Effects of Imprecise Weighting on the Water Poverty Index

Charles van der Vyver
Charles.vandervyver@nwu.ac.za
North-West University
South Africa

Abstract

This study aims to illustrate the effects of incorrect weightings on the water poverty index (or WPI) process through the use of a practical example. It uses the WPI values of three towns in South Africa to show how incorrect weightings can lead to a misallocation of resources. The WPI values for the towns are calculated with the use of four different weighting groupings, after which a comparison is drawn. The comparison clearly indicates that unless all stakeholders provide input, incorrect weightings can lead to the wrong type of intervention. This leads to the conclusion that unless the weightings are unanimously agreed upon, weightings should be left out of the equation. Future research should focus on expanding the possible weighting groupings, or on modifying the WPI formula to lessen the impact of incorrect weightings.

Keywords

Water Management, Water Poverty Index, Weightings.

1. Introduction

The norm has been to think of water poverty merely in terms of a lack of the actual resource, whereas Sullivan *et al.* (2003) and Sullivan (2005) have shown that water poverty should be expressed in terms of five components, namely resource, access, capacity, use and environment. These five components are contained in the Water Poverty Index (or WPI), as developed by Sullivan *et al.* (2002), and refined by researchers at the Centre for Ecology and Hydrology in Wallingford, UK. These five components each consist of different sub-components, which are typically chosen based on the intended use and application area of the index. According to Kaczan *et al.* (2011), when working on a small scale, like in this study, there is a definite correlation between water poverty and poverty. Therefore a reduction in the water poverty of a region, will lead to a reduction in poverty as well.

2. Water Management

During recent years the two major shortcomings of water management that have been widely recognized are, firstly, very little or no pollution control, and secondly inefficient utilization. According to Pallett (1997), the aim of water management should be to supply people with essential water supplies whilst ensuring that water continues to be shared amongst all the components of the human and the natural environment in a river basin. Water and poverty interface in more than one way (Ahmad, 2003), and the management of water resources is, therefore, a vital process element of sustainable human development. If we continue to use our water resources as we currently do, the world will be facing a severe water shortage as early as 2025 (Clarke *et al.*, 2004). This will lead to reduced food production, which in turn will lead to malnutrition and disease, and also to increased ecological damage.

3. The Water Poverty Index

The conventional methods to assess water management were purely deterministic relying on the availability of large-scale data. A method that was easy to calculate, cost effective to implement, based mostly on existing data, and that uses a transparent process (i.e. easy to understand), was needed. This motivated Sullivan *et al* (2002) to design the Water Poverty Index (WPI). The WPI has the following advantages over conventional methods:

- The WPI is mainly designed to help improve the situation for people facing poor water endowments and poor adaptive capacity;
- It provides a better understanding of the relationship between the physical availability of water, its ease of abstraction, and the level of welfare;
- It is a tool for monitoring progress in the water sector;
- It is a mechanism to prioritize water needs.

The WPI allows the use of different scales to be applied for different needs and defines water poverty according to five components. These components are:

- **Resources**. The availability of water, taking into account the variations in seasonal and inter-annual fluctuations and water quality.
- **Access**. The accessibility of water for human use.
- **Capacity**. Capacity is interpreted in the sense of income to allow purchase of improved water, and education and health, which interact with income and indicate a capacity to lobby for and manage a water supply (Cullis, 2005; Lawrence *et al.*, 2002).
- **Use**. Captures the actual amount of water being used and extracted from the system.
- **Environment**. This variable captures the environmental impact of water management (Lawrence *et al.* 2002).

Each of the five components consists of a number of sub-components and a weighting (see section 6) can be applied to each component to indicate the component's importance. The components are standardized to fall in the range 0 to 100, resulting in a final WPI value between 0 and 100. The highest value 100 is taken to be the best situation and 0 being the worst.

The five key components are combined together in a general expression:

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

Where
WPI = Water Poverty Index score of a particular location
R = Resources component
A = Access component
C = Capacity component
U = Use component
E = Environment component
w = weighting factor for each component

The WPI was the preferred indicator for this study, although other indicators like the Water Stress Index (Gleick, 2002), the Water Scarcity Index (Asheesh, 2004), etc. were considered. However these indicators did not provide sufficient detail, especially when working on a smaller scale. A high level of detail is required to allow targeting of resources to address specific problems.

4. Demarcated area

South Africa's water resources are limited and in global terms are scarce (Hemson *et al.*, 2008), and has been rated as one of the 20 most water-deficient countries in the world (Meyer, 2007). South Africa also has a high unemployment rate, which means that many people simply cannot afford to pay for basic water and sanitation (Holland, 2005), and many people who can afford to pay simply don't pay for public services because they consider it a right. South Africa, being a water-stressed country, with less than 1700 m^3 of water for each person per year (Rand Water, 2008), has limited fresh water resources and budgets for the supply of basic infrastructure services. Currently over 6 million people in South Africa are without access to even a basic level of water supply or have a very limited level of access (Cullis, 2005).

