Multidimensional analysis of the water-poverty nexus using a modified Water Poverty Index: a case study from Jordan

Hatem Jemmalia and Lina Abu-Ghunmi

Abstract

Water as a strategic natural resource is of fundamental importance for human development, prosperity, and poverty alleviation. Over the last three decades, Jordan’s water resources have been severely degraded, threatening the livelihoods of countless people, particularly in rural and poor communities. The inadequate provision of water-related facilities has contributed to the rapid decline in quantity and degradation of quality in these communities. This study depicts the theoretical foundations and development of a water-focused and thematic indicator of poverty, which allow a comprehensive understanding of the crosscutting nature of water issues and impacts. It is with this in mind that a modified Water Poverty Index ($m$WPI) is developed herein to exemplify the utilization of the index, and to test its applicability and validity at the Jordanian governorate’s level. The results show that water poverty fluctuates broadly between northern and southern regions suggesting a need for location-specific management plans and more targeted policy interventions. Overall, the $m$WPI, as a holistic tool, can assist decision-makers and other stakeholders in achieving sustainability and can be used to communicate the progress of sustainability to the wider community.

Keywords: Jordan; Poverty; Sustainable development; Water Poverty Index; Water resources management

1. Introduction

Water is increasingly being recognized as one of the most critically stressed resources, especially in arid and semi-arid areas. At present, one in nine people does not have access to drinking water from improved sources and one in three lacks access to sanitation facilities (World Health Organization/United Nations Children’s Fund (WHO/UNICEF), 2015). It is not an overstatement to claim that water can be a key to unlocking the productivity of a society and the livelihood of its members, and that by allocating it more efficiently and equitably, poverty can be alleviated significantly (Sullivan & Meigh, 2003). Without sustainable management of water resources that maximizes the resultant

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economic and social welfare in an equitable manner and maintains the sustainability of vital ecosystems, there are obvious risks that unregulated, formless, or haphazard actions may lead to massive wasting of resources without considerable accomplishments (Williams, 1998).

Issues related to water supply/demand imbalance are intrinsically local, mutually dependent, and strongly reliant on the inter-linkages between humans and their socio-technical environments (Alexander et al., 2010). Recently, steady population growth, accompanied by socio-economic development and environmental change, has become a major challenge in current water resources management policies. The development and implementation of appropriate policies should take into account the complexity of these multi-faceted issues. Thus, any assessment of water resources, which is the first step in developing policies, based only on one dimension and ignoring others may overshadow a range of areas that require specific attention. It is with this in mind that a set of composite indices containing a cluster of data from different disciplines has been developed to assess the multidimensionality of water issues. A relevant attempt has been made by Sullivan (2002) and a team of 30 researchers in consultation with >100 water professionals, who advanced the water-poverty interface as an indicator through the water poverty index (WPI). The index has been widely used as an effective tool to express the multidisciplinary nature of water issues in an easily comprehensible form.

The WPI is a holistic tool that aims to address a wider range of issues, which link water resource availability to human and ecological needs (Sullivan, 2001, 2005; Lawrence et al., 2002). As stated by Juwana et al. (2012), the index belongs to the family of water resources sustainability indices such as the Canadian Water Sustainability Index (Policy Research Initiative, 2007), Watershed Sustainability Index (Chaves & Alipaz, 2007) and West Java Water Sustainability Index (Juwana et al., 2010). All these indices have a common objective to assist water resource managers, policymakers and different stakeholders in achieving water sustainability and communicate the progress of this sustainability to the wider community. Specifically, the WPI has been broadly used to manage water resources towards a sustainable future worldwide and at various scales: international (Lawrence et al., 2002; Jemmali, 2013; Jemmali & Sullivan, 2014), national (Heidecke, 2006; Sullivan & Meigh, 2006; Jemmali & Matoussi, 2013), district/basin (Sullivan & Meigh, 2006; van Ty et al., 2010), sub-basin (Komnenic et al., 2009; van Ty et al., 2010), and community (Sullivan & Meigh, 2003, 2006; Sullivan, 2005).

Regardless of agreement on the utility of the index, some problems with this way of assessing water poverty have been identified. Pérez-Foguet & Garriga (2011), Jemmali (2013), and Jemmali & Sullivan (2014) raised three key conceptual deficiencies in the construction of the index, including selection of variables, weighting scheme, and aggregation method. While a few studies (e.g. Schulze, 2007; van Ty et al., 2010) have tried to address these shortcomings by selecting more appropriate WPI indicators and applying equal weights to all WPI components. Other authors, such as Pérez-Foguet & Garriga (2011), Jemmali & Matoussi (2013), and Jemmali & Sullivan (2014), have used different indicator selection criteria, a new aggregation function and a more objective weighting scheme to overcome the aforementioned weaknesses. It is noteworthy, too, that selection of indicators that relies on readily accessible information rather than requiring further data collection is criticized in the literature.

