THE ENHANCED WATER POVERTY INDEX: TARGETING THE WATER POOR AT DIFFERENT SCALES

Ricard Giné Garriga *, Agustí Pérez Foguet **

Grup de Recerca en Cooperació i Desenvolupament Humà

Universitat Politècnica de Catalunya - ETSECCPB
C. Jordi Girona, 1-3, Edifici C2 (Campus Nord)
08034 - Barcelona

ricard.gine@upc.edu*, agusti.perez@upc.edu**

ABSTRACT:

For a large proportion of the world's population, the provision of a reliable, sustained and safe water supply has become a top priority. As water stress increases, the need for effective water management becomes more pressing. However, the conventional approaches to water assessment are inappropriate for describing the increasing complexity of water issues. Instead, a multi-faceted approach is required to achieve real water poverty reduction.

In order to link the biophysical, social, economic and environmental aspects which are influencing sustainable development of water resources, as well as the existing pressures and policy responses into one single, comparable, dynamic indicator, an enhanced Water Poverty Index (eWPI) has been developed and is proposed in this study. A pressure – state – response function is combined with the original Water Poverty Index (WPI) framework to produce a holistic tool for policy making. In particular, the index is aimed at allowing resource managers to determine and target priority needs in the water sector, while assessing development process.

This paper 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. It highlights some of the applications of the index at different spatial scales, and two different case studies are presented: in Bolivia, at local scale; and in Peru, at watershed scale.

KEYWORDS:

water poverty, enhanced water poverty index; water resources planning and management, spatial scale, Peru, Bolivia

INTRODUCTION

Water supports livelihoods in different ways, and the link between poverty and access to water has long been recognized [1-3]. There is an increasing need to provide an insight into this relationship, since the provision of a reliable, sustained and safe water supply still remains elusive for vast numbers of people worldwide [4]. This is evidence of both a knowledge and policy failure [4], lack of infrastructure [5], and poor capacities to deliver benefits to society over the long term [6]. In consequence, it demands the attention of resource managers and governments. Further, appropriate policy frameworks are also required to support equitable allocation of water resources and foster sustainability. Against this background, sound, evidence-based information backed up by adequate monitoring tools is an essential prerequisite to effective decision making, since it might be used:

i. to report on progress;

ii. to determine what needs to be done to maximize performance; and to

iii. focus attention on needy areas and efficiently allot resources.

In recent years, much effort has gone into the development of indicators and indices of water issues [1, 3, 7-10]. At the international level, monitoring of access to water and sanitation is being carried out by the WHO and UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP), whose main goal is to track progress towards the MDGs in the form of number of people with access to improved facilities [3, 5, 11]. Main value of these reports is that they provide harmonized data sets, and thus improve the comparability between different countries, and over time. On the other hand, they are not exhaustive [12], thus failing to represent the complexities of water issues on the ground [13, 14]. An interdisciplinary approach appears more adequate to produce an integrated assessment of water scarcity, and this has been adopted by Sullivan [1], who advances the water-poverty interface as an indicator through the Water Poverty Index (WPI). The index takes into account physical estimates of water availability and the socioeconomic drivers of poverty, and thus combines information from different disciplines. Its core theoretical framework encompasses water resources availability, people's ability to get and sustain access to water, to use this resource for productive purposes, and the environmental factors which impact on the ecology which water sustains.

As a complementary approach to the original framework of the WPI, the concept of water poverty should be dealt with in a more systemic way, by integrating the policy cycle of problem perception, policy formulation, monitoring and policy evaluation [15]. This would allow a comprehensive understanding of the crosscutting nature of water issues. In particular, such approach would accommodate all the causal inter-relations between the variables of the index, providing policy planners with a valuable tool to address water problems.

