Water Poverty and its Impact on Income Poverty and Health Status in Sudan: The Case of Gezira State (1993-2013)

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Abstract

Water resource development can address poverty, improve well-being, and enhance people's opportunities in different fields of life. Even though water resources are available in Sudan, some parts of the country still continue to face significant water provision challenges. This research is aimed at measuring water poverty in Gezira State, Sudan over the period of 1993-2013 using the methodology of Sullivan et al. (2003). The research employed data collected from the Central Bureau of Statistics, Khartoum, Sudan. Both descriptive and empirical approaches are used to analyze the data. The average incidence of the water poverty index (WPI) over the period under consideration is estimated at 41.8 %, which is quite high given the fact that Gezira State is endowed with huge water resources and capacities. Environmental problems are found to be the main contributor to water poverty in the state. The results also assert that water poverty significantly increases income poverty. In this case, a 1% increase in water poverty is found to increase income poverty by 2.3%. It is worth noting that agriculture is the dominant economic activity in Gezira State because water is of paramount importance for production, grazing, and agro-industries. Furthermore, the results reveal that water poverty significantly reduces life expectancy at birth. The elasticity of life expectancy at birth with respect to changes in the WPI is estimated at -0.11. The study recommends the adoption of better water use in various fields of development besides solving the water supply problems, particularly in rural areas of the state, solving the environmental challenges that face water resources, enhancing institutional capacities for the water sector, improving the level of water management by the adoption of effective water regularity systems, and encouraging water awareness programs through the different types of media. Investing in water and sanitation is highly recommended to generate rapid returns.

Introduction

There's no doubt that water is essential for life. It covers 70% of the Earth. Water also is considered a key factor for development since a good water supply will increase productivity in agriculture, livestock, and industry, and help eradicate extreme poverty and hunger. The Millennium Development Goals (MDGs) as well as the Sustainable Development Goals (SDGs) were put forward by the United Nations in 2000 and 2015, respectively, to improve the quality of life for people around the world. It is worth noting that the MDGs and the SDGs are directly or indirectly water dependent.

Water contributes to rural and urban livelihood in many ways. Adequate access to water is a prerequisite for realizing development. Water resource development can address poverty, improve well-being, and enhance people's freedom and opportunities to accumulate assets that give them dignified lives. Currently for many rural poor, water security is necessary for livelihood security. Even with diversification of rural livelihood and with increasing urbanization, it is estimated that 50% of the poor people will remain in rural areas by 2035; a significant number of them are small producers (IFAD, 2001).

It is a well-known fact that water is essential for life, and an adequate water supply is a prerequisite for human and economic development. Global water resources are limited, and only through a more sustainable approach to water management and more equitable and ecologically sensitive strategies of water allocation and use can we hope to achieve the set international development targets for poverty reduction by 2015 (Sullivan, 2002).

Although water may be abundant globally, water scarcity may be a problem regionally or locally, especially if quality and sustainability considerations are included in the assessment of the resources. Even though water resources are available in Sudan, some parts of the country still continue to face significant water provision challenges. Some parts of Gezira State, Sudan still lack water supplies, particularly in rural areas of the state. The situation becomes worse in summer every year.

The main objective of this paper is to highlight the issue of water poverty in Sudan with special reference to Gezira State. The paper also aims at computing the water poverty index (WPI) in the Gezira State during the period of 1993 to 2013. Furthermore, the paper investigates the impact of the WPI on income poverty and health status in Gezira State.

The importance of this research stems from the fact that water is essential for life and development. Water, both for production and consumption, plays a critical role in any population's development. Furthermore, improvement in the water supply and sanitation sector would also increase the likelihood of achieving the rest of the MDGs and SDGs.

This paper uses both descriptive and analytical approaches. After computing the water poverty index, some descriptive statistics namely, the mean, standard deviation, and coefficient of variation, will be extracted and analyzed. The Ordinary Least Squares (OLS) technique will also be used to investigate the impact of the WPI on income poverty and health status in Gezira State.

The rest of this paper is organized as follows: Section 2 deals with the literature review, while Section 3 illustrates the methodology and data used in the study. Section 4 discusses the empirical results and policy implications and the findings. Finally, section 5 finishes the paper with some concluding remarks.

