The Water Poverty Index: Assessing water scarcity at different scales

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ABSTRACT

An assessment of water stress and scarcity requires a multi-faceted approach to achieve real water poverty reduction. Several issues impact the ability of people to access to and properly use water and improved sanitation facilities. Among them are the availability of water resources, the capacity of communities to manage the schemes, the economic aspects of services affordability, and the environmental issues. However, they are often treated separately, and not as an integrated, dynamic process.

In order to integrate these biophysical, social, economic and environmental issues, as well as the existing pressures and policy responses into one single, comparable, dynamic indicator, an enhanced Water Poverty Index, which uses a pressure–state–response function, has been developed and is proposed in this study. It is primarily designed to produce a holistic tool for policy making, aimed at allowing resource managers to determine and target priority needs in the water sector, while assessing development process.

This paper highlights some of the applications of the index at different spatial scales. It is concerned not with the development or the underlying methodology of the index, but with how the tool can best be applied in practice to generate useful data, which then may be used to support decision-making.

INTRODUCTION

It has long been recognized that there is a link between poverty and access to water (Molle and Molinga, 2003; Sullivan, 2002; WHO/UNICEF, 2000). The pressing need to explore this relationship further is highlighted by the vast numbers of people who still do not properly access water services. In fact, the provision of a reliable, sustained and safe water supply for people worldwide has become a top priority on the international agenda. It is certainly a challenge for the Millennium Development Goals (MDGs), particularly Target 10 of Goal 7, which explicitly deals with people who do not access safe drinking water and basic sanitation.

This is evidence of both a knowledge and policy failure (Sullivan and Meigh, 2007), lack of infrastructure, and poor capacities to deliver benefits to society over the long term (Giné and Pérez-Foguet, 2008a). As a result, appropriate policy frameworks are urgently required as essential tools to support equitable allocation of water resources and to foster sustainability. Effective policy making is based on an interdisciplinary approach, and the international commitment to the MDGs has emphasized the necessity to come up with meaningful and feasible integrated tools to assess the development process.

Against this background, much effort has gone into the development of indicators and indices of water problems in recent years (Falkenmark, 1986; WHO/UNICEF, 2000; Ohlsson, 2000; Feitelson and Chenoweth, 2002; Sullivan, 2002). In particular, a relevant attempt to design an integrated indicator to assess water scarcity and accessibility to water of poor populations has been made by Sullivan (2002), who advanced the water-poverty interface as an indicator through the Water Poverty Index (WPI). The index is an interdisciplinary tool that takes into account the key issues relating to water resources, combining physical, social, and economic information. Its core theoretical framework encompasses water resources availability, people's ability to get and sustain access to water and to use this resource for productive purposes, and the environmental factors which impact on the ecology which water sustains.

However, it is believed that current framework tends to oversimplification and appears to be not very conducive to allow a comprehensive understanding of the complex nature of water poverty. Since water resources management is a dynamic and holistic process, there is a need to incorporate cause-effect relationships to capture the crosscutting nature of water issues. Such approach would accommodate all the causal inter-relations between the parameters, providing policy planners with a valuable tool to address water problems.

Taking the original WPI as a starting point, and integrating the concept of causality, we propose a definition of an enhanced Water Poverty Index, eWPI. This paper is concerned not with the development or the underlying methodology of the index, but with how it can best be applied in practice to generate useful data, which then may be used to support decision-making.

THE ISSUE OF SCALE

Water resources are often extremely variable, both on a spatial and temporal scale. Therefore, to develop effective policy guidance is essential that any assessment tool be applied at the appropriate scale (Sullivan and Meigh, 2007). In particular, the extent to which indices will accurately reflect actual variations will depend on the scales at which they are applied. For example, an index at the national level may say nothing about regional variations; and improvements in access and availability to water resources at household level might be obscured by indices which operate at inappropriate scales.