This paper discusses how an integrated and multidimensional assessment of water poverty, which handles the aforementioned limitations, can be applied to assess the specific concerns of water sustainability in Jordan. It considers previous studies using the initial WPI as significant inputs and a starting point for developing the improved WPI. The main objective of the exercise is to provide whole information about water-related issues in Jordan, including identifying all factors contributing to the improvement of the current water-stressed situation. Further, the developed WPI can be used to assist
decision-makers and different stakeholders to prioritize issues, challenges and programmes linked to water resource management. It provides an appropriate water governance assessment tool that aims to alleviate water scarcity effects on well-being and livelihood in both short and long terms. Indeed, sustainable water governance, based on WPI, can coordinate the supply, delivery, use (including demand management), and outflows of water in a way that ensures sufficient and equitable levels of socio-economic welfare without compromising the long-term integrity of supporting ecosystems (Rogers & Hall, 2003; Brooks, 2006; Langsdale et al., 2009; Wiek & Larson, 2012; Kuzdas et al., 2014).

The paper first presents an overview of the magnitude of water scarcity and poverty issues in Jordan, then introduces, in the third section, the theoretical basis of the WPI index by exploring the water-poverty linkages. In light of the main strengths and limitations of the initial WPI, an appropriate methodology for weighting and aggregating different components is explained in the fourth section. A step-by-step method for developing the composite index is proposed in this section. To exemplify the utilization of the improved index, it has been piloted and implemented in Jordan as a case study to spotlight the inter-linkages between water-related issues and poverty in this country. The main results are discussed and mapped in the fifth section. The policy relevance of this exercise is highlighted in the sixth section, and finally in the last section the study concludes.

2. Background on Jordan

2.1. An overview of Jordan’s water resources

Jordan is a Middle Eastern country bordered by Syria in the North, Iraq in the East, Saudi Arabia in the South and East, and Palestine and Israel in the West. The surface area of Jordan is 89,318 km² with a population density of 73.5 cap/km² as of 2013. Jordan is divided into three administrative zones: North, Middle, and South, which are subdivided into 12 governorates, which, in turn are subdivided into brigades and districts that consist of cities and villages (Department of Statistics, 2013).

Jordan has a semi-arid climate that is characterized by low, irregular, and uneven annual precipitation, depending on the geographical location. The precipitation, i.e. rain and snow (if any), falls during the winter season that extends from September to May, and 93% of this precipitation is lost to evaporation while the rest forms the main supply of water resources, i.e. surface and groundwater, in the country. More specifically, the remaining 7% of precipitation is distributed: 2.34% as floods and 4.54% as recharge of groundwater. Jordan is actually classified as the world’s third-poorest country in water resources.

Water resources in the country consist of 15 surface water basins and 12 groundwater basins that are distributed across the kingdom (Ministry of Water and Irrigation, 2012). In 2012, the average precipitation was 5,943 million m³, which fell 30% short of the long-term average (Ministry of Water and Irrigation, 2012). Surface water sources include: (1) precipitation in the form of floods, run-off, and springs; (2) reclaimed wastewater; and (3) international water from Yarmok River and Tiberias Lake. Groundwater sources include: (1) renewable resources such as the portion of precipitation that recharges groundwater, and water from a shared aquifer in the northern part of the country; and (2) non-renewable resources.
The population of Jordan is expected to reach 10 million in 2025, with a total demand on water resources of around 1,379 million m³, which is projected to result in a 54% water deficit. The demand for water is distributed as follows: 50% for agricultural use, 34% for domestic use, and 16% for industrial use. The change in the demand pattern across sectors, compared with 2012, is based on an expected increase in public awareness, which in turn decreases domestic water consumption, and an increase in industrial development (Ministry of Water and Irrigation, 2012).

Ground and surface water contributions to the water budget in 2012 were 30% and 70%, respectively. Water demand was 849 million m³ distributed across the three sectors, with agricultural use claiming 54% of this demand, while domestic and industrial sectors claimed 42% and 4%, respectively. The demand exceeded supply by almost one-third despite the contribution made by reclaimed wastewater that amounted to 19% of the available surface water. However, the loss in surface water was 41% in the form of floods, brackish water, storage in dams, and discharge to valleys. The deficit in the water budget was compensated for by over-extraction from groundwater resources. The over-extraction in 2012 was equivalent to 460% of the available renewable resources and 200% of both renewable and non-renewable resources.

Jordan is an agricultural country, even though cultivated land amounts to only 1.16% of the total land area. The agricultural sector in 2013 consumed 54% of total water resources while its contribution to the gross domestic product (GDP) was only 3%. At the same time, the industrial sector consumed 4% of water resources while contributing 19.4% to the GDP. The total area of cultivated lands in 2013 was 2609.4 km², of which 40% were irrigated and 60% were non-irrigated lands (Department of Statistics, 2013). Furthermore, 43% of the irrigated land, which is located in the lowlands, or ‘Jordan Valley’, relies on surface water, while the remaining 57%, which is located in the highlands and deserts, is irrigated by groundwater (Ministry of Water and Irrigation, 2012; Department of Statistics, 2013).

