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David Kaczan & John Ward

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Water statistics and poverty statistics in Africa: do they correlate at national scales?

David Kaczan[a]* and John Ward[b]

[a]*Department of Rural Economy, University of Alberta, Edmonton, Alberta, Canada;* [b]*Policy and Economic Research Unit, Commonwealth Scientific and Industrial Research Organisation (CSIRO) Sustainable Ecosystems, St Lucia, Australia*

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There is a general consensus that agricultural water scarcity contributes to the severe levels of poverty observed in Africa. However, the results of analyses to determine whether a lack of water is either actively contributing to the poverty observed, or when it is incidental, have been inconsistent. This paper examines the extent to which country-level water statistics and poverty/development statistics align. The authors find limited correlation, suggesting either that the water–poverty relationship is relatively inconsequential, or more likely, that the aggregated nature of these statistics obscures the actual relationship. The authors suggest that variables that better capture spatial heterogeneity may help rectify this.

Keywords: water scarcity; water poverty; indicators; spatial scale; Africa

Introduction

In 2009, 700 million people in 43 countries were estimated to live below the water-stress threshold of 1700 cubic metres per person. By 2025 that number is estimated to reach three billion (UNDP 2006). Agriculture is central to this issue: global water diversions for agriculture represent approximately 70% of total water consumption and are expected to grow by up to 17% by 2025 (de Fraiture *et al.* 2001). Hussain and Hanjra (2004), The Niger River Basin Authority (2005) and Namara *et al.* (2010) maintain that investments in irrigation and agricultural water use are central to addressing water-related poverty – identified as a primary contributor to the acute and chronic nature of poverty in Africa.

In terms of agricultural water use, Cook and Gichuki (2006) defined water wealth–poverty as "a function of water availability and water productivity of the agricultural water management system that enables people to derive a livelihood". This definition takes into account three variables:

- the water system – which determines the availability, access to and reliability of water;
- the agricultural system – access to infrastructure and institutions that enable the conversion of water into livelihood support through food, income or other attributes. This is defined as water productivity; and
- the livelihood system – which modifies water access according to social relations, institutions or organizations.

*Corresponding author. Email: dkaczan@ualberta.ca

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Molden (2007) contends that in 50 years there will be sufficient water to provide food and livelihoods for the estimated world population, but suggests that water crises in specific regions are likely without considerable water-management reform. Elements of the reform required are described by Falkenmark (2006), who also describes the enormity of the challenge. A key recommendation is a conceptual shift towards integrated management of water resources, with a particular focus on improving rainfed agricultural productivity (see also Rockström *et al.* 2009). Mitigating factors of water-related crises are not limited to the reliable provision of sufficient water volumes, but also the provision of fit-for-purpose quality, the capacity to utilize available water productively, and equitable distribution, access and control (Cook *et al.* 2009).

Developing and directing effective solutions to water-related poverty requires careful measurement of the water situation faced by specific communities and countries and enumeration of the influence exerted on the rate, persistence and extent of poverty. This research evaluated the correlation of existing and widely deployed national water-situation indicators with national poverty statistics. Water statistics that are not aligned, or are only weakly aligned with poverty statistics, may suggest that "water poverty" is a minor and inconsequential occurrence. Alternatively, water poverty may be real and severe, but not adequately detected by the suite of water-scarcity indicators currently utilized. In this paper we suggest that such a situation may arise due to a lack of consideration of spatial heterogeneity. A high level of aggregation, often up to a national spatial level, may render water-poverty statistics ineffective if the diversity of water situations found in the aggregated area is high. Water-policy initiatives that rely solely on hydrologic probabilities, or fail to account for the different causal relationships of spatially differentiated poverty may be either ineffective or accelerate poverty levels and disparities of wellbeing.

