assessed water-related challenges for more than 145 countries.

Mlote (2002) studied an approach to assessing water availability using WPI and how to use this indicator for water resources allocation and applied it in selected pilot sites in Tanzania, South Africa, and Sri Lanka.

Water Poverty Index was used widely in different countries and for several purposes. The WPI was calculated internationally in 2002. For Jordan, the value was 46.3% compared with higher values for developed countries such as 77.8 for Canada, 68.0 for France, 64.5 for Germany, and 65 for UAS. The higher value indicated the better water management performance [Lawrence et al., 2002]. WPI was adopted as an efficient indicator to assess the water stress and management policies in China; the study evaluated the spatial–temporal trends of water stress during the period of 2003–2015 for three basins using WPI; accordingly two basins showed improvement in the water situation while the third one showed a small decrease (Huang et al., 2017). WPI was calculated in Nepal's upper Bagmati River Basin that resulted in three categories High–Medium–Low. Low scale

means that the water situation is better, which was found for two areas Sundarijal and Lubhu. Daman region is categorized as a medium level which means poor water accessibility. While Kathmandu, Sankhu, and Thankot were found within low to medium scales, which indicates a neutral water situation [Thakur et al., 2017]. A score of 59% was found during the creation of WPI in Rio Valles Basin in Mexico [Alvarez et al., 2015]. Koirala et al., 2020, used five components to determine WPI of water stress in Koshi river basin and found that there was a significant variation in WPI values in different districts. The results recommended to give priority for the districts with low WPI. Also, WPI was used to evaluate Nigeria's water management strategies, where people have real issue inaccessibility, where 60% of the population has no access to potable water, and many children die because of poor sanitation. WPI calculated for local government areas in Nigeria and ranged from 11.29 to 47.89%, which is considered within the unsafe categories as the safe to medium shall not be less than 56%. Additionally, the results concluded with a need for more research in order to create a clear image [Awojobi, 2014]. It was also calculated for Tunisia to assess water scarcity using an improved methodology for 24 governorates, and the results were ranged from 21.99 to 77.42% [Jemmali and Matoussi, 2013]. In the border colonies of west Texas, WPI was used as a tool for decision makers to evaluate the poverty in the area [Korc and Ford, 2013]. WPI was used to evaluate the water situation and the deterioration in Gaza strip from 2000 to 2010; based on the study, the results showed a bad current water situation with serious deterioration [Mogheir and Aiash, 2013]. In 2006, WPI was calculated for 12-farms in North-eastern China, and the results helped to rank its water scarcity conditions from good to poor [Qiang et al., 2008]. The mentioned studies revealed that WPI can be used successfully in water management, and there are significant differences in its value among different countries. For this reason, it is very important to determine WPI for Jordan and to utilize it as a key performance indicator of water management. The applied methodology represents that a helpful approach could be followed in the future water researches.

In this paper, the WPI will be calculated for Jordan that help in evaluating the running plans, strategies and tracking the efficiency performance at any time. Also, WPI will be predicted for 2025 based on the predicted data of different WPI components as described in Sect. 2.2. Any improvement in WPI indicates an improvement in the water sector either in resources, environment, access, management, and use.

2 Data and Methodology

2.1 Data Sources

The data collected to complete this study were mainly from online sources; the data published on the Department of Statistics and the Water Authority of Jordan reports. According to the latest statistics in 2017 by the Department of Statistics (DOS), the Jordan population is 10.05 million with a growth rate of 2.4% [DOS, 2017]. Jordanian education capacity is high compared to other developing countries; the percent of Jordanians attending any primary schooling level is 94.8%. The poverty ratio (person %) is 14.4% which refers to the persons with minimum revenues of 336.0 JOD/Capita/y (480$) [DOS, 2017]. Unemployment rate, rangeland area, irrigated area have taken from the annual report of DOS 2017. Data related to the water consumption, wastewater, sanitary system have been collected from MWI reports [MWIa, 2016, MWI, 2020].

2.2 WPI Calculation

2.2.1 Overall WPI Calculation

As a concept, WPI composite structure is based on the approach used in the Human Development Index (HDI). The general expression for scheming WPI is [Sullivan et al., 2006]:

$$WPI = \frac{\sum_{i=1}^{N} wiXi}{\sum_{i=1}^{N} wi} \tag{1}$$

where WPI is the Water Poverty Index value for a location, Xi refers to component i, and wi is the weight applied to that component. In this study, equal weighting (20%) will be used for each component. In detail, the components of WPI are Resources, Access, Capacity, Use, and the Environment as explained below. These components have been used in many researches internationally [Sullivan et al., 2006].