For the purpose of this study the water poverty index was calculated for three towns in South Africa that together form the region referred to as the Vaal Triangle. The three towns are Vanderbijlpark, Vereeniging and Sasolburg. The first two of these are in the southern part of the Gauteng province and fall under the governance of the Emfuleni local municipality. The last one is in the northern part of the Free State province and falls under the governance of the Metsimaholo local municipality.

5. WPI calculation

The following sections will briefly discuss the WPI component scores for each of the towns mentioned in the previous section. For a full discussion on the chosen sub-components and the benchmark levels see Van der Vyver & Jordaan (2011).

Resource

After an analysis of the operations of the local municipalities and the local bulk water services provider, it was identified that looking at the total resource availability in an area in terms of groundwater and surface water availability is an irrelevant method for the Vaal Triangle area that is under consideration in this study. The method suggested by the analysis is motivated firstly by the fact that it is the method currently used by management when looking at total resource availability, and secondly because it is a method that supports prediction. It recommends that the resources of the area should be expressed in terms of the percentage of water that the service provider actually extracts from the water system in comparison to the amount of water that may be extracted.

Table 1 lists the resource component score for each of the three towns in the study.

Table 1 Resource component score

	Value (Extraction rate %)	**Score (%)**
Vanderbijlpark	90	100
Vereeniging	90	100
Sasolburg	90	100

The values for the three towns under consideration are the same because all three towns receive their water from the same water system.

Access

The access component value is calculated as

$$A = \frac{\text{Households with access to secure water source}}{\text{Total households}}$$

A secure water source is defined as being piped water either inside the dwelling or inside the yard. This study is limited to these two sources of water as there are too many factors influencing access to a communal water source such as certain community factions monopolizing the facility, etc. The data for the access and capacity components are obtained from Census data, which is available from Statistics SA (www.statssa.gov.za). Table 2 lists the access component score for each of the three towns in the study.

Table 2 Access component calculation

	Households With Safe Water Source	**Total Households**	**Value (Proportion)**	**Score (%)**
Vanderbijlpark	25 422	26 602	0.955	95.564
Vereeniging	21 103	22 884	0.922	92.217
Sasolburg	7 456	7 644	0.975	97.541

Capacity

The capacity component consists of Educational Capacity as well as Income Capacity. The Educational Capacity value is calculated as

$$EC = \frac{\text{People with education greater than grade 4}}{\text{Urban population}}$$

and the Income Capacity value is calculated as

$$IC = \frac{\text{Households with income greater than R26400 per annum}}{\text{Total households}}$$

The two sub-components used for the capacity component have been assigned equal importance (Cullis, 2002; 2005), although weightings can be introduced if all stakeholders feel its inclusion is relevant. The capacity component value is therefore merely the average of the two sub-components and is calculated as

$$C = \frac{EC + IC}{2}$$

Table 3 lists the capacity component score for each of the three towns in the study.

Table 3 Capacity component calculation

	People With Education > Grade 4	**Total Population**	**Education Capacity (%)**	**Households With Income > R26 400**	**Total Households**	**Income Capacity (%)**	**Score (%)**
Vanderbijlpark	63 529	474 081	13.4	18 432	26 602	69.288	41.344
Vereeniging	58 649	497 600	11.786	15 135	22 884	66.14	38.963
Sasolburg	19 906	141 000	14.118	6 220	7 644	81.371	47.745

Use

The use component value is calculated as

$$U = \frac{\text{Direct requirement urban}}{\text{Urban population}} * \frac{10^9}{365} \text{ l/c/d (liters/capita/day).}$$

As this study and water poverty mapping generally focus on residential water poverty alleviation, it is important to differentiate between residential and non-residential water use. The local municipalities indicated that, on a month-to-month basis, residential water use tends to fluctuate between 50% and 55% of the total water use and non-residential between 45% and 50% of the total water use. Therefore, a figure of 52% will be used for residential use, and 48% for non-residential use.

The data for the use and environment component is obtained from the Water Situation Assessment Model (or WSAM) version 5.001, which is available from the Department of Water Affairs. From the three towns under consideration, Vanderbijlpark was the only town where the use component value was not adjusted, as the major non-residential water consumer in the town obtains their water directly from the local water services provider, and not from the local municipality. This is however not the case for Vereeniging and Sasolburg, as both these towns have major non-residential water consumers that obtain their water from the local municipality, and including these two towns in the usage figures corrupts the use component score. Table 4 lists the use component score for each of the three towns in the study.