Establishing statistically significant correlates is one of the antecedents to the reliable and defensible estimation of causality. This paper focuses on the former and builds upon the discussion by Chenoweth (2008) and Cho *et al.* (2010). They posed a similar question to that considered here – to what extent do national water situation indicators correspond to poverty statistics – but arrived at different conclusions. The Chenoweth (2008) analysis is broadened by considering composite indicators of water scarcity in addition to biophysical indicators, and does so for a more economically homogenous group of countries, continental Africa and Madagascar. Cho *et al.* (2010) created simplified composite indicators of water scarcity from those already existing, and tested them for correlation with poverty statistics. They concluded positively, however, we argue that this may be due to the measure constructs rather than a fundamental relationship between water and poverty at a national level. This paper reports the analyses of an expanded set of water-scarcity and poverty indicators than those tested previously. There are a number of country-level poverty indicators applied regularly (but not exclusively) for supra-national comparisons.

First we define water poverty before discussing the variety of metrics used to quantify a country's water situation, and their comparative advantages and disadvantages. Second, we introduce some common poverty metrics, before revisiting Chenoweth (2008) and Cho *et al.* (2010) to posit an alternative hypothesis for their findings. We argue that accounting for spatial heterogeneity and the imputed scale is central to the efficacy of both these types of water and poverty measurement constructs, evidenced by correlations of simple water and poverty statistics from African countries. This simple analysis of the extent to which national-level development and water statistics align suggests that more spatially explicit water-situation indicators are warranted in many situations. Despite comparisons of several metrics, the results indicate low correspondence between water and poverty measures. We conclude that either more nuanced spatial scales of analysis or measures that explicitly include a component of variance may overcome this problem.

The meaning and measurement of water poverty

Water poverty occurs as the combined effect of factors including increasing and competing water demand, changes in hydrological regimes due in part to climate change, increasing population, environmental degradation, reduced water quality, impediments to water access, conflict, corruption and changing levels of water productivity.

Namara *et al.* (2010) noted that limited water quantity is a common, but far from only, cause of water-related poverty. Water-related poverty (herein defined as water poverty) may be a function of insufficient water quantity, quality, productivity or accessibility, and often involves a combination of these elements. Thus the water-poor may have sufficient access and availability of water at a fit-for-purpose quality, but productivity is severely limited due to a lack of infrastructure, capital or institutional impediments. Conversely the water-poor may have access to the factors of production but have constrained access or availability to water resources. This broad definition draws on the numerous definitions contained in the literature, many of which differ markedly in their comprehensiveness. For example, a purely physical definition is used by Salameh (2000), who proposed a definition based on domestic and agricultural need. Feitelson and Chenoweth (2002) incorporated a socio-economic component by describing water poverty as "a situation where a nation or a region cannot afford the cost of sustainable clean water to all people at all times". Lawrence *et al.* (2002) also defined water poverty as a function both of physical water resources and the socio-economic ability to make use of those resources. Cullis and O'Regan (2004) incorporated an equity component, defining water poverty as a lack of entitlement or capability to use water.

We base our discussion of water poverty on the concepts of water insecurity and water scarcity. A person who lacks safe and affordable water for their domestic consumption and/or income generation is defined as water insecure. When a large number of people are water insecure in a particular geographic area, that area is defined as water scarce. Water scarcity and hence water poverty occur when people are either unable to access dependable water resources or are constrained in their capacity to use them for basic needs, for food production or for wider economic and environmental services.

Thus water scarcity may arise due to physical, economic or social constraints. Social constraints include managerial, institutional and political factors (Molle and Mollinga 2003). Hence alleviating water poverty is a complex issue and a singular reliance on technical and financial policy initiatives may be necessary but insufficient interventions (Harrington *et al.* 2009, Molle 2009). In contrast, Komnenic *et al.* (2009) and Molden (2007) argued that improving the water situation can have a disproportionately large positive impact due to the number and variety of linkages in the water–poverty nexus. For detailed descriptions of some of these linkages, see Namara *et al.* (2010) and Cook *et al.* (2009).

There are a number of factors that complicate the objective quantification of water scarcity. For instance, water scarcity will depend on how people's needs are defined, the water required to maintain ecological health and the spatial and temporal scale of the study (Rijsberman 2006). Despite these complexities a number of attempts at quantification exist, which generally fall into one of three categories: (1) uni-variate measures of physical water availability; (2) uni-variate measures that incorporate both supply and demand aspects; and (3) multivariate composite indices.