2.2.2 Resources Component

It is a measure of water resources availability and reliability. In 2018, the total available water resources as reported in the Jordan- National Water Strategy (NWS) is 1034 MCM/a, and it's expected to be 1459 MCM/a by 2025. In 2018, the total value of the renewable water resources was 886 MCM/a, while the remaining is non-renewable. MWI is looking to increase the sustainable water resources to 1341 MCM/y by 2025. Currently, the total demand is 1442 MCM/a and will be increased to 1548 MCM/a by 2025 indicating a deficit value of 408 and 88 MCM representing 28.3 and 5.6% of the total demand and 46.05 and 6.56% of the total renewable Water Resources (RWR) for 2018 and 2025, respectively. The resources component was calculated based on two factors: water scarcity and water reliability, as shown in the equation below.

$$R = Ws \times Wr \qquad (2)$$

where R is the Resources component, Water resources reliability (Wr) was calculated by dividing the sustainable water resources by the total demand as shown in Eq. (3), Ws: water scarcity factor and was calculated by dividing per capita water resources by water scarcity limit (500 m^3.y) as shown in Eq. (4).

$$Wr = \text{sustainable water resources/water demand} \qquad (3)$$

$$Ws = \text{per capita water resources/water scarcity limit} \qquad (4)$$

Table 1 below illustrates the values and calculation of different subcomponents of R.

2.2.3 Access Component

It is a measure of access to water supply and sanitation systems, as well as the percent of irrigated agriculture. The percent of households with access to a water supply system in 2018 is 94.00% and will reach 95% in 2025, while only 62% of the population have access to sanitation, and it is projected to be 80% in 2025 [DOS, 2017]. The percent of irrigated agriculture is 39.00%, and it will remain constant during the period 2018–2025 [DOS, 2018]. The value of the access component was calculated as the average value of the three subcomponents (access to water supply, access to sanitary system, percentage of the irrigated agriculture) as shown in Table 2.

2.2.4 Capacity Component

It is a measure for the socioeconomic variables which impact the water quantity and quality, including (1) the percent of Jordanian attending any level of education, (2) the percent of mortality of children before 5 years of age, (3) the percent of Jordanian with ownership of key items, (4) poverty ratio and (5) unemployment rates among Jordanian labor force 15 + years of age. In 2018, the values of the above indicators were 94.8%, 1.9%, 51.2%,14.4%, and 18.7% respectively. By 2025, a slight change is expected due to an increase in the percent of the educated people (95%), household ownerships (53.5%), an increase in the poverty ratio (16%), and an increase the unemployment ratio to 20% (80% find jobs) while the children mortality will decrease to 1.7% (child survival = 98.3%). There is no accurate prediction for most of the capacity components, especially the unemployment and poverty ratios because these

Table 2 Calculation of access component

Year	Access to water supply, % A	Access to sanitary system, % B	Irrigated agriculture, % C	Access component = (A+B+C)/3
2018	94	62.1	39	65.03
2025	95	80	39	71.33

Table 1 Calculation of resources components

Year	Sustainable water resources MCM	Total water resources MCM	Water demand, MCM	Per capita water resources, m3	Wr, % Eq. (3)	Ws Eq. (4)	R, % Eq. (2)
2018	886	1034	1442	103.4	61.44	0.20	12.71
2025	1341	1459	1548	120.57	86.63	0.24	20.89

indicators depend on many national and international political and socioeconomic parameters [DOS, 2016]. The capacity component was calculated as the average value of the five subcomponents as shown in Table 3 below.