2.2. Poverty in Jordan

The absolute poverty line in Jordan was estimated as JD 67.8 ($95) per individual per month for 2010, while per household, this line was JD 366.3 ($512.8) per month, which amounted to an absolute poverty rate of 14.4% (Department of Statistics, 2010). Figures of the abject poverty line for the same year were estimated as JD 28 ($39.2) per individual per month and as JD 51.2 ($71.68) per household per month, which amounted to an absolute abject poverty rate of 0.32% (Department of Statistics, 2010). During 2002–2010 there was a decrease in the absolute poverty rate but an increase in the abject poverty rate. However, in light of the population increase between 2002 and 2010, these figures can be seen as an increase in the total number of individuals who were below poverty lines under both poverty definitions.

The absolute poverty rate varies across governorates, with Ma’an hitting the highest rate and Jerash hitting the lowest rate (Department of Statistics, 2010). Poverty incidence is 13.9% in urban areas and 16.8% in rural areas. On the other hand, 80.35% of the poor reside in urban areas, with the largest number in Amman. In fact, the number of urban poor is 698,321 and the number of rural poor is 178,458 (United Nations Development Programme (UNDP), 2013). Furthermore, other poverty measurements such as the poverty gap index and poverty severity index were 3.6 and 1.21, respectively, for the same year (UNDP, 2013). A decreased poverty gap index between 2002 and 2008, being significant in rural areas, indicates that the poor are getting poorer and the poor in rural areas are the poorest of all (UNDP, 2013). The inequality in income, which is measured by the Gini coefficient, was 0.376 for
2010, which means that the poorest 10% of the population was responsible for 3.5% of the national consumption (UNDP, 2013).

3. A framework for assessing water-poverty linkages

Water and poverty are inextricably related through a range of aspects. Rijsberman (2003) distinguishes five main aspects: water for basic services (sanitation, hygiene, and health); water for food production and job creation; water for sustainable environmental management; water for gender equality; and water rights and entitlements for the poor. Water supply is both a cause and a consequence of poverty and access to consistent sources of clean water is crucial to poverty alleviation (Abrams, 1999). Besides, Sen (2001) stated that insufficient access to water is one of the main causes of poverty. Indeed, lack of safe water is attenuating efforts to mitigate poverty by reducing labour productivity and increasing the costs of collecting the required volume of water. This is an undesirable impact on, particularly, the economically disadvantaged groups of people who lack social security and a minimum level of income (Barker et al., 2000; Hansen & Bhatia, 2004; Wang et al., 2005).

A society with a low social-adaptive capacity due to socio-economic difficulties could not effectively handle water scarcity issues, thus entering a situation that Turton (1999) has qualified as ‘water poverty’. Recently, the World Water Development Report (2015) has raised an alarm over the water crisis threatening developing and less-developed countries in the form of government failure to manage available water resources. The report reveals that the key issue is the impact water has on the daily lives of the poor and impoverished in relation to water-linked diseases and the inability to earn a living and acquire enough to eat for survival.

In the recent literature, the water-poverty relationship has been studied differently depending on the approaches adopted by researchers. On the one hand, many authors assume that water is essential for achieving sustainable socio-economic development. Over the past five decades, such views have afforded an impetus for the implementation and the promotion of massive investment in the water sector in order to maintain economic growth, rural and agricultural development, national food security, protection against famine, and intensified land use. These efforts are assumed by many organizations and experts to have contributed considerably to the alleviation or eradication of both absolute and chronic poverty in some developing countries. Nevertheless, an opposing view holds that water resource development also has some negative outcomes, when the development becomes environmentally destructive and unsustainable, and that it may negatively affect, either directly or indirectly, the lives of thousands of vulnerable people, particularly the poor.

Although there are contradictions between the two views, they share the common agreement that there is a strong relationship between water and poverty and that water is a vital resource for life which positively or negatively affects the livelihood of the world’s most impoverished. In fact, water can be considered as a socio-economic ‘good’ when it contributes to increased domestic welfare, agricultural and other production, and a more healthy environment. It can be seen as a socio-economic ‘bad’ for human health when it contributes to the spread of waterborne diseases, such as malaria and schistosomiasis, and for the environment when it results in flooding and contributes to land degradation through water logging, salinization, and the spread of pollutants. Improved water management systems are crucial but not alone sufficient to enhance the benefits of water for the poor.
The assessment of water and poverty linkages began emerging first through the use of the Human Poverty Index (HPI), a derivative of the Human Development Index (HDI). According to this index developed by UNDP (2004), a decent standard of living is assessed by the weighted average of two simple indicators: the proportion of the population without regular access to safe water and the proportion of moderately and severely underweight children below the age of five.