The Falkenmark Water Stress Index (Falkenmark and Widstrand 1992) is an example of the metric uni-variate category (1), considering the total per capita renewable water resources (TARWR) of both surface and groundwater available within a region. The water situation is then classified in one of four categories from < 500 m^3/year/person (absolute scarcity) to > 1700 m^3/year/person (relative sufficiency). The simplicity of the Falkenmark indicator ensures its wide use, however it is limited by its inability to describe if and how the water available impacts the social-economic conditions of affected people.

To partially improve the usefulness of the Falkenmark Index, the TARWR has been augmented by considering the proportion of available water that is exploited for human use, an example of a category (2) metric. According to the metric developed by Raskin *et al.* (1997), countries with total withdrawals between 20% to 40% of total water available are considered to have moderate water scarcity and countries which exceed 40% are considered severely water-scarce. Seckler *et al.* (1998) developed a metric to consider the future demand for water also. The statistic is based on: (1) withdrawals as a proportion of available water resources; and (2) future withdrawals as a proportion of current withdrawals. As this metric is based on two components, the authors do not present a single score to encapsulate the water situation, but divide countries into groups that share similar water circumstances. Those that have current withdrawals greater than 50% of current availability are considered severely water-scarce. Those with current withdrawals less than 50% but with a future demand double that of present are considered severely economically water-stressed, and other categories exist for other particular thresholds of these two metrics.

A criticism made of the Raskin *et al.* (1997) index is that whilst it considers water withdrawals, it does not account for the large variations in traded water (Molle and Mollinga 2003). This weakness is addressed by Islam *et al.* (2007) who developed a globally disaggregated model of water stress based on local runoff, routed flow from upstream and "virtual water" imported or exported in the form of agricultural goods. A region may have a high degree of water scarcity as measured by the local availability of water, however, provided it has sufficient financial resources, it may be able to alleviate the situation through the purchase of food imports. Despite the reduction in water scarcity that is estimated to occur due to trade, it is likely that food self-sufficiency remains a policy goal for many developing and water-stressed countries to avoid the political and economic vulnerabilities perceived to be associated with such import-dependency (Molden 2007).

The need to recognize both the availability of a resource and the impact the use of that resource has on a community's socio-economic situation has led to the construction of category (3) multivariate water poverty indices. Ohlsson (2000) and Turton and Warner (2002) discussed water scarcity as a product of a "first-order" resource scarcity and a "second-order" social scarcity. The former is due to physical limitations whilst the latter refers to the institutional capacity required to utilize or re-allocate the water resource in question and thus better manage overall scarcity. Countries which suffer from both order scarcities are considered "water-poor" and may consequently find themselves trapped in a spiral of under-development. In order to capture both elements, Ohlsson (2000) suggested the use of a Social Resource Water Stress/Scarcity Index, made up of a physical indicator such as the total available renewable water resources (for example, the Falkenmark Index) divided by a second-order proxy such as the Human Development Index (HDI).

The Water Poverty Index (WPI) also attempts to reflect physical first-order characteristics of the water situation (such as total quantity available and its quality) and a range of second-order social factors (such as income, inequality, child mortality, education and availability of water infrastructure) (see Lawrence, *et al.* 2002). The aggregate statistic is made up of five components: resources (physical water availability and human population); access (proportion of population with access to clean water, sanitation and irrigation infrastructure); capacity (income, inequality, child mortality and education); usage levels and environmental quality. The WPI has been widely applied at both sub-national and international scales.

Multivariate indices, despite addressing the multi-dimensionality of water poverty, create a new measurement challenge by compiling disparate and non-commensurate data aggregated according to somewhat arbitrary weights. The addition or removal of an indicator, or a change in the relative importance that indicator holds, can produce diverse results. The extent to which indicators are correlated will further affect outcomes: inclusion of two similar indicators may cause undue emphasis on one aspect of the phenomenon in question. Hence indicators do not represent reality, nor do they pretend to. They provide a viewpoint for a specified purpose, and implicitly represent the personal values of their architects (Molle and Mollinga 2003).