Furthermore, natural water resources planning unit (watersheds) generally do not align themselves with jurisdictional boundaries and political governance. And despite the incongruence between water systems and national boundaries, the state is the basic unit for which most socio-economic data is collected, and it should be taken into account when defining suitable scales to apply indices and indicators.

Equally important, the scale at which various types of knowledge can be applied to water management also varies widely (Sullivan and Meigh, 2007), since: (i) climate models tend to be based on grids of about hundred kilometres; (ii) assessment of water resources use smaller grids, typically covering areas of few thousands of km^2; (iii) at the socio-economic and political levels, the scale relevant to policy making can range from the household to the nation; and (iv) in terms of water quality, both spatial and temporal scales may vary depending on impacts of both point and diffuse sources of pollution. An attempt to address this consists on the use of geo-referenced datasets, which provide a means of integration of data from different sources (Mlote et al., 2002; Sullivan, 2002) at any point on the globe (and thus regardless of the scale). For instance, and by geo-referencing the various WPI variables, the link can be made between macrolevel hydrological data reflecting regional or catchment-level water availability, and microlevel data on household water stress. Therefore, within such a framework, for any specific point on the map (identified by its grid reference) detailed and accurate data from both the social and physical sciences can be combined in an integrated way.

On the temporal scale, water resources seasonality needs also to be taken into consideration, in order to storage sufficient water to ensure access when it is needed (Sullivan and Meigh, 2007). Likewise, appropriate knowledge of inter-annual variability is essential to assess vulnerability of water resources to climate change at a watershed level, and then foresee if water supplies secure meeting future demands for water of the ever increasing population. Temporal variability of resources is subjected to high levels of uncertainty, and thus is more difficult to deal with than spatial variability.

The accuracy of original WPI has proved to be meaningful at all different levels: national (Komnenic, 2007; Lawrence *et al*., 2002), regional (Heidecke, 2006), and local scale (Cullis and O'Regan, 2004; Giné and Pérez-Foguet, 2009; Sullivan *et al*., 2003). However, the index fails to efficiently tackle the problem of temporal scale. This paper attempts to bring all these issues together. It highlights two applications of the revised index at different spatial scales (basin and community), and incorporates the concept of causality to deal with temporal variability.

THE CONCEPTUAL FRAMEWORK OF THE ENHANCED WATER POVERTY INDEX

The Water Poverty Index is a holistic tool to address poverty linkages to water provision. Its structure and the component variables were identified through participatory consultation with a variety of stakeholders (Sullivan *et al*., 2003). Based on the original structure of the index, the conceptual framework adopted for the enhanced WPI comprises two different dimensions, combining a classification in terms of subject/issue with a classification in terms of the position along the causal chain.

Therefore, it first uses the Pressure - State – Response (PSR) model introduced in 1993 by the OECD (OECD, 1993), which provides a means of selecting and organising indicators in the context of a causal chain. The idea seems to be that by placing indicators within a causality-issue matrix, the cause-effect relationships and interconnections between the parameters will become obvious.

Second, and equal to WPI (Sullivan, 2002), it distinguishes a number of aspects which reflect major preoccupations and challenges in low-income countries related to provision of water: physical availability of water resources (R), extent of access to water (A), effectiveness of people's ability to manage water (C), ways in which water is used for different purposes (U), and the need to allocate water for ecological services (E). Thus, for each of these five variables, indicators of pressure, state and societal responses are defined.

Numerically, the enhanced WPI is given by:

$$eWPI = 0.2\,(R_{PSR} + A_{PSR} + C_{PSR} + U_{PSR} + E_{PSR}) \qquad (1)$$

To each parameter or combination of indicators, a score between 0 and 1 is assigned, where a value of 0 is assigned to the poorest level (i.e. highest degree of water poverty), and 1 to optimum conditions.

As seen from previous equation, equal weights are used for all indicators, since there is no evidence that it be otherwise. Furthermore, the linear aggregation is simple and transparent, and it allows compensation between different variables. Even though other aggregation options are being explored, they have not been taken into account in the analysis presented in this work.