The measurement of water-poverty linkages has been further improved through the development of the WPI (Lawrence et al., 2002; Sullivan, 2002; Sullivan & Meigh, 2003). Sullivan has defined the holistic index using a multidisciplinary approach for an integrated appraisal of water stress and scarcity, involving physical estimates of water availability or shortages with social, economic, and environmental variables strongly linked to the well-being of people. The main aim of the index is to uncover the relationship between access to improved water sources and the prevalence of poverty. It has been recognized that the poor often experience inadequate water provision, which results in a considerable loss in time, money, and effort, specifically for the most impoverished populations in the majority of developing and underdeveloped countries. By means of the multidisciplinary approach, a more fair allocation of available water resources is suggested in each application of the WPI (Cohen & Sullivan, 2010; Manandhar et al., 2012; Jemmali, 2013; Jemmali & Matoussi, 2013; Jemmali & Sullivan, 2014). It has been established in an application at the international scale that the linkage between water consumption and economic development is positive (Sullivan, 2002). This implies that development is likely to be affected by water resources management and also the rate of water use in a country. Countries or regions with a higher level of income tend to have a higher rate of water consumption (Sullivan, 2002). The WPI is considered as an endeavour to implement an international or local measure in order to compare performances in the water sector across or within countries in a holistic way taking into account the various aspects linked to water management (Lawrence et al., 2002; Sullivan, 2002).

While some water scarcity indices, such as the WPI, emphasize the current state of the water sector and thus comprise variables that depict access to improved water sources, sanitation facilities, and the situation of water resources, other indices address structural water poverty by focusing only on the costs required to equitably and sustainably provide clean water to all people in a country (Feitelson & Chenoweth, 2002). The main distinction between the two approaches is that the former indices looking at the existing situation are liable to fail to differentiate between ‘situational failures in human adaptive capacity and structural impediments’ (Feitelson & Chenoweth, 2002). In contrast, the structural water poverty indices are intended to recognize countries liable to face grave difficulties in improving their water supply due to structural problems intrinsic within the country, such as mismanagement, power structures, a shortage of technical and administrative capacity, and corruption, among others. The latter indices are of much importance to the current study of the WPI as they afford a feasible, realistic, and simple method of calculation compared to the second type of indices.

In addition, water-poverty linkages have been looked at in terms of water supply and provisions for home consumption (Kulindwa & Lein, 2008). The main topics emphasized in this approach include the impact on human health due to using unsanitary water by which diseases such as diarrhoea, typhoid, and cholera cause more than 2.2 million deaths annually, mainly of children. The prevalence of such

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1 The Human Development Index (HDI) is a composite index developed by the United Nations Development Programme (UNDP), which incorporates quantifiable aspects of basic needs and longevity achievements. It depicts the understanding that poverty encompasses more than material deficiency by affording a new ranking of countries according to their citizens’ quality of life exhibited by life expectancy, educational attainment, and adjusted real income (GDP per capita (PPP US$)).
diseases further negatively influences school attendance and contributes to low productivity at work and high costs of treatment; they diminish considerably the capability of self-reliance. Besides, the issue of lost time has been discussed by numerous studies highlighting the opportunity cost of time used to search for water over long distances, particularly in rural areas. People in urban regions may not walk long distances to get clean water but they may spend more time queuing for water.

4. Methodology and data

To deeply evaluate the water-poverty nexus, one must look beyond the physical availability of water reserves and investigate how water is exploited, managed, and shared (Sullivan, 2002). The theoretical framework of the WPI used in this study accompanied by structural and empirical improvements is founded largely on the entitlements approach of Sen and the sustainable livelihoods analytical framework of Scoones (1998). By calculating the WPI based on a multi-criteria framework used in the HDI, the multivariate water poverty approach used in this study is aimed to assess people’s ability to access improved water sources.

Empirically, the WPI contains five distinguished components (aspects): physical availability of water resources (Resources), extent of access to water (Access), effectiveness of people’s ability and capacity to provide and manage water-associated services (Capacity), ways in which water is used (Use), and the requirement to allocate water for environmental services (Environment). These WPI components, and the indicators and variables used to calculate the different components are summarized in Table 1.

4.1. Normalization of variables

The WPI framework in the current study, as shown in Table 1, comprises five components, nine indicators, and 13 variables. Data used to calculate these WPI components and the final WPI were collected from a range of sources, such as the Jordanian Ministry of Water and Irrigation, Department of Statistics, Ministry of Agriculture, research institutes, Ministry of Planning and International Cooperation, and others (see Table 2). The conceptual description, calculation, and normalization methods of the various indicators of the composite index are illustrated below.

Standardization of the variables, except those expressed as rates or percentages (e.g. precipitation in depth (mm/year), per capita per day domestic water use (l/d), enrolment rate (%), etc.), defined and recorded in various ways is required for comparisons. Among several normalization methods, the minimum-maximum (Min-Max) method used broadly in many WPI studies (Sullivan & Meigh, 2003, 2006; Sullivan, 2005; van Ty et al., 2010) to get the data into a standard comparable range of 0–100 is applied in the current study. This is to conform to recommendations of Nardo et al. (2005) who state that normalization should be carried out to render the variables comparable. It is notable too that the method is applied only when data are reported with various units and/or scales.

Using the Min-Max method, each variable score \( x_i^* \) for a given Jordanian governorate \( i \) is standardized as follows:

\[
x_i^* = \frac{x_i - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}} \times 100
\]
where $x_i$, $x_{\text{min}}$, and $x_{\text{max}}$ are respectively the current value of variable $x$ for governorate $i$ before scaling, the lower and the upper thresholds of the variable $x$ across the 12 governorates in Jordan. Generally appropriate thresholds (or benchmarks) were initially chosen as maximum and minimum values if they were available; otherwise, thresholds of the various variables under consideration in the current study were taken during standardization. As the normalization process can be sensitive to extreme values, it is crucial to carefully select these thresholds to ensure a fair and accurate representation of the data.