Furthermore, the described indicators fail to capture temporal fluctuations in water availability, arguably just as important as spatial heterogeneity in assessing a region's water situation. Brown and Lall (2006) demonstrated this by using variables of mean annual temperature, mean annual precipitation, intra- and inter-annual variability and spatial variability of rainfall to predict macroeconomic performance. As well as demonstrating the significance of temporal variability of rainfall on gross domestic product (GDP), they argued that different water policies are required for different categories of water-concerned countries. Those with insufficient mean rainfall require "soft" policies (efficiency, water trading, food importation), whilst those with inadequate temporal distribution require "hard" policies (construction of impoundments). This temporal sensitivity has often been lacking from many econometric studies which bundle climatic variation into loosely defined "tropical" variables such as distance from the equator (see for example, Bhattacharyya 2004, Rodrik *et al.* 2004). In particular, mean rainfall is a poor descriptive of the water situation a country faces due to temporal and spatial variation.

Thus water poverty is a subjective condition. It is multifaceted, being economically, biophysically and socially determined and is heterogeneous over space and time. Exactly what any one researcher or decision maker intends by the term water poverty will depend on their agency mandate and research foci.

Indicators of poverty

Univariate measures of poverty are predominantly focused on economic income. These include the Headcount Ratio (the proportion of a country's population subsisting on less than $1.25 per day [$US, purchasing power parity), GDP per capita, the Total Poverty Gap (which measures the intensity of poverty) or the Foster, Greer and Thornbecke Index (which combines information on the extent, intensity and inequality of poverty) (Ray 1998). A practical and more holistic alternative is health variables. Human health often reflects the quality of a person's socio-economic and environmental situation.

Alternatively, a variety of indices built from weighted collections of statistics are available, which are designed to capture the multi-dimensional nature of the poverty problem. Widely used examples include the Human Development Index (HDI) and the similarly designed Human Poverty Index (HPI). The HDI is an equally weighted summation of life expectancy, school enrolment/literacy and per capita GDP, and is intended to describe average development *achievement*. The similarly compiled HPI is argued to provide a more complete measure for lesser-developed countries by describing levels of average development *deprivation* (UNDP 2007). For lesser developed countries (the HPI-1 Index), it is made up of the probability at birth of not reaching 40 years of age (1/3 weighting), the adult illiteracy rate (1/3 weighting), the proportion of the population not using an improved water source (1/6) and the proportion of children under weight for their age (1/6) (UNDP 2007). A final poverty measure we considered in this assessment is the Social Vulnerability Index, formed specifically to measure the social vulnerability of African countries to climate change. It is made up of nine sub-indices that represent economic wellbeing and stability, demographic structure, institutional stability and strength of public infrastructure, global interconnectivity and dependence on natural resources (for details, see Vincent 2004).

The problems of quantifying poverty are similar to the problems of quantifying the water situation: each alternative uni-variate measure emphasizes isolated elements of poverty, generally considered non-systematically and independently of other poverty-related factors. Multi-variate indices attempt to correct for this deficiency but are subject to similar problems of arbitrary weighting and the potential conflation of disparate, non-commensurate variables that are also used as water-scarcity indicators.

Previous assessments of water scarcity and poverty correlations

Although much of the reviewed literature is concerned with the relationship between water scarcity and the incidence of poverty, Lawrence *et al.* (2002), Chenoweth (2008) and Cho *et al.* (2010) are examples of a limited number of studies that undertake a systematic evaluation of either uni-variate or aggregated poverty and development statistics. Chenoweth (2008) used a dataset of 173 countries to investigate water and poverty correlations at a national level, however only considered physical water-scarcity indicators. Based on the resulting low correlations Chenoweth concluded that the availability of water resources is uncorrelated with a country's ability to meet the basic needs of its population. Similarly, he concluded that there is "no indication that water shortages hold back the development of nations even though common sense would suggest that in any given country more water should enable a higher GDP". Chenoweth (2008) argued that socio-economic development, rather than the natural environment, drives the ability of a country to productively harness water for development. A minimal GDP contribution of a free or nearly free good, and the low economic returns to water-intensive agriculture relative to less water-intensive activities are introduced as additional reasons for low correlation coefficients.