THE ISSUE OF SCALE

Water resources are often extremely variable, both on a spatial and temporal scale [4, 16]. Poverty is also a spatially heterogeneous phenomenon [17]. And intuitively, water poverty should represent a more obvious geographic variation than income poverty, as its incidence and magnitude owes to factors with spatial dimensions, such as water resource endowments, as well as to people's ability to access reliable water supplies [18]. In policy making, it is thus essential that any assessment tool be applied at the appropriate scale to avoid misleading results [4]. For example, national-level data may say nothing about regional variations; and inadequate provision of safe water at household level might be obscured by indices which operate at inappropriate scales [4, 19].

The spatial scale at which various types of knowledge are generated also varies widely [4], 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.

Similarly, 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 monitoring tools. An attempt to integrate information that has been generated at different spatial scales consists on the use of geo-referenced datasets, which provide a means of linking data from different sources at any point on the globe [1, 18, 20]. For instance, and by geo-referencing the various index variables, the link can be made between catchment-level hydrological data reflecting water availability, and micro-level data on household water stress. Within such a framework, for any specific point on the map, detailed and accurate information from both the social and physical sciences can be combined in an integrated way.

On the temporal scale, seasonality of water resources needs also to be taken into consideration, in order to storage sufficient water and ensure access to it when needed [4]. Likewise, appropriate knowledge of inter-annual variability is essential to mitigate vulnerability of water resources against the impact of climate change, and then foresee if water supplies will 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 [4]. One way to address this may be through single iteration [19], i.e. to regularly assess how the resources and conditions in a particular location have changed over time. This would provide a monitoring tool that enables trends to be revealed, as well as changes to be noted. Another approach to tackle temporal variability is to integrate cause-effect relationships, not only taking into account all existing pressures exerted on the environment but the policy responses that are implemented in a given place, in a given period.

In an attempt to bring all previous issues together, this paper exploits the enhanced Water Poverty Index, eWPI as a policy tool. Its theoretical framework takes the original WPI as a starting point, and then incorporates the concept of causality. In order to show how the index can be applied in practice, we discuss some of the applications at two different spatial scales: the community and the watershed.

THE CONCEPTUAL FRAMEWORK OF THE ENHANCED WATER POVERTY INDEX

The Water Poverty Index was designed as a water management tool to address poverty linkages to water provision. Its structure and the component variables were identified through participatory consultation with a variety of stakeholders [14]. Based on the same concept of the original index, the conceptual framework adopted for the eWPI 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 [15], 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 variables will become obvious. Second, and equal to WPI [1, 14], 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 have been identified.

In terms of the method and technique, index construction involves three key steps: (a) selection of key indicators for each subindex (P, S and R variables of five WPI components); (b) combination of these subindices into their corresponding components (R, A, C, U, E); and (c) determination of weights for each of these five components and their aggregation to yield an overall index.

In the first stage, a set of context-specific indicators is selected and classified based on the eWPI framework. All parameters are standardized to fall in the range 0 to 1, where a value of 0 is assigned to the poorest level (i.e. highest degree of water poverty), and 1 to optimum conditions A multivariate analysis (Principal Component Analysis, PCA) is performed at subindex level to remove all correlated indicators. After deciding the number of factors to keep and calculating all 15 subindices, next step is to combine the set of variables (V_i, i = P, S, R) for each index component (X_i, i = R, A, C, U, E). At this level, since variables can compensate each other's performance, an additive aggregation is employed. Furthermore, all variables have the same weight, since there is no evidence that it be otherwise (Equation 1).

$$X_i = \frac{1}{3} \sum_{i=P,S,R} V_i \qquad \text{(Eq. 1)}$$

The last step is the aggregation of components. A weighted multiplicative function is the most appropriate aggregation function for estimation of water poverty [21], since it does not allow compensability among the different components of the index. The weighting system is assigned through multivariate techniques, which determine that set of weights that explain the largest variation in the original variables [22]. Numerically, it can be formulated as:

$$eWPI = \prod_{i=R,A,C,U,E} X_i^{w_i} \qquad \text{(Eq. 2)}$$

where eWPI is the value of the index, X_i refers to component i of the eWPI structure, and w_i is the weight applied to that component.

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 requires the attention of policy makers. In this context, it is believed that the index might serve 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.