### Table 1. WPI composition: components, indices, and variables.

<table>
<thead>
<tr>
<th>Component</th>
<th>Indicator</th>
<th>Variable</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource</td>
<td>Availability (R1)</td>
<td>Average water supply per capita (R11)</td>
<td>High R11-Less water poverty</td>
</tr>
<tr>
<td></td>
<td>Variability (R2)</td>
<td>Coefficient of variation in rainfall (R21)</td>
<td>Less R21-Less water poverty</td>
</tr>
<tr>
<td></td>
<td>Access</td>
<td>Percentage of the population using an improved drinking water source</td>
<td>High A11-Less water poverty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>in urban areas* (A11)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percentage of the population using an improved drinking water source</td>
<td>High A12-Less water poverty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>in rural areas (A12)</td>
<td></td>
</tr>
<tr>
<td>Use</td>
<td>Domestic (U1)</td>
<td>Per capita per day domestic water use (U11)</td>
<td>High U11-Less water poverty</td>
</tr>
<tr>
<td>Capacity</td>
<td>Economic capacity (C1)</td>
<td>Average annual income of household Member (C11)</td>
<td>High C11-Less water poverty</td>
</tr>
<tr>
<td></td>
<td>Physical capacity (C2)</td>
<td>Under-five mortality rate (C21)</td>
<td>Less C21-Less water poverty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average annual percent of typhoid and Paratyphoid cases (C22)</td>
<td>Less C22-Less water poverty</td>
</tr>
<tr>
<td></td>
<td>Social capacity (C3)</td>
<td>Enrolment rate (C31)</td>
<td>High C31-Less water poverty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unemployment rate (C32)</td>
<td>Less C32-Less water poverty</td>
</tr>
<tr>
<td></td>
<td>Institutional capacity (C4)</td>
<td>Total cost of water projects (C41)</td>
<td>High C41-Less water poverty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total cost of sewage projects (C42)</td>
<td>High C42-Less water poverty</td>
</tr>
<tr>
<td></td>
<td>Environment</td>
<td>Water quality (E1)</td>
<td>Less E11-Less water poverty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percentage of unfit cases after microbial analysis of drinking water samples (E11)</td>
<td></td>
</tr>
</tbody>
</table>

Sources: adapted and modified from Sullivan (2001); Lawrence et al. (2002); Heidecke (2006); van Ty et al. (2010); Pérez-Foguet & Garriga (2011); Manandhar et al. (2012); Jemmali (2013); Jemmali & Matoussi (2013).


### Table 2. Data and sources.

<table>
<thead>
<tr>
<th>Data</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation and discharge data</td>
<td>Department of Meteorology (2007–2012)</td>
</tr>
<tr>
<td>Water supply</td>
<td>Ministry of Water and Irrigation (2006–2011)</td>
</tr>
<tr>
<td>Domestic water use</td>
<td>Ministry of Water and Irrigation (2011)</td>
</tr>
<tr>
<td>Average annual income</td>
<td>Department of Statistics/Household Expenditure &amp; Income Survey (2010)</td>
</tr>
<tr>
<td>Number of typhoid and paratyphoid cases</td>
<td>Ministry of Health (2004–2011)</td>
</tr>
<tr>
<td>Under-five mortality rate</td>
<td>Ministry of Health (2012)</td>
</tr>
<tr>
<td>Enrolment rate</td>
<td>Department of Statistics/Population and Housing Census (2004)</td>
</tr>
<tr>
<td>Total cost of water and sewage projects</td>
<td>Ministry of Water and Irrigation (2010)</td>
</tr>
<tr>
<td>Microbial analysis of drinking water samples</td>
<td>Ministry of Health and Environment Health (2011)</td>
</tr>
</tbody>
</table>
outliers (Nardo et al., 2005), all variables were initially in part corrected by means of a methodology analogous to that applied to calculate the Environmental Sustainability Index (Nardo et al., 2005, p.84) by which ‘any observed value greater than the 97.5 percentile is lowered to match the 97.5 percentile [and] any observed value lower than the 2.5 percentile is raised to the 2.5 percentile.’ It is noteworthy as well that the upper threshold of a considered variable such as the under-five mortality rate could be the inferior boundary (minimum value) of the variable and vice versa (see the fourth column in Table 1).

4.2. Calculation of indicators

The introduction of the Resources component in the calculation of final WPI is aimed at assessing the physical availability of water for each Jordanian governorate. A higher value of this component reflects an abundant availability of water resources taking into account annual variability of precipitation, and a lower value means a severe shortage of water resources. As illustrated in Table 1, the Resources component comprises two indicators: the availability indicator (R1) measured by the per capita annual water supply standardized using the formula shown in Equation (1), and the variability indicator (R2) calculated using the following formula (Equation (2)):

\[
R2 = \left(1 - \frac{CV_i}{0.3}\right) \times 100
\]

where \(CV_i\) is the variation coefficient of rainfall of the \(i\)th governorate. Such variability measure is used as a proxy for variation of rainfall over space and time (van Ty et al., 2010; Pandey et al., 2011a). A lower value of the variability indicator means a high consistency of water resource availability and a higher value means a lower consistency which may reveal higher climate-induced risks and vulnerability of available resources.