Lawrence *et al.* (2002) presented the WPI in a national-level form. After calculating aggregate WPI statistics for 147 countries, they presented a correlation matrix of the index components and the HDI. The HDI statistic, along with the Gini coefficient of income inequality, forms the "capacity" component of the national-level WPI statistic, and hence their findings of strong correlations are expected. Cho *et al.* (2010) used data from 147 countries to develop a simplified WPI. They used principle components analysis to create two more data-efficient metrics which have only slightly reduced descriptive power. In order to demonstrate their usefulness they present correlations with the HDI and HPI-1 metrics which again were found to be high. As stated in both papers, high correlations are to be expected between measures that include common components.

In summary, Lawrence *et al.* (2002) and Cho *et al.* (2010) found high correlations, which are explained at least partly by the common components present in the indices tested. Alternatively, Chenoweth (2008) found low correlations, derived from a biophysical water-scarcity metric correlated with the constraints of GDP. The explanation for low correlation coefficients does not include the hypothesis that spatial scales of water scarcity and poverty are neither aligned nor correspondent.

The importance of spatial consideration

There are a number of spatially explicit water-situation assessments in existence including some of global extent. Vörösmarty *et al.* (2000) assessed the likelihood of water shortages due to climate change and population growth at 30' grid cells. Islam *et al.* (2007) developed a similar global assessment which included virtual water. Meigh *et al.* (1999) compiled a regional model (southern and eastern Africa) based on surface and groundwater as well as projected changes in demand. On a smaller scale, Sullivan, *et al.* (2003), Sullivan *et al.* (2006) and Cullis and O'Regan (2004) demonstrated the feasibility and usefulness of mapping the WPI at a community level to identify water-poverty hotspots. However, most studies use country-level statistics in their assessment of water issues. For example, Hoekstra and Hung (2005) in their assessment of virtual water flows, Lawrence *et al.* (2002) in their development of an internationally comparable water poverty index, and Feitelson and Chenoweth (2002) in their proposed indicator of resource abundance and adaptive capacity.

A country-level approach is not necessarily inappropriate; in some cases it may be adequate to address the issue in question. However, when using country-level indicators it is important to understand the extent to which they represent typical (not just average) conditions on the ground. Given that the relationships between water and poverty are numerous and of critical importance, water-poverty measures that accurately describe typical conditions (not just average conditions) are likely to correlate closely with development indicators.

As an example, we considered first the water situation experienced by the countries of the Niger Basin, West Africa. The Basin has a population of approximately 94 million people (UN Population Division 2006). The majority of these people are highly impoverished and life expectancies of all Niger Basin countries are in the bottom 15% of countries worldwide (UNDP 2007). The population is predominantly rural and thus vulnerable to changing climates and water regimes. A 30% long-term reduction in rainfall in the Sahelian regions since the 1970s may be indicative of a new, drier, climatic regime (Niger Basin Authority 2005), although consensus is lacking on whether this decrease is permanent. Mali, Niger and Chad are all classified as relatively water sufficient (see Table 1), given their high levels of endowment ($>$ 1700 m^3/year/person). However, this water is geographically

Table 1. Water status (total available renewable water resources – TARWR) in countries of the Niger Basin in 2005 and 2025.