Literature Review

Water poverty is a catchall term used to refer to a lack of access to clean water for drinking, washing, and bathing, and it includes a lack of access to proper sanitation. According to Tobin (2014), water poverty means that your nearest source of water is far away, unclean or unaffordable. Around the world, 783 million people suffer from water poverty. Water is so fundamental to every aspect of life that water poverty affects people in many other ways – children fetch water instead of going to school, women are trapped in endless hours of back-breaking work fetching water, and people suffer from fatal and debilitating water-borne diseases. Water poverty also includes sanitation (toilets) and the promotion of hygiene. Sanitation is an even bigger problem than lack of water with 2.5 billion people worldwide suffering from a lack of good enough toilets or latrines. Getting hold of clean water isn't good enough if the water is being made dirty because there are no toilets, and toilets aren't good enough if there is no hygiene promotion to get whole communities to change the habits of generations so they use the latrines.

According to the World Wide Fund for Nature (2012), water poverty was measured as a combination of resource availability and people's ability to access the resource. For instance, people were considered water poor if sufficient water for their basic needs was not available. Similarly, they were water poor if they had to walk long distances to collect water. Overall, only the availability of natural water sources at the village level has been considered in calculating water poverty. Subsequently, it was realized that many other factors apart from availability and accessibility can be responsible for water poverty. Today, it is accepted that people can be water poor because, among other reasons, they do not earn an adequate income. People can also be water poor if they do not have the means to ensure purification of drinking water. The Water Poverty Index (WPI) was developed to express the complex relationship between sustainable, water resource management and poverty at all levels, whether community, village, district, region or nation. In recent times, the WPI has been used as a policy tool to assess the degree to which water scarcity impacts human populations.

The WPI is an integrated assessment of water stress and scarcity, linking physical estimates of water availability and the socio-economic factors which impact the access and use of this resource. The purpose of the index should thus be to identify the ability of countries or regions to address their water supply needs. In other words, it is hoped that the development of such an index will enable decision makers to target (at various levels) crosscutting issues in an integrated way, by identifying and tracking the physical, economic and social drivers that link water and poverty. The WPI indicates that there is a clear link between poverty, social deprivation, environmental integrity, water availability and health (Giné & Foguet, 2009).

Yahaya et al. (2009) evaluated the WPI as an integrated tool available to all local government areas in the Ondo State of Nigeria to address their water sector. Simple time analysis and composite index approaches were employed to compute WPI values in all the sampled areas. Variables such as water resources, access to safe water, use of water, and environmental impacts were considered. The study evaluated the water poverty index using two approaches and also some other indexes such as human development, and combined their finding together to determine the degree of water stress in each of the local government areas in the state then recommended realistic measures to address the pathetic situation. The results obtained from the two approaches indicated that the Ese-Odo, Ilaje and Irele local government areas are the most water-stressed regions. These findings were coupled with a low Human Development Index in the state, while areas such as Ose, Owo, Ondo-West, and Ondo-East local government areas had far better access to portable water and a better Human Development Index. Heuristic application of the composite index approach to test the generated dataset provided flexible and strong decision-making strategies in such a way as to construct a holistic water management tool that addressed the problems of poverty and its relationship to water access and use. The results also asserted that many state and local government areas were moving towards a point where water resources are insufficient for agriculture, drinking and other domestic uses.

Using household data from the 2009 General Household Survey, Matshe et al. (2010) investigated the role of natural resource scarcity in rural development in South Africa, with a particular focus on water scarcity. The study examined whether there was a direct link between household water and economic poverty of rural households, with household total monthly income used as an indicator of economic poverty. An adaptation of a comprehensive water poverty index, which considers water access, quality, use, and water-related environmental aspects, could be used to measure household-level water poverty. The empirical analysis used an instrumental variable estimation framework in order to deal with the potential endogeneity between water and economic poverty. The results supported the existence of a direct link between water and economic poverty, with water-poor households likely to be economically poor. More precisely, the results suggest that access to good quality water from a reliable source significantly enhances a rural household's economic status. Also, access to water determines the realized impact of overall water poverty on a household's economic status. The paper thus cautions that the development of policy not treat water and economic poverty in isolation; there is need for the development of policy in South Africa to streamline water use in rural development. In addition, development of policy needs to take into account the role of household heterogeneity as conditions of both household water and economic poverty levels.

The WPI is based on five components: resources, access, capacity, use and environment as argued by Lawrence et al. (2002). The WPI can be used then through its individual figures or in the form of its components as an interdisciplinary and monitoring tool that expresses precisely the water situation in various areas. The WPI must be based on equally weighted averages to produce single component index scores.