Table 1. WPI component variables and indicators used at community scale.

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

Table 1 lists all variables used to assess the eWPI at community scale. It should be noted that with the aim of setting a methodology replicable in other regions, the selection of indicators has not been based on what is desirable to measure but on the need to use available data, avoiding further field data collection. According to Table 1, the set of identified variables has been found appropriate to describe at household level the essence of the five components of the index (R, A, C, U, E) in all three different stages (P, S, R).

The results shown in Table 2 suggest that there are at least two communities which require special attention, with eWPI values of 0,528 and 0,568. In contrast, the least water poor community scores 0,718. In any case, 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.

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

Community	WPI	Resources	Access	Capacity	Use	Environment	Pressure	State	Response
1	0,629	0,768	0,646	0,647	0,502	0,608	0,653	0,632	0,619
2	0,637	0,703	0,568	0,667	0,693	0,570	0,575	0,636	0,710
3	0,619	0,620	0,498	0,670	0,810	0,540	0,627	0,738	0,519
4	0,612	0,447	0,694	0,655	0,765	0,555	0,599	0,743	0,527
5	0,631	0,563	0,689	0,624	0,697	0,592	0,647	0,671	0,581
6	0,718	0,790	0,727	0,659	0,798	0,633	0,777	0,685	0,702
7	0,662	0,608	0,744	0,647	0,728	0,596	0,686	0,620	0,688
8	0,568	0,483	0,614	0,569	0,707	0,494	0,614	0,640	0,466
9	0,592	0,706	0,480	0,636	0,842	0,401	0,621	0,648	0,570
10	0,528	0,368	0,661	0,492	0,707	0,484	0,586	0,591	0,450
Average	*0,620*	*0,606*	*0,632*	*0,627*	*0,725*	*0,547*	*0,638*	*0,660*	*0,583*

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

	Cluster 1	Cluster 2	Cluster 3
No. Cases	*3*	*2*	*5*
WPI	0,569	0,606	0,655
Resources	0,433	0,663	0,686
Access	0,656	0,489	0,675
Capacity	0,572	0,653	0,649
Use	0,726	0,826	0,684
Environment	0,511	0,470	0,600
Pressure	0,600	0,624	0,667
State	0,658	0,693	0,649
Response	0,481	0,545	0,660

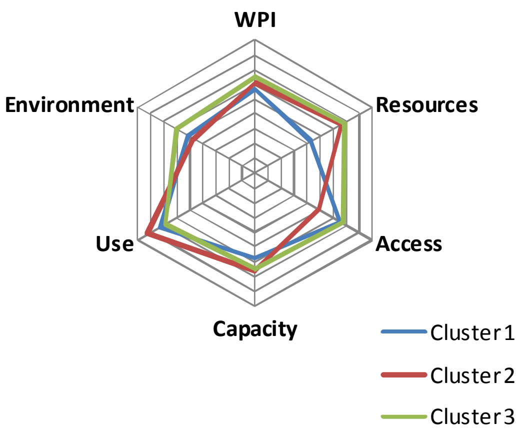

Figure 1. Diagram of WPI components for three cluster classes

It is shown for example that first Cluster (which includes 3 communities) scores the lowest WPI values and thus represents 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. First intervention would be directed to increase water reservoir availability. In parallel, all sector-related actors at local level should conduct capacity building through appropriate training, so as to enable water entities to manage the schemes. It is also remarkable that both pressures and societal response in these communities are critically low, and thus major improvements in the near future should not be expected. Communities included in Cluster 2 (2 communities) scores best in “Capacity” and “Use”, though access to basic services remains inadequate, and water sources are not properly protected from potential pollutant sources. The direction to be adopted should foster the construction of new infrastructure to improve coverage, while water sources need to be protected to prevent water from being contaminated. Finally, Cluster 3 (5 communities) performs notably better, being the least water poor. Only water usage remains considerably poor, and sanitation campaigns are thus needed to raise awareness among the population of the importance to increase domestic water consumption.