Country	TARWR per capita 2005 (m^3/yr)	2005 status	TARWR per capita projected[1] 2025 (m^3/yr)	2025 projected status
Benin	3820	Water-abundant	1629	Water-stressed
Burkina Faso	930	Water-scarce	538	Water-scarce
Cameroon	17,520	Water-abundant	9431	Water-abundant
Chad	4860	Water-abundant	2357	Water-abundant
Cote D'Ivore	4790	Water-abundant	2189	Water-abundant
Guinea	26,220	Water-abundant	14,739	Water-abundant
Mali	7460	Water-abundant	5261	Water-abundant
Niger	2710	Water-abundant	1335	Water-stressed
Nigeria	2250	Water-abundant	1164	Water-stressed

Note: Water abundance is defined as $>$1700 m^3/year/person, water-stressed 1700–1000 m^3/year/person, water-scarce $<$1000 m^3/year/person (Source: UNESCO 2006); [1] based on projected population growth only.

concentrated, and for the balance of the country (and many of their inhabitants), water scarcity is a regular occurrence. Only Burkina Faso is considered to be consistently water-scarce using the TARWR indicator. Contrary to expectations, projecting the per capita water situation to 2025 based on current population growth, Burkina Faso remains the only water-scarce country, with some additional water stress experienced in Benin, Niger and Nigeria.

Such a result is to be expected, given the simplicity of the indicator used. An alternative indicator designed to capture both first-order physical scarcity and second-order social capacity is likely to be more closely correlated to overall development performance. Here we consider two water-scarcity indicators, the simple Falkenmark Index and the more comprehensive Water Poverty Index, and assess the extent to which they correlate with national-level development statistics. Data represent the continental states of Africa and also Madagascar, with some omissions due to non-availability of data.

Four measures of a country's development were selected based on data available, the Human Development Index (HDI), the Headcount Ratio, the Genuine Savings Indicator (GSI) and the Social Vulnerability Indicator (SVI). These measures are described below, with the exception of the GSI. The GSI is a development index based on GDP, investment in education and environmental damage (Hamilton and Clemens 1999). Countries that undertake destruction of their environmental resources, and furthermore fail to invest in human capital, are considered to be saving less or negatively. This accounting system is one of a number of alternative progress measures and it is not without criticism (see Everett and Wilks 1999). None of these four measures contains an explicit water component. All of the measures utilized here have been criticized (although the HDI is a fairly well established metric) and no particular one is considered the ultimate measure of poverty and vulnerability. Each emphasizes different aspects of poverty and so have been used in parallel to facilitate analytical comparison.

Table 2 presents the correlation between the two water-scarcity indicators and the four poverty/vulnerability measures. Correlations are estimated using a non-parametric Spearman's rank test. Note that higher WPI and Falkenmark Index values indicate an improved water situation (less water poverty), higher HDI values indicate an improved development level, and a higher GSI indicates more sustainable development. Alternatively, a higher Headcount Ratio indicates a greater proportion of people in poverty

Table 2. Correlation matrix for all African countries of the Falkenmark Index, the Water Poverty Index (WPI), the Headcount Ratio (proportion of people living under US$1 per day, PPP), the Human Development Index (HDI), the Genuine Savings Indicator (GSI) and the Social Vulnerability Index (SVI).

	Falkenmark	WPI	Headcount Ratio	HDI	GSI
Falkenmark[1]	-	-	-	-	-
WPI[1]	0.30*	-	-	-	-
Headcount Ratio[2]	0.26	−0.34*	-	-	-
HDI[3]	−00.21	0.67*	−0.58*	-	-
GSI[4]	−00.18	−00.08	−00.17	0.16	-
SVI[5]	0.07	−00.47*	0.48*	−00.48*	−00.02

Note: * - statistically significant correlation ($\alpha = 0.05$)
Sources: [1] Lawrence *et al.* (2002); [2] World Bank (2009); [3] UNDP (2007); [4] Hamilton and Clemens (1999); [5] Vincent (2004).

and higher SVI values mean higher vulnerability. The sample is made up of all African countries for which data are available (excluding small island states).

Correlations are generally moderate to weak at the national scale. The Falkenmark Index has no significant correlations ($\alpha = 0.05$) with any poverty or vulnerability measure. The quantity of water (the first-order scarcity) has no observable correspondence with the poverty and vulnerability levels of a country. The Falkenmark Index's correlation with the WPI is to be expected given that the latter incorporates a form of the total water-resources statistic.