TARGETTING THE WATER POOR AT COMMUNITY SCALE

This index construction method has been tested at local scale in Bolivia, in 10 pilot communities located at Tiraque Valley (Department of Cochabamba). In this region, water is seen as one of the most critically stressed resources, suffering from an increasing and competing demand, increased sources of pollution, inadequate management of water resources, low capacities to anticipate and mitigate against the impacts of flooding, poor access to consistent information relating to water supplies …. It seems evident that water sector development urgently demands the attention of policy makers and resource managers. In this context, it is believed that the index might serve decision-makers as a policy tool to support strategic planning in the water sector, to target priority needs for interventions, and to assess the impacts of sector-related development policies.

It is within this background that the Universitat Politècnica de Catalunya (Spain) and Centro AGUA (Universidad Mayor de San Simón, Bolivia) launched a collaborative research project, funded by AECID, aimed at assessing the water-poverty linkages in rural areas in Cochabamba. An outcome of this project has been the development of an enhanced WPI, based mainly on data provided by a comprehensive questionnaire developed at household level in 20 communities by Centro AGUA in cooperation with DANIDA, within the framework of a program entitled "Competing for Water: Understanding Conflict and Cooperation in Local Water Governance". Additional information sources used have been: (i) published census data; (ii) a survey on water and sanitation issues carried out by the INGO "Water for People"; and (iii) the "Plan de Desarrollo Municipal", which is being implemented by local authorities to promote sustainable development at community level.

The variables used (listed in Table 1) to compile the eWPI values have been found appropriate to describe at household level the essence of the five components of the index in all three different stages (PSR). They have been then averaged to produce a community value for the index.

The results shown in Table 2 suggest that there are at least two communities which require special attention, with eWPI values of 0,542 and 0,573. In contrast, the least water poor community scores 0,721. However, the final index provides a starting point for analysis. An accurate focus on the five subindices might help to direct attention to those water sector needs that require special policy attention. At the same time, a proper study of the three states should provide valuable information to assess the impact of institutional and societal responses. To this end, a cluster analysis has been performed to classify all ten communities into manageable sets, by exploiting their similarity on different indicators and variables.

Table 1
WPI component variables and indicators used at community scale. *Source*: Piulats, J. (2009)

Variables	Indicator – Pressure	Indicator - State	Indicator – Response
Resources			
Water resources availability	Annual Population Growth	Water Availability	Adequacy of water storage capacity
Rainfall	Rainfall variability	Rainfall	
Access			
Access to safe water	Variation in safe water accessibility	Percent Population with access to safe water	Improvement in adequate water infrastructure (sector expenditure)
One way distance to water sources	Percent of HH who consider distance to water source an issue to solve	Distance to waterpoint	
Access to sanitation	Adequacy of hygienic practices	Percent Population with access to improved sanitation	Improvement in adequate sewage treatment (sector expenditure)
Access to water for irrigation purposes	Rights to water for irrigation	Percent Population with access to water for irrigation purposes	Improvement in adequate irrigation treatment (sector expenditure)
Capacity			
Educational level	Variation in Educational Level	Educational level	Educational level of HH leader
Water sector institutional framework	Confidence in water institutions	Institutional control on water access	Percent of complaints regarding the water service level.
Operation and Maintenance	Adequacy of the maintenance programs		
Gender issues and the role of women	Variation in ratio of average female educational level to male educational level	Ratio of average female educational level to male educational level	
Financing strategies and cost-recovery	Cost of water	Percent of arrears on water fees	
Use			
Domestic water consumption	Conflict over water sources (Human – Human)	Domestic water consumption	Domestic Water-use efficiency
Agricultural water use	Conflict over water sources (Human – Agriculture)	Agricultural water use	Agricultural Water-use efficiency
Livestock water demand	Conflict over water sources (Human – Livestock)		Livestock Water-use efficiency
Environment			
Environmental regulation and management	Use of pesticides and fertilizers	Percent of area with natural vegetation	Adequacy of the environment sector-related institutional framework
Water quality	Percent of people suffering from Water-related diseases	Water Quality, for domestic use	Water source protection

A spider diagram is displayed in Figure 1 to summarize the differences in the means between clusters, which are presented in Table 3. To understand particularities of these three groups allows policy planners to identify target groups and determine specific intervention strategies.