Adequate access to clean water sources and sanitation services improves hygiene practices and sanitary environment, which are indispensable (but not alone sufficient) to eliminate severe poverty (Sullivan & Meigh, 2003). Whereas, inadequate access to water or access to unimproved water sources implies spread of diseases and a loss of time in water collection that could be exploited for profitable economic/productive activities. The Access component in the traditional WPI, as in the current study, considers regular access to a sufficient volume of clean drinking water and sanitation facilities better for human health and well-being (Sullivan & Meigh, 2003, 2006). Otherwise, only the two access indicators to water supplies in urban areas (A11) and rural ones (A12) are included in the structure of the component; the sanitation indicator was not considered due to lack of appropriate data. The computed values of the obtained indicators were self-standardized in a range of 0–100 as shown in the following equation:

\[
A11 = \frac{P_U}{P} \times 100 \quad A12 = \frac{P_R}{P} \times 100
\]

where \(P_U\), and \(P_R\) are the population living in urban and rural areas, respectively, with improved water supplies, and \(P\) is the total population in the study.

The Capacity component reveals the effectiveness of people’s capacity to manage available water resources. With close linkages between policies, welfare of society, human health, and water
management, the important role of economic, physical, and institutional capacities in the management of water scarcity is increasingly being recognized in several works in the literature since Appelgren & Klohn (1999) and Sullivan (2001). Then, capacity could be interpreted in terms of institutional capacity that permits government or other stakeholders to invest in the water sector and gain access to technology to afford the needed quantity of improved water supplies to the entire population. Besides, capacity could be interpreted in terms of physical, social, or economic capacities that allow people to purchase sufficient quantities of clean water to satisfy their basic requirements in a sustainable manner, taking into account water, sanitation, health, and environmental issues (Sullivan & Meigh, 2003; Pandey et al., 2011a). The economic capacity is assessed using normalization of the average annual income per capita for each governorate shown in Equation (1). Similarly, the physical, social and institutional capacities are assessed using the same formula.

Water is a vital source of life and an important prerequisite to human activity and its consumption generally has a tendency to rise with economic development (Sullivan, 2001). The Use component is the appropriate index that links the ways in which water is used for various purposes and its contribution to the overall economy. Domestic and agricultural sectors, two major water users, were considered broadly as indicators of the use component, but this study uses only the domestic indicator due to lack of data dealing with agricultural water consumption in Jordan.

The domestic water use indicator is aimed at depicting the existing state of resource use in daily household activities (most vitally water for basic needs such as cooking, hygienic purposes, and laundry) (Sullivan & Meigh, 2003; Cullis & O’Regan, 2004). As noted previously in this section, any shortage in provisions of sufficient water for domestic uses lead to a considerable loss of time and effort which may result in severe poverty and slower economic growth. This indicator is measured easily by the daily water use per capita, normalized using the Min-Max approach (see Equation (4)) (Lawrence et al., 2002; Jemmali, 2013; Jemmali & Matoussi, 2013; Jemmali & Sullivan, 2014), where the lower threshold (minimum volume of water needed for domestic hygiene) is taken as 20 litres-per-capita-per-day (lpcd), and the upper threshold (maximum volume of water that fulfils all water needs) is taken as 100 lpcd.

\[
U1_i = \begin{cases} 
\frac{x_l}{20} \times 100, & x_l \leq 20 \\
100 - \frac{x_l - 20}{x_{\text{max}} - 20} \times 100, & 20 \leq x_l \leq 100 \\
100 - \frac{x_l - 20}{x_{\text{max}} - 100} \times 100, & 100 \leq x_l 
\end{cases}
\]  

(4)

where \(x_l\) is the current value of the domestic water use variable in lpcd in the governorate \(i\), with \(x_{\text{max}}\) being the highest value of the variable in the whole country.

It has been established that environmental integrity increases people’s ability to cope with water stress and its negative effects on welfare and livelihood. Besides, it constantly affords benefits and advantages to the entire society from ecosystem goods and services (Sullivan & Meigh, 2003). Major water quality issues arise from environmental degradation due, for example, to poor land use practices, excessive use of fertilizer, and pollution. Thus, maintaining ecological quality and ecosystem health is essential to achieve a sustainable use of available water resources.
As recommended by Lawrence et al. (2002) and Sullivan (2002), water quality could be considered as one of the main indicators of the environment component in the WPI framework. In the current study, due to lack of data related to the environment issues, the considered component contains only one indicator of water quality, which consists of the results of a microbiology analysis of drinking water performed regularly in Jordan. The variable was normalized using the same formula shown in Equation (1).