The WPI, which includes both first-order physical scarcity and second-order social capacity has significant correlations with three of the four poverty/vulnerability measures. Correlation is strongest with the HDI, however, given that elements of the HDI form components of this measure, it is of reduced importance here. Correlation with the Headcount Ratio is negative and significant as expected ($r = 0.34$, $\alpha = 0.05$), but relatively weak. The WPI includes variables such as child-mortality rates, education-enrolment rates and access to clean water and sanitation which are highly correlated with monetary-poverty levels (Klasen 2008). Furthermore, variables such as child-mortality rates have been suggested as superior to monetary-poverty measures in some situations given that they are less influenced by alternative and traditional barter economies (Setboonsarng 2005). Given these already established relationships, the correlation between the WPI and the Headcount Ratio is surprisingly weak. There is a significant but moderate correlation ($r = -0.47$, $\alpha = 0.05$) between the SVI and WPI but neither water indicator shows any significant correlation with the GSI.

Thus at a national level, there is little evidence for a strong association between a country's water situation and its development performance on the African continent. This conclusion is at odds with Hanjra and Gichuki (2008), who argued that there is "near concordance" between WPI, HDI and the proportion in absolute poverty (< US$1 per day) for the 20 African countries of the Limpopo, Nile and Volta River basins. We calculated Pearson correlation coefficients for their sample of countries, and found that there is indeed a statistically significant correlation between HDI and WPI ($r = 0.78$, $\alpha = 0.05$), however we expected this due to the common components present in both indices. The more informative correlation between WPI and those in absolute poverty is also statistically significant but considerably reduced ($r = 0.44$, $p = 0.052$).

The correlation analysis is intended to highlight two points. First, it provides some justification for the use of a more sensitive indicator capable of capturing both the first-order physical conditions of water stress as well as the second-order social conditions of institutional capability. Compared to the single-factor Falkenmark Index, the correlation coefficient between the WPI and development status was both higher and statistically significant (α=0.05) for three of the four variables. These efforts were designed to test the hypothesis posed by Turton and Warner (2002), that ". . . the relative abundance (or scarcity) of the second-order resource determines the [development] outcome". Thus despite the criticism of the WPI as a subjective amalgamation of disparate variables, it is arguably superior to the single-factor index. The results reported in Table 2 support the Turton and Warner hypothesis (2002), although a more refined analysis is required to identify precise limits and qualifications of this statement.

Second, we demonstrate that although the multi-variate indices represent improvements over the Falkenmark Index, there remains a surprisingly low correlation between water poverty and development when measured at a national scale. It is likely that the data compression that occurs when spatially aggregating to a national level masks the otherwise prominent association between water scarcity and poverty. This has been noted by previous studies typically investigating a particular country (see for instance Amarasinghe *et al.* (2005)) and we demonstrate the same point here for the general case. Describing a country's water situation often requires recognizing temporal heterogeneity also, as demonstrated by Brown and Lall (2006). Without such sensitivity to both space and time, water might be dismissed as a contributor to development outcomes. Consequently potentially beneficial policy approaches may be ignored.

Although we found similar results to Chenoweth (2008), we conclude differently. Spatial heterogeneity in water and poverty metrics is likely to be too great to allow for meaningful correlations at a national level. The ability of a country to utilize its water resources is as important, if not more so, than the gross quantity of water available. Our analysis tested this hypothesis by using multi-faceted water poverty indicators, and revealed only weak correlations with the key development indicators for African countries. The results shown here indicate that it is difficult to build a case for water-related investment in Africa based on country-level statistics alone, and particularly unreliable when those national-level results are restricted to a singular consideration of the physical measures of water scarcity. The results suggest that wherever possible, researchers should endeavour to use spatially specific water variables at higher resolution in models of poverty. Alternatively, a variable (or vector) that at least captures the heterogeneity of the water distribution across a country may be appropriate if national level statistics are otherwise preferred.

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