Table 2
Final values of all e-WPI parameters (at community scale)

Community	WPI	Resources	Access	Capacity	Use	Environment	Pressure	State	Response
1	0,634	0,768	0,646	0,647	0,502	0,608	0,653	0,632	0,619
2	0,640	0,703	0,568	0,667	0,693	0,570	0,575	0,636	0,710
3	0,628	0,620	0,498	0,670	0,810	0,540	0,627	0,738	0,519
4	0,623	0,447	0,694	0,655	0,765	0,555	0,599	0,743	0,527
5	0,633	0,563	0,689	0,624	0,697	0,592	0,647	0,671	0,581
6	0,721	0,790	0,727	0,659	0,798	0,633	0,777	0,685	0,702
7	0,665	0,608	0,744	0,647	0,728	0,596	0,686	0,620	0,688
8	0,573	0,483	0,614	0,569	0,707	0,494	0,614	0,640	0,466
9	0,613	0,706	0,480	0,636	0,842	0,401	0,621	0,648	0,570
10	0,542	0,368	0,661	0,492	0,707	0,484	0,586	0,591	0,450
Average	*0,627*	*0,606*	*0,632*	*0,627*	*0,725*	*0,547*	*0,638*	*0,660*	*0,583*

Table 3
Final values of all e-WPI parameters (for all three cluster classes)

	Cluster 1	Cluster 2	Cluster 3
No. Cases	*2*	*5*	*3*
WPI	0,637	**0,652**	**0,580**
Resources	**0,736**	0,657	**0,433**
Access	**0,607**	0,628	**0,656**
Capacity	**0,657**	0,647	**0,572**
Use	**0,598**	**0,775**	0,726
Environment	0,589	**0,552**	**0,511**
Pressure	**0,614**	**0,671**	0,665
State	0,634	**0,672**	0,658
Response	0,665	**0,612**	**0,481**

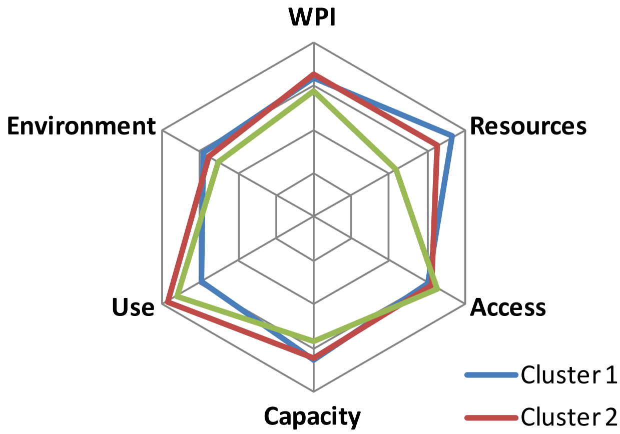

Figure 1. Diagram of WPI components for three cluster classes

It is shown for example that first cluster (which includes 2 communities) scores best in “Resources”, though access to basic services remains inadequate and water usage is considerably poor. The direction to be adopted should foster the construction of new infrastructure to improve coverage. Additionally, sanitation campaigns are needed to raise awareness among the population of the importance to increase domestic water consumption. Cluster 2 (5 communities) performs notably better, being the least water poor. Only the “environment” component needs to be improved, and water sources should thus be better protected to prevent water from being contaminated. Finally, communities (3) included in Cluster 3 score the lowest WPI values and thus represent the highest degree of water poverty. This group is characterized by significant levels of water scarcity, though they also lack capacities to manage water facilities and to minimize environmental impact on water sources. First intervention would be directed to increase water reservoir availability. In parallel, all water sector actors at local level should conduct capacity building through appropriate training, so as to enable water entities to manage the schemes. And equal to Cluster 2, awareness of the importance to protect water sources needs to be increased. It is also remarkable that societal response in these communities is critically low, and thus major improvements in the near future should not be expected.