4.3. Aggregation and weighting

The nine indicators calculated in the first stage after appropriate normalization and aggregation of the 13 variables are aggregated to compute the five WPI components using the simple additive aggregation function. In the second stage, assuming that there is not any compensability between the obtained components, the five indices were aggregated to derive the final WPI using a simple multiplicative function (Equation (5)),

\[ mWPI_i = \prod_{i=1}^{n} \left( \sum_{j=1}^{m} x_{ij} \times w_{ij} \right)^{w_i} \]

where \( mWPI_i \) is the modified WPI value of the \( i \)th governorate; \( n \) is the total number of components which is equal to five; \( m \) is the number of indicators in the \( i \)th component; \( x_{ij} \) is the value of the \( j \)th indicator in the \( i \)th component; \( w_{ij} \) is the weight assigned to the \( j \)th indicator in the \( i \)th component; and \( w_i \) is the weight assigned to the \( i \)th component. The highest value of the WPI which is 100, denotes the best situation (i.e. the lowest possible level of water poverty), whereas 0 is the worst case scenario, as it indicates a more severe instance of water poverty.

In previous works, due to priorities and statistical issues, a non-equal weighting scheme was broadly used to compute the value of the WPI and its components. To objectively estimate weights of both indicators and components, a participative, consultative process, including all stakeholders and beneficiaries and adequately incorporating the knowledge and experience available for the study areas should be used to estimate the appropriate weights to be assigned to different indicators and components (Pandey et al., 2010). Nevertheless, such objective weighting has largely been criticized. In the current study, no weighting structure was used to rationally calculate the values of the WPI and its five components. Such a balanced approach was used by Schulze (2007), van Ty et al. (2010), and Pandey et al. (2011b) in order to diminish bias and make the index more transparent to decision-makers and stakeholders.

5. Results and discussion

The WPI and its five components were computed for the 12 Jordanian governorates, and the resulting indices are mapped in Figures 1–6. As mentioned in Section 4, all component indices, are calculated using an equal weight scheme since no decisive reason was found to favour one component over another. It is noteworthy that in this study, the WPI calculated is used both through its individual
The average WPI ($\text{mean} = 39.77$) in Jordan was found to be lower than the value at the national level ($\text{WPI} = 51.8$) given by Lawrence et al. (2002), indicating a relatively worse case of water poverty for the majority of governorates even if the method of calculation and selection of data differ. A simple view of all maps (Figures 1–6) show that Access and Environment values do not differ significantly except for a few cases in which Resources, Capacity, and Use components are substantially scattered at the national level. To more completely investigate the spatial variation of the computed WPI and its components, focus should simultaneously be placed on the maps that clarify the differences in performance between the considered governorates.

figure and in the form of its components as an inter-disciplinary and monitoring tool that expresses precisely the water situation in various Jordanian governorates.

Fig. 1. Spatial variation of WPI.

Fig. 2. Spatial variation of Resources Index.
Although the average WPI value is somewhat worse than at the national level, it varies widely within the country (SD = 24.76), as shown in the first map (Figure 1). The analysis considering governorates as sub-units of the country shows that the WPI varies largely from 0 (in Amman) to 62.98 (in Ajloun). Ajloun in the northern region of the country is found to have the relatively best situation, when looking at water poverty, compared to other governorates. It has the advantage of the increase in urbanization accompanied by good access to water supplies and sanitation facilities and a lower poverty rate. While, Amman, the capital city, is a governorate more in need that has previously sought aid in gaining access to safe water and sanitation facilities. Balqa, in the central part of the country, had nearly the same WPI score as the average of all districts. The five WPI components in the governorates with high, low, and average WPI scores are further illustrated in maps in Figures 2–6 to improve visualization of the water poverty situation in Jordan.
These maps show that priorities in the governorates differ, for instance, capacity < resource < use < environment < access in Amman; environment < access < capacity < resource < use in Balqa; and environment < access < use < capacity < resource in Ajloun. As for the rest of the governorates, two (Ma’an and Aqaba) have WPI values below the governorates’ average (WPI = 39.77); all of them have a zero score as one of the component scores is equal to zero. The three governorates (Amman, Ma’an and Aqaba) considered as the water poorest in Jordan have the lowest WPI values (WPI = 0) due to the adopted assumption of the non-compensability between different components explained in the previous section. Each of these governorates has a null value of component performance (for Aqaba and Ma’an Use = 0 and for Amman Env = 0), and Amman is found to be the governorate with the relatively worst situation when looking at water poverty and that has previously sought aid in all five component areas,
particularly in access and environment issues. The other seven governorates (Mafraq, Zarqa, Kark, Jerash, Madaba, Irdib, and Tafilah) have WPI values exceeding the governorates’ average.

The spatial variation of the WPI shown in the first map (Figure 1) illustrates that the entire northern part of the country is the least water poor in Jordan; while the most water poor governorates, such as the capital, Aqaba, and Ma’an, are located mainly in the central and southern regions. When looking at component maps (Figures 2–6) to better comprehend the main drivers of such spatial disparity of water poverty between different regions in Jordan, it is surprising that some ‘water wealthy’ governorates in the North, such as Jerash, Irdib, and Ajloun, do not have enough water resources to meet the needs of their populations. The latter governorates, as shown in the Resources map (Figure 2), are struggling for reliable water supplies, while Aqaba and Amman give an impression of better water resource availability. The Access component better illustrates the situation than any other WPI components except for the capital governorate that has a zero score (Access = 0). Zarqa, located in a largely barren desert, has also poor access to water and sanitation facilities, hence it scores the lowest among all the remaining governorates (except Amman).