IMPROVING WATER RESOURCES MANAGEMENT AT BASIN SCALE

In Peru, in 2008 Law 1081 created the National System for Water Resource. Under this law, the river basin becomes the territorial unit for the implementation of the National Water Resource Policy. However, a 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, which clearly undermines their involvement as a decision-making entity. Among the problems that have impeded its successful strengthening, there is the lack of consistent baseline data, needed to avoid planning decisions based on false assumptions.

It is therefore worthwhile that any effort to improve the management of water resources needs to be implemented at this scale. In an attempt to exemplify the application of the eWPI as an appropriate policy tool to reverse previous background, a case study has been undertaken in the Peruvian Jequetepeque River basin, a 4.372,5 km^2 watershed located in the north part of the country. The “Gallito Ciego” reservoir separates the upper-middle part from the lower part of the watershed. The study focuses on the upper-middle catchment, which is made up of 41 sub-basins, covering 3.564,8 km^2 (Fig. 2).

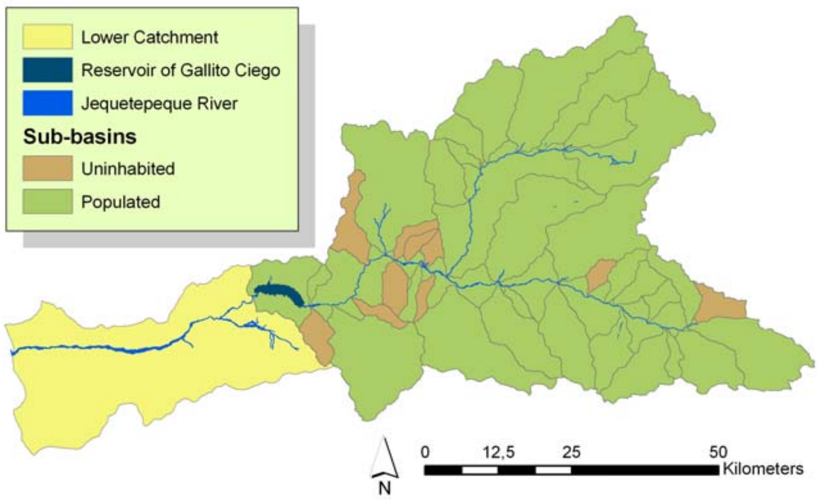

Figure 2. The Jequetepeque River Basin and its subbasins

After field data compilation, information has been classified following the eWPI framework. All variables and indicators used are listed in Table 4.

Table 4. WPI component variables and indicators used at watershed level

Variables	Indicator - Pressure	Indicator - State	Indicator – Response
Resources			
Water availability	Population growth rate	Per capita water availability	
		Rainfall	
IWRM	Variation in the HDI-Education	Institutional framework in IWRM	Adequacy of programmes to support IWRM
Access			
Access to safe water	Variation in safe water accessibility	Access to safe water	Improvement in water supply infrastructure
		Continuity of water service	
Access to sanitation	Variation in improved sanitation accessibility	Access to improved sanitation	Improvement in sanitation facilities
Equity in access	Population living in non-durable dwellings	Inequality index in terms of access to basic services (water and sanitation)	
Capacity			
Human Development	Variation in the HDI	HDI	Educational level of household head
Institutional Capacity	HDI – Education	% of technicians in relation to the labour force	% of health centres reporting illness due to water supplies
Gender Issues	Variation in the women HDI-Education	Equally distributed index, in relation to educational level	
Use			
Water-related diseases	Variation in prevalence of water-related diseases	Prevalence of water-related diseases	
Agricultural water use	% irrigated land with proper technological approach	Agricultural water use, expressed as the ratio of irrigated land to total cultivated land	Improvement in agricultural water-use efficiency
Environment			
Environmental Preservation	Arable land as a percent of potential arable land	Percent of area with natural vegetation	Adequacy of the environmental institutional framework
	Grazing land as a percent of potential grazing land		
	Soil erosion		
Water Quality		Water Quality (qualitative assessment)	Surface water quality surveillance
Agricultural Water Quality		Agricultural Water Quality	

To illustrate the complexity of water issues, a map has been developed (Figure 3) to show at a glance the level of water poverty, based on the index values, which enables policy planners to quickly identify the locations in which to focus their efforts for maximum impact [17]. Similarly, and by showing the values of all five components in a visually clear way (Figure 4), it helps decision-makers to detect major water sector needs and facilitates cause-effect relationships not to be lost. Again, to identify more risky subbasins is straightforward thanks to the maps.