IMPROVING WATER RESOURCES MANAGEMENT AT BASIN SCALE

In an attempt to exemplify the application of the methodology at different scales, the enhanced WPI has been also assessed at the watershed scale.

In fact, to focus on this scale of intervention appears to be meaningful, since it is clearly the natural water resources planning unit. Nevertheless, major constraint at this scale is related to the ability of basin authorities to effectively fulfil their management commitment. They generally lack strategic oversight and appropriate resources, so even when basins are correctly delimited and basin management bodies created, their involvement as a decision-making entity is poor. Among the problems that have impeded its successful strengthening, there is the lack of consistent baseline data at this scale, needed to avoid planning decisions based on false assumptions.

In consequence, a pilot test has been done in the Catamayo - Chira River basin, an international 17,200 km^2 watershed shared between Peru and Ecuador, where sector-related data were readily available. The basin is made up of six different sub-basins (see Fig. 2), though for the purpose of this study, only the three basins located in Peru (Chira, Chipillico and Quiroz) have been considered.

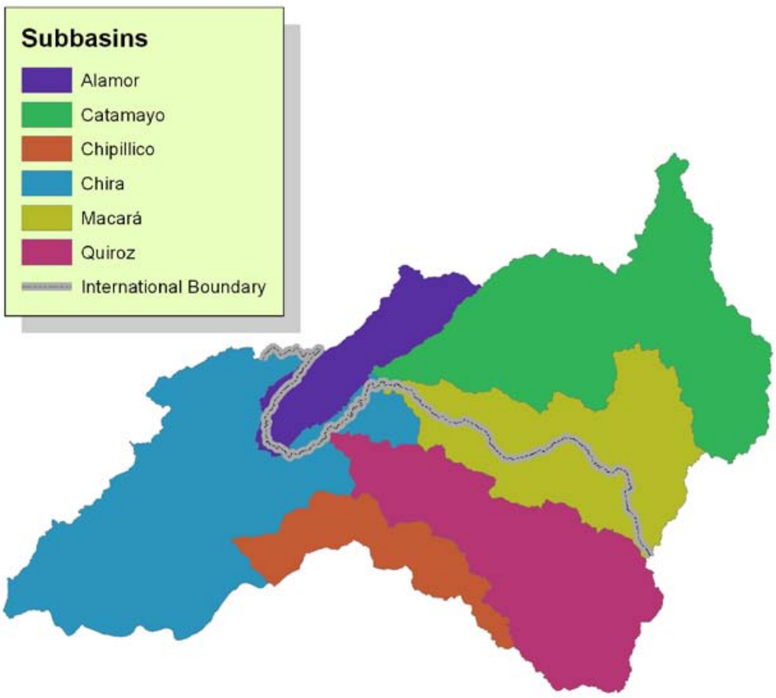

Figure 2. The Catamayo – Chira River Basin and its subbasins

After data compilation, information has been classified following the WPI-PSR framework. All variables and indicators used are listed in Table 4, and a more detailed description of indicators is given elsewhere (Giné and Pérez-Foguet, 2008b).

Once the parameters of all five components have been obtained, the WPI is calculated according to Eq. 1. The results are presented in Table 5.