Manandhar et al. (2012) used the WPI to evaluate the state of water resources in the context of the Nepalese river basins with a case study of the Kali Gandaki River Basin (KGRB) located in western Nepal. They selected suitable indicators with due care of local context and data availability to apply the WPI that was felt to be a holistic tool for water resource planning and management. The study suggested and described a set of ten WPI indicators and twelve variables suitable for the Nepalese context. The selected set of indicators and variables were used to discuss the water poverty situation in the study basin, spatial variation within the basin, and variation at different spatial scales in the basin, that is, basin, sub-unit of the basin (district) and sub-unit of the district (the Village Development Committee (VDC)). The study results show that the WPI varies widely (from 37.1 to 56.5) within the study basin suggesting the need of location-specific policy interventions. On different spatial scales, there is no clear trend. However, analysis of the WPI components show higher resources and access at the basin level, i.e. higher use, environment and capacity at the sub-sub-unit of the basin level. Such variations suggest the need of scale-specific policy interventions and management plans to improve the overall water poverty situation in the study basin. Overall, the WPI can help to examine the water poverty situation and recommend priority areas for policy interventions for the improvement of the water-poverty situation in the basin.

In an examination of other parts of the world, Fenwick (2010) argued that Mexico has had an astounding array of water challenges where even areas with a natural abundance of water face difficulties in the provision of an adequate water supply. Particularly compelling is the region of Los Altos. Situated within Mexico's most water-rich state, Los Altos' access to water is exceptionally constrained. This contrast of scale was the incentive for selecting the rural communities of Pozuelos and El Mash to examine water poverty in detail. A careful examination of water poverty was first undertaken at the state level. Next, water poverty was assessed in the community through an extensive field study comprising of a thorough assessment of infrastructure, water quality analyses, researcher observations, informal interviews and participatory focus groups. These data provided the basis for calculating the WPI at the community level. Analyses were then undertaken focusing on statistical correlations using Pearson's product moment correlation coefficient informed by researcher observations, regression analyses and community perceptions. As the only indicator to assess the multiple dimensions of water poverty, the WPI, by definition, is the best tool available. However, the issue of scale continues to be challenging whilst predictions of water poverty are complex and marred by subjectivity. A lack of consensus surrounding appropriate variables is problematic and inhibits comparisons across localities. Perceptions of water poverty at the community level differ from results obtained using the WPI which further questions reliability. Notwithstanding, the WPI highlights the need for a multi-dimensional approach to the determination of water poverty by demonstrating the lack of relationship between water resource availability and overall water poverty across scales. However, this research has demonstrated the complex nature of the WPI rendering its application in practice as being quite difficult.

Gezira State

Gezira State is located in the middle of Sudan. It is delimited on the North by Khartoum State, Sinner State on the South, Gadarif State on the East, and White Nile State on the West (Latiude 14-25 North, Longitude 33-30 East, and 407 meters above sea level). Gezira State has an area of 25,549.2 km^2 and an estimated population of approximately 3.6 million. The average household size is estimated to be 6 persons. Gezira is divided into seven localities from North-East to South-West namely Alkamlin, Eastern Zone, Alhasahisa, Um Al Guar, Greater Wad Medani, Almanagil and Southern Gezira. The normal annual rainfall ranges from 120 to 200 mm in the northern part of the state and between 200 to 300 mm in the southern part. The population of Gezira state was about 3.8 million in 2011 according to the 2008 census. Gezira State ranks second after Khartoum State in terms of human development. The adult literacy rate is high (about 80%). The incidence of poverty is about 38% compared to 26% in Khartoum and above 55% in eight other states in Sudan. The unemployment rate (10+) is 17%, while unemployed people seeking work for first time (10+) is 68%. The economic activity rate is 34%. Regarding agricultural production, sorghum is a main crop, which is planted under rain fed irrigation (Gezira State Environmental and Natural Resources Council, 2012).

Gezira State enjoys water resources from the Blue Nile, Rahad and Dinder Rivers. Groundwater quality is generally good, except in some locations such as Abu Guta and Managil where *Hafir* and filtered water from irrigation canals are the sources of drinking water. In the last few years, great efforts have been made to dig very deep artesian wells to improve the water supply in these areas.

The Gezira Agricultural Scheme (GAS) was founded in 1913 to cover an area of 153,415 hectors, making it one of the largest irrigation schemes in the world as it comprises 35-50% of the total cultivated area in the country (about 32% of the state). The scheme is divided into 18 sections. The main agricultural products in all the sections are cotton, sorghum, wheat, groundnuts and vegetables. The canalization network consists of 5,649 km with a depth ranging from 0.50 to 0.75 meter. In this scheme, more than 85% of the pesticides imported into Sudan are used for the control of cotton pests (Thorton, 1972.). Every year, the scheme receives intensive aerial spraying of pesticides from different classes that is directed toward cotton, wheat and vegetable pests. Cotton spraying starts in August and ends in November, while wheat spraying starts in February and continues through March, and vegetable spraying is performed all year round according to the pests and the cultivated vegetables.