Table 4 Use component calculation

	Direct Requirement Urban	Population	Value (l/c/d)	Score (%)
Vanderbijlpark	22.26	474 081	128.641	80.401
Vereeniging	25.896	497 600	142.58	89.113
Sasolburg	10.598	141 000	205.926	71.296

Environment

The environment component value is obtained directly from the WSAM, and no calculation is required to determine the component value. It has a range of 0 to 5, with 0 indicating a "very poor" ecological state and 5 a "perfect" ecological state. Table 5 lists the environment component score for each of the three towns in the study.

Table 5 Environment component calculation

	Index (Rating)	Score (%)
Vanderbijlpark	4.086	81.72
Vereeniging	3.641	72.82
Sasolburg	3.856	77.12

Component summary

Table 6 contains a summary of the component scores for each of the towns in the demarcated area. These are the scores that will be used in the WPI calculation.

Table 6 Component score summary

	Resource	Access	Capacity	Use	Environment
Vanderbijlpark	100	95.564	41.344	80.401	81.72
Vereeniging	100	92.217	38.963	89.113	72.82
Sasolburg	100	97.541	47.745	71.296	77.12

6. Component Weighting

The option of adding different weightings to the components has been included in the WPI to compensate for different priorities and circumstances. When deciding which weightings to use for the calculation of the WPI, the hydrological and economic conditions, as well as the national/regional priorities of the specific area need to be considered. Table 7 contains the various weighting groupings as compiled by Sullivan *et al.* (2002). This is not intended as an exhaustive list, but more of a guideline with regards to options that have proven viable in similar studies.

Table 7 Weighting options for the WPI

	Local condition descriptors			Component weights				
Weighting Option	Hydrological condition	Economic condition	National priorities	Resource	Access	Capacity	Use	Environment
1	Very good	Unknown	Agriculture, Industry & Social	1	2	2	3	1
2	Average	Average	Social	1	2	2	1	1
3	Very good	Good	Environment & Social	1	2	2	1	2
4	Unknown	Unknown	Industry & Agriculture	1	2	2	2	1

7. Index calculation

After calculating each of the individual component scores, the weightings have to be used to calculate the final WPI for each town. The formula to be used for the final calculation of the WPI is given below.

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

Table 8 summarizes the WPI values for each of the towns that were obtained using the various weighting groupings, as discussed in section 6.

Table 8 WPI values with various weighting groupings

	WPI Value		
Weighting Option	**Vanderbijlpark**	**Vereeniging**	**Sasolburg**
1	77.415	78.058	75.731
2	76.562	74.899	76.998
3	77.207	74.639	77.014
4	77.042	76.676	76.286

A WPI of 100 indicates that there are no water related problems in an area. The worst WPI that an area or region can have is 0, which indicates that there are numerous water related problems and that a lot of time and money will have to be spent in an effort to rectify the situation. The three towns in this study all have a WPI value in the high seventies, which is relatively high seeing that the entire country had a WPI of only 52.

As highlighted in the work of Cullis (2005) and Van der Vyver *et al.* (2011), the WPI can be represented graphically with the use of Geographical Information Systems (GIS) and various mapping software. These water poverty maps aid mainly with the dissemination of water poverty information. This further simplifies and facilitates the process of water poverty alleviation, and as mentioned earlier, poverty alleviation. This fits in perfectly with the post-apartheid South African government's view that information and communication technologies (ICT) represents modernization and that it is a key technology for poverty alleviation (Moodley, 2005).

8. Recommendations

The main idea behind the calculation of the WPI is to highlight where the allocation of resources should be focused to achieve the best results, i.e. the most significant water poverty alleviation. Depending on the chosen scale and the intended use of the WPI values, the first step typically entails choosing the country, province, region, or town with the worst WPI. As shown in table 8, even in the relatively small area considered in this study, the town with the lowest score can either be Vereeniging or Sasolburg, depending on which group of weightings was chosen. Although this will still lead to a reduction in water poverty, the effect would have been more profound if the resources were directed to the neediest area.

Although the differences between the various WPI values seem small and insignificant, a large weighting assigned to a specific component of the WPI might skew the overall WPI value significantly. For example, a town might have a fairly high access component score along with an extremely poor capacity component score. If an unreasonable weighting has been assigned to the access component, it has the potential to completely overshadow the lack of capacity. As a result it prevents already scarce resources from reaching the areas where it could have had the most significant impact.

Unless significant time and effort is therefore invested in the process of assigning weightings, the usefulness of the entire WPI process will be greatly undermined. Cullis (2005) recommends that the weightings should be assigned through a multi-criteria decision analysis process. If everyone involved in the process cannot reach a conclusion about the relevant weightings to be used, the recommendation is that neutral weightings are used, i.e. a weighting of 1 for each component. This has the added advantage that the index can be calculated even when some of the data is unavailable (Sullivan *et al,* 2003). Even though a lack of data is not ideal, it provides for a sufficient approximation especially when the scale used is relatively small.