Furthermore, when looking at the performance of the remaining components, it is evident that the top four governorates (Ajloun, Tafilah, Irdib, and Madaba), the least water poor, are well ranked and belong to the upper classes in all maps except in the Resources map (Figure 2). This means that the population in such governorates, despite the shortage of water resources that characterizes their locations, have regular access to safe water and sanitation services. While in other water-rich governorates, such as the capital and Aqaba, endowed with relatively abundant water resources, residents cannot regularly access safe drinking water and sanitation facilities.

After analysing the water poverty situation in the country using different maps, it is notable that appropriate water management interventions should help both to increase the water supply and consumption at the domestic level and to improve the economic, physical, social, and institutional capacity to more effectively use available resources. This implies that any management intervention and policy must be developed in an integrated fashion, taking into account the multidimensionality of water problems and all factors influencing water resource availability and variability.

6. Policy implications

The constructed WPI affords a better understanding of the linkages between the physical extent of water availability, its ease of abstraction, and the level of societal welfare. The main findings of the current study offer significant implications for both water resources management and academic research. They support sustainable livelihoods and prioritize the water needs in the country which otherwise may lead to a failure of planning and subsequently to economically inefficient investments. In addition, a higher level water poverty assessment, such as the international scale applied in Jemmali & Sullivan (2014), may completely hide lower (governorate) level water poverty. For this reason, a robust assessment of water poverty at a governorate spatial scale provides an efficient basis for management interventions. With the findings of location- and scale-specific WPI component and indicator values, this study clearly illustrates a need for location/problem-specific policy actions and planning at different local and spatial scales to enhance the water poverty situation within the country.

It is clear that the index appeals as a policy tool for project planning, performance monitoring, and resource allocation. Practically, the developed WPI values help to prioritize and choose appropriate
study area(s) among competing areas; for instance, in this study, the 12 governorates in decreasing order of priority could be listed as Amman, Ma’an, Aqaba, Balqa, Mafraq, Zarqa, Karak, Jerash, Madaba, Irbid, Tafilah, and Ajloun. Conversely, a comparison of component values helps prioritize focus areas; the indicator values help prioritize sub-areas (under the considered areas) as well as to monitor the extent of progress in the sub-areas of the chosen focus-area (Manandhar et al., 2012). For instance, Amman, which has the lowest WPI, should receive first priority, and its Access and Environment components should get top focus as both of them are equal to zero. Yet, some of the components and indicators linked to the natural factors are uncontrollable (e.g. resource availability and variability), and some directly refer to development policies (e.g. water supply and sanitation) and others to socio-demographic and economic conditions of the area. Enhancement of the water-poverty situation could be simpler if the aspects that require more awareness are linked to development policies, as they are controllable through policy actions. If the spotlight were placed on raising socio-demographic and economic features, long-term policies, strategies, and programmes would be required.

7. Conclusion and recommendations

With less than 150 m$^3$/capita/year of water available, Jordan ranks as the third-poorest country in terms of water resources in the entire world. This situation is exacerbated by the disparity between governorates as shown in WPI results and over-exploitation of the few available water reserves. Thus, providing the required quantity of water for the population, industry, and agriculture presently poses a great challenge. Considerable population growth and major influx of refugees from neighbouring conflict zones have aggravated the already difficult situation. If there are not substantial changes in the nature and level of water consumption, the results could be catastrophic for human health and the environment.

The WPI approach used in this study answers the call for an interdisciplinary approach merging both the socio-economic and biophysical realities within spatial frameworks, ensuring a better comprehension of the liaison between water, poverty, and livelihoods. Arguably more useful and robust than the one-dimensional analysis of water issues, the WPI calculations prove particularly useful to development organizations if computed prior to project implementation, for baseline surveys and midterm reviews, and for project completion reports. Besides, the approach clearly reveals its ability to differentiate between the 12 Jordanian governorates and allows comparisons to be made through the five components and the modified WPI. Indeed, targeting the water poor locations through obtained maps compares favourably with other methods presently used (statistics, reports, tables and graphs), since they are a powerful, visual and easy-to-understand tool that can be used by all stakeholders.

Further, the developed WPI can be used as a swift assessment tool for local-level poverty assessment in unprivileged zones where a focus on water resources is considered vital. Yet, it’s noteworthy that this is the first iteration of the improved WPI, and as such, supplementary efforts are required to refine and upgrade the tool. For example, the index can only be as precise as the data used to compute its five components, and it has been stated that some indicators incorporated in the exercise were weakly documented. Accordingly, if policy decisions are to be made based on this tool, continued involvement of relevant stakeholders, policymakers, scholars, or development organizations will be crucial to make it easier to collect more accurate and appropriate WPI data, as well as to highlight the need for repeatedly updated databases.
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