Methodology and Data

This section focuses on the research methodology that was used in the analysis of the findings, and the sources of data employed in the study. As mentioned earlier, the purpose of this paper has been to compute the WPI for Gezira State, Sudan during the period of 1993 to 2013, and to investigate the impact of the WPI on income poverty and the health status in the state.

The researcher used the methodology developed by Sullivan et al. (2003) for computing the WPI. The WPI stems from a realization that assessing a household’s access to water requires a holistic approach that takes into consideration, not only whether or not a household has access to water, but also issues related to water quality and variability, multiple uses of water, a household’s capacity to manage water, as well as environmental and spatial scale aspects related to water. In proposing a WPI that considers these aspects, Sullivan et al. (2003) identified, via a community participatory approach, the following five components as key to a holistic WPI:

1. Resources: This captures physical availability of both surface and groundwater,
2. Access: This considers access to water for human use (drinking and nondrinking),
3. Capacity: This relates to the ability of people to manage water,
4. Use: This considers the multiple uses of water, and
5. Environment: This seeks to factor in environmental integrity related to water resources.

These five components are used to construct a WPI. Sullivan et al. (2003) argued that the construction of the WPI should follow a structure similar to that of the Human Development Index (HDI). Specifically, each component is constructed via the following general formula:

$$WPI = \frac{\sum_{i=1}^{N} w_t X_t}{\sum_{i=1}^{N} W_i}$$

Where:
WPI = Water Poverty Index;
X_i = Component i of the household's WPI, with i = Resources (R), Access (A), Capacity (C), Use (U), and Environment (E).
w_i = The weight applied to the WPI.

The formula can be re-written as:

$$WPI = \frac{w_r R + w_a A + w_c C + w_u U + w_e E}{\quad}$$

The above formula gives the weighted average of the five components. Each of the five components is first standardized so that it falls in the range 0 to 100, thus the resulting WPI value is also between 0 and 100.

The data on the variables of interest are collected from the publications of the Central Bureau of Statistics (CBS), Sudan. It is worth mentioning that except for the average annual rainfall, annual time series data on the variables of interest are not available. Thus, using data from the years 1993 and 2008 (as shown in Table 1), and adopting the growth rate methodology between two end periods, annual time series data on the research variables was produced for the period under consideration.

Table 1
WPI Components and Indicators for Gezira State, Sudan (1993, 2008)

Components	Data Used (Variable)	1993	2008
Resources	Annual average rainfall (mm)	247.6	250.7
	Coefficient of variation of rainfall	20%	20%
Capacity	Population	2,715,605	3,549,026
	Illiteracy rate	44.4%	26.6%
	Education enrollment rate	67.9%	74.4%
	Under -five mortality rate	126	111
	Number of beds in hospitals for 100000 population	2.6	3.5
Access	Percentage of population with access to safe water	54%	60%
Use	Per capita domestic water use (in litre per day	16	20
Environment	Percentage of population with access to sanitation services	23.2	50

Sources: Central Bureau of Statistics (CBS), Khartoum, Sudan.

It is worth mentioning that the WPI according to the Sullivan et al. (2003) formula examined the index as a water management index in the sense that the high value of the index means a low water poverty rate. This research directly computes the water poverty rate by converting the variables of interest to deprivation indicators (school dropout, percentage of population without access to safe water, percentage of population without access to sanitation services, etc.).

After computing the WPI for the period of 1993 to 2013, this paper has investigated the impact of the WPI on income poverty (head count index; H) and health status proxied by life expectancy at birth (L). Time series data on these two variables are also computed using the growth rate for two end points. In the last two population censuses, namely in 1993 and 2008, life expectancy at birth in Gezira State was estimated at 58.4 years and 61.3 years, respectively. The head count index for the poverty rate in Gezira State in the years 1993, 1996, and 2009 was computed at 86%, 92%, and 37.8%, respectively. These objectives of impact analysis were realized by adopting the Ordinary Least Squares (OLS) technique. It was hypothesized that the WPI impacts positively on income poverty, while it impacts negatively on health status.

The Empirical Results

To carry out the research objectives, it was useful to provide some descriptive statistics for the study variables as given in Table 2.