9. Conclusion

The process of assigning weightings in the WPI calculation process is an extremely important one. If it does not receive a sufficient amount of time and effort, by consulting every stakeholder, those in management positions, and the end-users of the indices, its efficiency in dealing with water poverty will be greatly diminished. The WPI is an extremely useful index, and by allowing sufficient time and effort for the various stages of the calculation process, worldwide water poverty can be reduced significantly.

10. Acknowledgements

The work in this paper is based on a thesis entitled "*Water poverty mapping as a management tool"* which was completed during 2011.

References

Ahmad, Q. K. 2003. *Towards poverty alleviation: the water sector perspectives*, Water Resources Development, Vol. 19(2), pp. 263-277.

Asheesh, M. 2004. *Allocating the gaps of shared water resources (the scarcity index) case study Palestine Israel.* Finnish Institute of Technology, Kotkantie 1, 90100, Oulu, Finland. http://www.ipcri.org/watconf/papers/mohamed.pdf. [11 February 2010]

Clarke, R. & King, J. 2004. *The Atlas of Water. Mapping the world's most critical resource.* Earthscan, 8 – 12 Camden High Street, London, NW1 0JH, United Kingdom.

Cullis, J. D. S. 2002. *Targeting the Water Poor through Water Poverty Mapping: A Case study using Census Data and the Water Poverty Index for the Estcourt Municipal District, South Africa*. Unpublished M.Sc. Thesis, Environmental Change Institute, Oxford University.

Cullis, J. D. S. 2005. *Water poverty mapping: development and introduction using a case study at the local municipal scale for the Eastern Cape*. Water Research Commission, TT 250/05.

Gleick, P. 2002. *The world's water, The biennial report on freshwater resources, 2002 – 2003.* Island Press, 1718 Connecticut Avenue, N.W., Suite 300, Washington, DC 20009.

Hemson, D, Kulindwa, K, Lein, H & Mascarenhas, A. 2008. *Poverty and Water. Explorations of the reciprocal relationship*. Zed Books Ltd, 7 Cynthia Street, London, N1 9JF, United Kingdom.

Holland, A.S. 2005. *The water business. Corporations versus people.* Zed Books Ltd, 7 Cynthia Street, London, NI 9JF, United Kingdom.

Kaczan, D. & Ward, J. 2011. *Water statistics and poverty statistics in Africa: do they correlate at national scales?* Water International, Vol. 36(3), pp. 283 – 294.

Lawrence, P., Meigh, J. & Sullivan, C. 2002. *The water poverty index: an international comparison*. Keel Economics Research Papers, KERP 2002/19.

Meyer, W. N. 2007. *The economics of water, water for life; sanitation for dignity.* Van Schaik Publishers, 1064 Arcadia Street, Hatfield Pretoria.

Moodley, S. 2005. *The Promise of E-Development? A Critical Assessment of the State ICT for Poverty Reduction Discourse in South Africa.* Perspectives on Global Development & Technology, Vol. 4(1), pp. 1 – 26.

Pallett, J. 1997. *Sharing water in Southern Africa.* Desert Research Foundation of Namibia, PO Box 20232, Windhoek, Namibia.

Rand Water. 2008. http://www.wisa.org.za/patrons/randwater/index2.html [2 October

2008].

Sullivan, C. A, Meigh, J. R., Fediw, T. S. 2002. *Derivation and Testing of the Water Poverty Index Phase 1*: Final Report. DFID.

Sullivan, C. A, Meigh, J.R & Lawrence, P. 2005. *Application of the Water Poverty Index at different scales: a cautionary tale*. Water International, Vol. 31(3), pp. 412 – 426.

Sullivan, C. A., Meigh, J. R., Giacomello, A. M., Fediw, T., Lawrence, P., Samad, M., Mlote, S., Hutton, C., Allan, J. A., Schulze, R. E., Dlamini, D. J. M., Cosgrove, W., Delli Priscoli, J., Gleick, P., Smout, I., Cobbing, J., Calow, R., Hunt, C., Hussain, A., Acreman, M. C., King, J., Malomo, S., Tate, E. L., O'Regan, D. P., Milner, S. & Steyl, I. 2003. *The Water Poverty Index: Development and application at the community scale*. Natural Resources Forum, 27, pp. 189 – 199.

Van der Vyver, C. & Jordaan, D.B. 2011. *Water Poverty Mapping and its Role in Assisting Water Management.* Communications of the IBIMA, Vol. 2011, pp. 1 – 13.