Table 4
WPI component variables and indicators used at watershed level. *Source*: Giné and Pérez-Foguet, 2008b

Variables	Indicator - Pressure	Indicator - State	Indicator – Response
Resources			
Water resources availability	Annual Population Growth	Water Availability	HDI – Education
Water Quality		Water Quality, for domestic use	
Access			
Access to safe water	Variation in safe water accessibility in the last 2 years	Percent Population with access to safe water	Improvement in adequate water infrastructure
Access to sanitation	Variation in safe water accessibility in the last 2 years	Percent Population with access to improved sanitation	Improvement in adequate sewage treatment
Capacity			
Human Development	Variation in the women basin HDI – Education in the last 2 years	HDI	Daily per capita income, in US $
Use			
Domestic water consumption	Water-related diseases in the basin		Domestic Water-use efficiency
Agricultural water use		Agricultural water use, expressed as the proportion of irrigated land to total cultivated land	
Environment			
Environmental regulation and management	Impact of Pollutant Sources (Number of Sources * Individual Impact)	Percent of area with natural vegetation	Adequacy of the environment sector-related institutional framework

Table 5
Final values for all e-WPI parameters

		WPI	Resources	Access	Capacity	Use	Environment
WPI	Quiróz	0,458	0,542	0,333	0,417	0,5	0,5
	Chipillico	0,475	0,5	0,375	0,417	0,417	0,667
	Chira	0,442	0,417	0,625	0,5	0,250	0,417
Pressure	Quiróz	0,675	0,750	0,875	0,750	0,5	0,5
	Chipillico	0,675	0,5	0,875	0,750	0,5	0,750
	Chira	0,450	0,5	0,750	0,5	0,5	0,0
State	Quiróz	0,475	0,625	0,0	0,250	0,750	0,750
	Chipillico	0,475	0,5	0,125	0,250	0,5	1,0
	Chira	0,475	0,0	0,875	0,5	0,0	1,0
Response	Quiróz	0,225	0,250	0,125	0,250	0,250	0,250
	Chipillico	0,275	0,5	0,125	0,250	0,250	0,250
	Chira	0,4	0,750	0,250	0,5	0,250	0,250

At the same time, to illustrate the complexity of water issues, a set of diagrams has been developed (Fig. 3). By showing the values of all five components in a visually clear way, it helps decision-makers to detect major water sector needs and facilitates cause-effect relationships not to be lost.