Table 2

Descriptive Statistics for the Study Variables

Variable	average	Standard Deviation (SD)	Coefficient of Variation (C.V)
WPI	41.8	6.4	0.153
H	59.1	21.8	0.370
L	60.2	1.2	0.020

Source: Researcher's own calculations based on data of the appendix.

It is clear from Table 2 that the average incidence of the WPI is estimated at 42%. Environmental problems constitute the main cause of water poverty in the State. Although water poverty was reduced from 50.9% in 1993 to 42% in 2003 and further to 31.2% in 2013 (Table 3), the average WPI of 42% is quite high given the fact that Gezira State is endowed with huge water resources and capacities. It is also clear from Table 2 that on average, 59% of the population of Gezira State is classified as poor. The head count index is found to be highly volatile compared to the other two indicators, with a coefficient of variation of 37%. The average life expectancy at birth is estimated at 60 years.

Table 3

Water Poverty Index (WPI), Life Expectancy at Birth (L), and Head Count Index (H) for Gezira State, Sudan (1993 – 2013)

Years	WPI (%)	L (Years)	H (%)
1993	50.91	58.4	86
1994	50.04	58.6	87.9
1995	49.43	58.8	89.8
1996	48.93	58.9	92
1997	47.44	59.1	85.7
1998	46.79	59.3	79.9
1999	45.92	59.5	74.5
2000	44.53	59.6	69.4
2001	43.5	59.8	64.7
2002	43.84	60.0	60.3
2003	42.01	60.2	56.2
2004	40.21	60.4	52.4
2005	39.78	60.5	48.8
2006	38.92	60.7	45.5
2007	36.69	60.9	42.4
2008	35.57	61.3	39.5
2009	44.83	61.5	37.8
2010	33.48	61.7	35.3
2011	31.86	61.9	32.9
2012	31.98	62.0	30.7
2013	31.24	62.2	28.6

Sources: Central Bureau of Statistics, Khartoum, Sudan and Own Calculations based on the Growth Rate for Two End Points.

By applying the Ordinary Least Squares (OLS) technique, we investigated the impact of the WPI on income poverty and life expectancy at birth. The estimation results are shown in Table 4 where the figures inside the parentheses are the t-ratios of the estimated parameters (elasticities) and those inside the square brackets are the P- values.

The estimation results of Table 4 reveal that the WPI explains there is an 88% and 84% change in income poverty and health status, respectively. Both the estimated equations are statistically significant at the 1% level as indicated by the F–ratios in both estimated equations. The Durbin–Watson statistic (D.W.) indicates the absence of a serial correlation problem at the 1% level in both estimated equations. The results also signify that water poverty significantly increases income poverty. More precisely, a 1% increase in water poverty is found to increase income poverty by 2.3%. It is worth noting that agriculture is the dominant economic activity in Gezira State for which water is of paramount importance for production, grazing, and agro-industries. Furthermore, the results reveal that water poverty significantly reduces life expectancy at birth. The elasticity of life expectancy at birth with respect to changes in the WPI is estimated at -0.11.

Table 4

The Impact of WPI on Income Poverty in Gezira State, Sudan 1993 – 2013

Dependent Variable	**Estimated Coefficient (elasticity) of**		**F-Ratio**	R^2	**D.W.**
	Constant (a)	**Ln WPI**			
Ln H	- 4.6 (- 6.1) [0.000]	2.3 (11.5) [0.000]	133.2 [0.000]	0.88	1.92
Ln L	4.5 (105.5) [0.000]	- 0.11 (- 9.9) [0.000]	98.5 [0.000]	0.84	1.85

Source: Researcher's Own Calculations.

The study recommends the adoption of better water use in various fields of development, other than solving the water supply problems. Particularly in rural areas of the state, solving the environmental challenges that face water resources, enhancing institutional capacities for the water sector, improving the level of water management by the adoption of effective water regularity systems, and encouraging water awareness programs through different means of media should be the focus for creating policies. Investing in water and sanitation is highly recommended to generate rapid returns.

Concluding Remarks

This paper adopted Sullivan et al. (2003) methodology to compute the WPI for Gezira State during the period of 1993 to 2013. The average WPI during the period under study is estimated at 42%, which is considered quite high given the resources and capacities the state is endowed with. Environmental problems constitute the main cause of water poverty in the state. The results also reveal that the WPI impacts positively on income poverty and negatively on life expectancy at birth. The study recommends the adoption of better water management and use in various fields of development. Solving the problem of the water supply, particularly in rural areas of the state, is highly recommended in addition to adopting effective water regularity systems, encouraging water awareness programs, improving the environmental conditions for water resources, and investing in water and sanitation.

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