2.2.5 Use Component

It is a measure for the distribution of water resources used into three main categories; domestic, industrial, and agricultural. Previously the agricultural use percent was estimated with a value around 60%. Nevertheless, according to the recently collected data, the accurate percent is 49.13%, the percent of domestic water use is 46.35%, while the industrial consumes only 3.80% [MWI, 2020]. By 2025, irrigation water will represent only 45.0%, while the municipal and industrial sectors will represent 47.5% and 7.5%, respectively. During the period 2002–2011, unaccounted water (NRW) reduced from 52 to 44%, then it increased to 52% in 2014, and it is projected to be reduced to 25% by 2025 according to the NWS [MWIa, 2016]. The agricultural sector contributes about 5.5% of the total GDP, while the industry contributes 19.2% [SSIF, 2017]. While it is expected that agriculture production will increase by 10% in 2025, its share of the GDP will stay the same due to the similar growth of GDP. The industrial sector's share will increase to 25% of the GDP in 2025 [SSIF, 2017]. Use components are calculated based on water management effectiveness and water productivity as modified after El-Gafy (2015):

$$U = D \times Pd + \frac{Pa}{A} + \frac{Pi}{I} \qquad (5)$$

where U is the use component in the WPI. While D, A, I are water used (%) in domestic, agriculture, and industrial sectors, respectively, Pd is the measurement of water management effectiveness, namely the ratio of the accounted water, Pa is the share of the agriculture in the GDP, and Pi is the share of the industrial sector in the GDP. Since the high share of the industry in GDP, water productivity in the industrial (Pi/I) sector is taken = 1 as shown in Table 4.

2.2.6 Environment Component

It is a measure of environmental indicators that impact water management including a measure of water quality (A), a measure of carrying capacity of rangelands (B), the percentage of vegetation cover for the traditional grazing land (C), and the percentage of land that receives enough rainfall to maintain cultivation (D). The values of these parameters for 2018 were 99.3%, 30%, 80%, and 5% respectively [MWIa, 2016, DOS, 2022], and there is no significant change in these figures expected by 2025. While it is expected that MWI will maintain water quality at a high level (compliance > 99.5%), vegetation cover may reduce by 5% in 2025 due to change in rainfall patterns. The other parameters will be affected by climate change as well as lack of funding to implement the proposed projects so that no accurate prediction could be proved. The use component was calculated

Table 3 Calculation of the capacity component

Year	Educated people, % A	Child survival = 100%-mortality B	Ownership of key items, % C	Poverty index, (100-poverty ratio) D	Employment ratio E	Capacity component = (A + B + C + D + E)/5
2018	94.8	98.1	51.2	85.6	81.7	82.28
2025	95	98.3	53.3	84	80	82.12

Table 4 Calculation of use component

Year	D	Pd	Pa	A	Pi	I	Use component Eq. (5)
2018	46.3	0.52	5.5	49.1	19.2	4.5	39.7
2025	47.3	0.75	5.5	45.2	25.0	7.5	55.1

as the average value of the four subcomponents (water quality, rangeland capacity, vegetation cover, rainfed agriculture) as shown in Table 5.

3 Results and Discussions

3.1 WPI Components

3.1.1 Resources

Index of Resources components increased significantly during the period of 2002–2018 from 2.0 to 12.71%; this could be attributed to the new water resources from the Disi aquifer, which supported Jordan's water budget with 100 MCM/y of potable water. According to the NWS, a high jump in water resources is expected during the period of 2018, and 2025 reaches 425 MCM, as a result of a number of projects, mainly; Red Sea-Dead Sea Project (235MCM), Sheediyya–Al Hasa deep wells (50 MCM), Wadi Al Arab Water System (30MCM), resources in the remote areas (36 MCM), and increasing the WWTPs capacities by improving the operations and extension projects and expanding the wastewater networks to cover most of the big cities in Jordan (94MCM/y). The government of Jordan is looking to substitute the Red Sea-Dead Sea with the National Conveyer Project, consisting of a desalination treatment plant and a trunk pipeline parallel to Disi to convey the water from the south of Jordan to Amman the north areas [GWI, 2022]. According to the NWS, resources component will reach 20.89% in 2025 compared to 2% in 2002. In 2025, per capita water resources will reach 120 m^3/y, which is far below the water scarcity limit of 500 m^3/c.y, which subsequently negatively affected the resources component's value. It is expected that COVID has negative impacts on water resources component because some of the proposed projects could not be

Table 5 Calculation of the environment component

Year	A	B	C	D	Environment component = (A+B+C+D)/4
2018	99.3	30	80	5	53.58
2025	99.7	30	75	5	52.43

constructed due to financial constraints. In light of the previous analysis, 90 questionnaires were distributed for households to have an idea about their point of view regarding water resources and WPI. The result indicated that 90.6% of the sample notice a reduction in rainfall which affected water budget in Jordan. Also, it was found that water conservation in houses became a significant trend (77.4% of the sample), particularly due to the high-water price and public awareness.