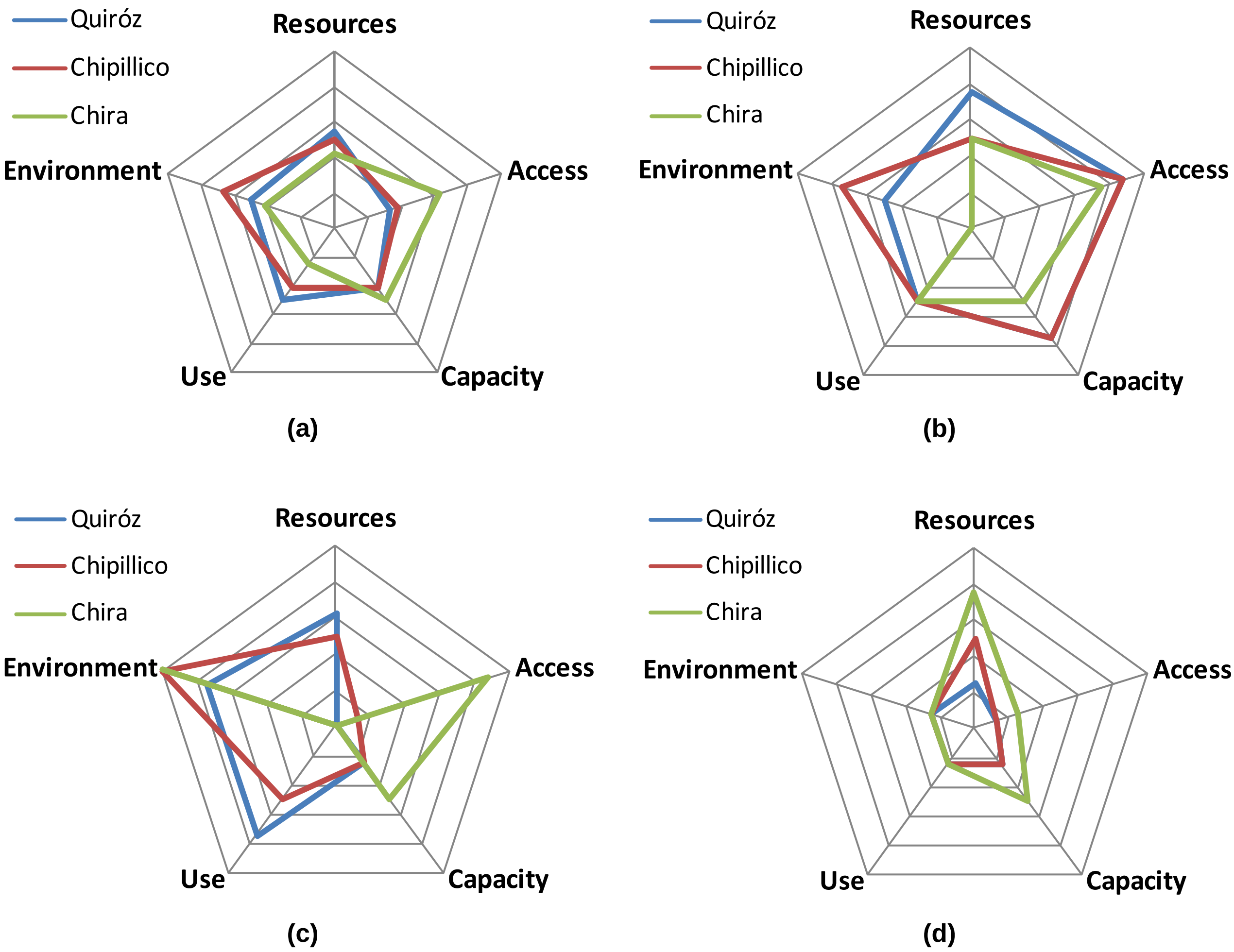

Figure 3. Pentagram presentation of the components of the WPI. (a) Total; (b) Pressure; (c) State; and (d) Resources. *Source*: Giné and Pérez-Foguet, 2008b

In brief, although final WPI results in three basins are similar, different conclusions can be achieved if a thorough analysis is done focussing either on the five components of the index or on a specific position within the causal chain. In particular, aspects needing attention by resource managers in these basins are those related to Resources State (Chira Basin), Access State and Response (Quiroz and Chipillico Basins), Use State (Chira Basin), and Environment Pressure (Chira Basin). Institutional response would be directed to (i) improve water quality; (ii) increase water and sanitation coverage through building and sustaining new infrastructure; (iii) reduce agricultural water demand and improve respective water-use efficiency; and (iv) minimize the impact produced by existing pollution sources, respectively (Giné and Pérez-Foguet, 2008b).

DISCUSSION

In this paper we have demonstrated the relevance of the use of an aggregated indicator as an effective water management tool in decision making processes. We have shown how the enhanced Water Poverty Index might be applied at different scales, and on this basis we believe that this tool has potential for wider implementation.

There is consensus on stating that this multidimensional approach to water poverty assessments appears attractive, and because of its simplicity, the tool appeals to policy-makers, since complexities of water situation at a particular location result to be straightforward if represented either as a single number or through a spider diagram.

Nevertheless, criticism has also been made of the index on several grounds (Feitelson and Chenoweth, 2002; Molle and Mollinga, 2003; Shah and van Koppen, 2006; Jiménez et al., 2007; Komnenic, 2007). This demonstrates the fact that the development of such a complex tool must be regarded as an iterative process, and this is acknowledged by the authors (Sullivan and Meigh, 2007; Sullivan *et al*., 2003).

We are aware of major limitations concerning the construction of a composite index: (i) correlation among indicators; (ii) weights assigned to the variables; and (iii) the method of aggregation. As part of this iteration, related research is currently being undertaken in order to refine the structure of the index.

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