3.1.2 Access

While there is no significant change in access components during the period of 2002 and 2018, it will increase significantly in 2025 due to the expansion of the sanitary system to cover about 80% of the population, access to water supply system will increase from 94 to 95% while no significant change in the percent of the irrigated area is expected. It is worth mentioning here that this optimistic prediction is questionable due to the limited financial resources to conduct the proposed projects, and the severe economic impacts of COVID-19. Before COVID-19 spread, it was projected to provide 80% of population with the sanitary system by 2025, whereas now it is expected to be less than 70%.

3.1.3 Capacity

The capacity components' calculation indicated a slight change from 82.28 to 82.12% during the period 2018–2025. Although an improvement in the percentage of the educated people is expected, in the percentage of children mortality, and ownership of key items, this improvement will be countered by an increase in the poverty ratio and the percent of unemployment. It is well known that the poverty and unemployment parameters are affected by many national, regional, and international issues such as political stability, petrol prices, and global economic growth, so these indicators may increase or decrease based on the driven parameters. Additionally, COVID-19 increased the rate of unemployment (up to 22%) and poverty ratio (up to 18%), which means that this component will be affected significantly [DOS, 2022]. Field survey of public awareness revealed that 94.2% of the participants who responded to the survey have a family member with ownership for land or house, 76.2% of

the households unsatisfied with healthcare in Jordan indicated the necessity to improve this sector. Also, it was found that the house's garden's role for food production increased significantly (94.1% of the sample) and 20.1% of the households have livestock at their own house, which may be attributed to the raising in the prices of vegetable and dairy products, increase in poverty percentage, and unemployment ratio.

3.1.4 Use

NRW represents leaks from water networks, nonmetered water, illegal connections, and unauthorized groundwater wells. The percentage of NRW in 2014 ranged from 28% in Aqaba to 73.2% in Maan and about 37.8% in Amman. The highest increase in WPI components during the period of 2018–2025 will occur in the use index. This is due to the expected high reduction in NRW from 52% in 2002 to 25% in 2025 and increase of the industrial share to the GDP. A slight decrease between 2002 and 2018 occurred as a result of the increase in NRW value. NRW is considered one of the main challenges of water management in Jordan. This goal could also be achieved by better managing the water sector, capacity building, maintenance, and replacement of the old networks. The increase in industrial share to the GDP from 19 to 25% has a significant impact on the value of use component, while agriculture contribution to the national GDP will stay constant. The negative impacts of COVID-19 on agriculture and industry will cause significant reduction in the value of use component but there is no reliable data about that.

3.1.5 Environment

The annual report of MWI indicated that high water quality is provided to domestic use, and the percent of the passed sample reached 99.3%. Since water quality has a high impact on human health, it is expected that high water quality should be maintained at a similar level. Although 99% of water samples comply with Jordanian standards, some households (30.9%) reported water disease or complained about water quality, which may indicate water contamination during transportation due to the damage in pipes and old networks. Since rangelands depend mainly on rainfall, there is a slight change (-5%) in vegetation cover, and rangelands' capacity will occur due to the change in rainfall pattern. Based on the mentioned assumptions, no significant change (-0.2%) in the environment component is expected in 2025.

3.2 Overall WPI Value

In order to conduct a comparison and evaluate the Jordan situation in terms of WPI, the values in 2002 for the five components were taken from previous research [Lawrence et al., 2002]. Table 6 and its related bar chart present each component's resulting

Table 6 Values of different components of WQI

Component	2002	2018	2025
Resources	0.4%	2.54%	4.18%
Access	13.0%	13.01%	14.27%
Capacity	14.9%	16.46%	16.42%
Use	10.8%	7.9%	11.03%
Environment	7.3%	10.72%	10.49%
WPI	**46.4%**	**50.7%**	**56.38%**
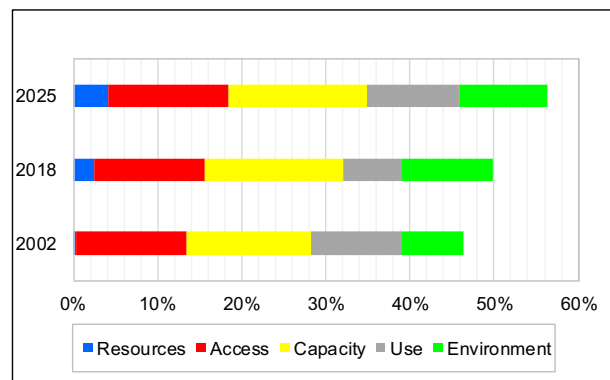
values as a percent of the aggregated WPI. While Table 7 and its associated radar chart show the values as an average of the sub-indicators.

It is clear that the WPI increased slightly during the period 2002–2018 from 46.6 to 50.70 with an average increase rate of 0.25%/y. A sharp increase in WPI during the period of 2018–2025 occurred to reach 56.38%, with an average increase rate of 1.4%/y. This increase is attributed to the high increase in resources and uses components. New projects will be implemented to increase the water resources, decreasing the deficit between the resources and the demand. Additionally, a significant increase in uses component is predicted primarily due to better water resources management and the significant reduction in the NRW. In comparison with other countries, WPI of Jordan in 2002 was very low and was classified as poor. For example, WPI values for Iran, Syria, Turkey, and Egypt were 60, 55, 56.7, and 59 respectively [Hawrami and Shareef, 2020]. By 2025, WPI index will increase to be acceptable compared to the regional countries like Egypt, Qatar, and Oman, as long as the NWS goals are fulfilled and within the planned timeline. The weight of WPI can be ranked as: capacity > access > use > environment > resource. In contrast, Ladi et al., (2021) found that the impact of WPI components on the human development index in Iran can be ranked as: resource > capacity > environment > use > access components. Public awareness survey indicated that most of the households (> 90%)
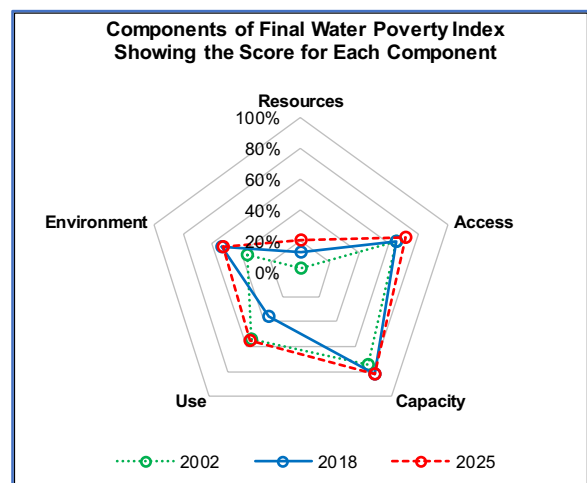
have adequate information about rainfall patterns, reduction in land cover, and the importance of water and the environment to human life and about 44.2% of the sample have an idea about WPI. This is a good indicator for the possibility of improving WPI, especially in the capacity components.

4 Conclusion

The strategic plans can significantly impact water resources improvement in Jordan and it needs to be updated and tracked regularly using international indicators such as WPI. Currently, the results show WPI value of 50.7%. The weight of WPI can be ranked as: capacity > access > use > environment > resource. If the improvements are successfully implemented by 2025, the value will increase to be 56.38%. Such value can be used as a tracking indicator for the Jordanian decision-makers. In addition to the Jordan-NWS plans, it is necessary to upgrade and improve Jordan's irrigation systems and shall be highlighted in national plans; hence, the percent of irrigated agriculture is only 39%, with a low share percentage to the GDP. Despite a significant increase in water resources in 2025, it is still far below the water scarcity limit. Environmentally, plans shall be provided to prevent land degradation and reduce the impact of climate change on water resources and the environment. The environmental component is the most important to

Table 7 WPI for 2002, 2018, 2025

Component	2002	2018	2025
Resources	2.0%	12.71%	20.89%
Access	65.0%	65.03%	71.33%
Capacity	74.5%	82.28%	82.12%
Use	54.0%	39.7%	55.14%
Environment	36.5%	53.58%	52.43%
WPI	**46.40%**	**50.7%**	**56.38%**

be considered thoroughly because it's the most sensitive component. The Jordanian new taxation law might have hazard impact on the capacity component. Nevertheless, this impact can't be easily captured presently. COVID-19 has negative impacts on many of WPI components. Public awareness survey showed that > 90% of the households have adequate information about rainfall patterns, reduction in land cover, and the importance of water and the environment to human life. This is a good indicator for the possibility of improving WPI especially in the capacity components. In conclusion, tracking the national plans' implementation closely using WPI as a reference indicator is very important for future planning and assessment.

Data Availability Statements The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest The authors declare no competing interests.

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