According to Figure 4, aspects needing primary attention by resource managers are those related to water sector-related institutional strengthening, as well as to water usage efficiency. Further, both “pressure” and “societal response” maps appear critically low, thus a worsening of current situation is foreseen in the near future.

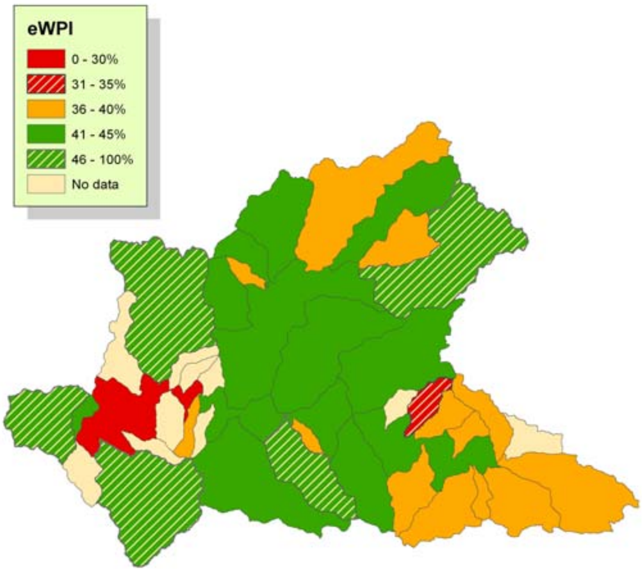

Figure 3. The enhanced Water Poverty Index, at subbasin level

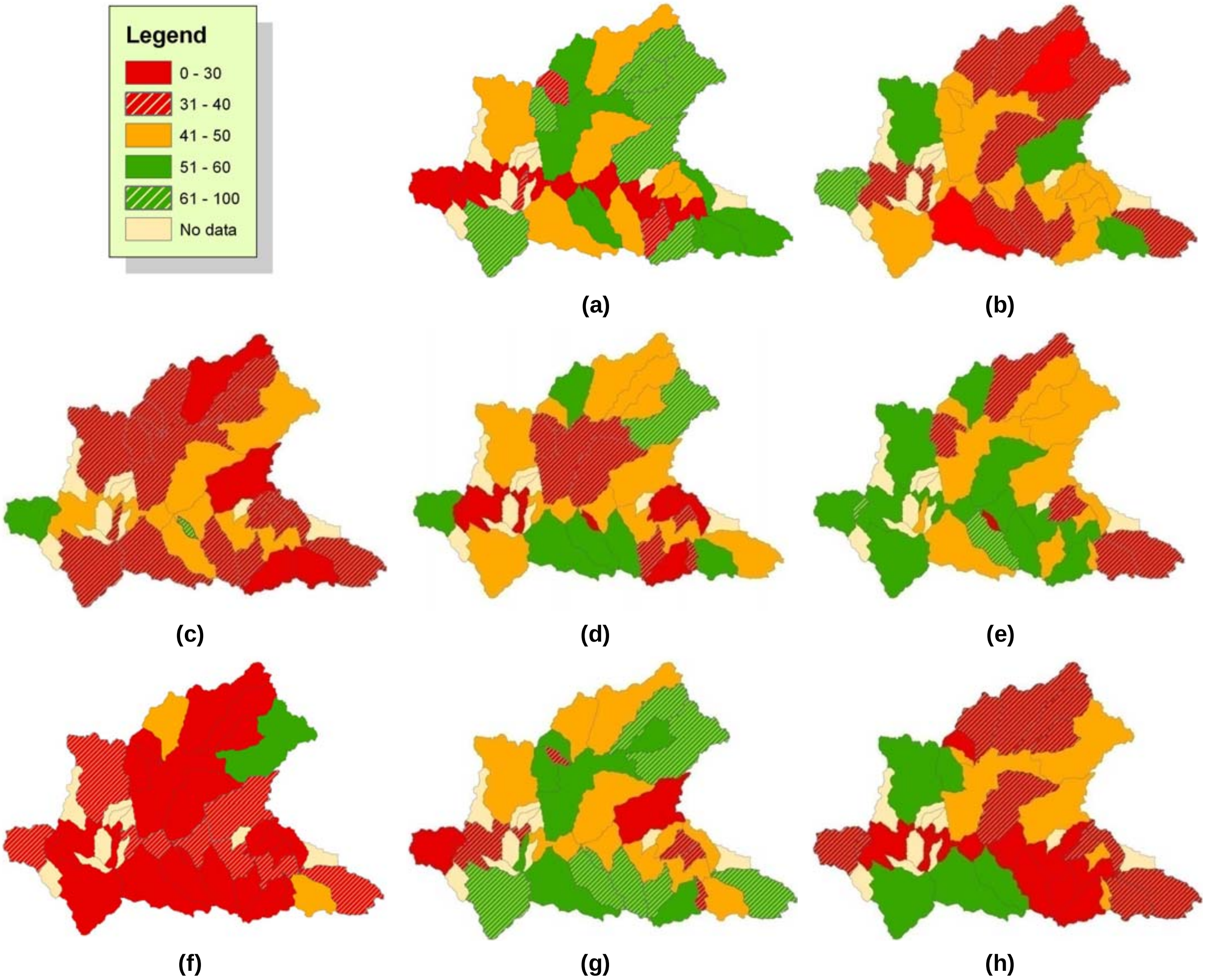

Figure 4. Water poverty maps. (a) Resources; (b) Access; (c) Capacity; (d) Use; (e) Environment; (f) Pressure; (g) State; and (h) Response

To reverse this trend, institutional response would be directed to (i) build up capacities of sector stakeholders, (ii) reduce agricultural water demand by improving respective water-use efficiency, (iii) increase domestic water consumption through adequate hygiene promotion, and (iv) raise water and sanitation coverage through building and sustaining new infrastructure, respectively.

DISCUSSION

The main aim of this paper is to demonstrate the relevance of the use of an aggregated indicator as an effective water management tool in decision making processes. In order to integrate the physical, social, economic and environmental issues which are influencing sustainable development of water resources, as well as the existing pressures and policy responses into one single, comparable, dynamic indicator, an enhanced Water Poverty Index (eWPI) has been developed and is proposed in this study.

It has been shown how the index might be applied at different spatial scales, and on this basis it is believed that this tool has potential for wider implementation. Its major advantage is that exploited in a user-friendly format, it enables more comprehensive understanding of the water sector constraints and challenges, and enhance decision-making processes. Two different approaches have been presented:

- A cluster analysis allows classifying a set of communities into manageable sets, based on their similarity on all indicators and variables. Understanding particularities of each group allows policy planners to identify target groups and determine specific and more coherent strategies, which in terms of poverty reduction and allocation of resources is more efficient and cost-effective.
- Targeting the water poor through related maps compares favourably with other methods currently used (reports, tables and graphs). Maps are a powerful visual tool and are easily understood by stakeholders, thus representing adequate information tools to identify areas where development lags and where investments in infrastructure and services could have the greatest impact.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to Centro AGUA (Universidad Mayor San Simon, Bolivia), Joel Piulats, and to Ferran Sayeras, who have contributed and provided support for the assessment in various ways. We also thank to DANIDA for all data provided within the framework of a program entitled “Competing for Water: Understanding Conflict and Cooperation in Local Water Governance” (launched in cooperation with Centro AGUA, Bolivia).

Financial support from the Centre de Cooperació per al Desenvolupament (Universitat Politècnica de Catalunya); the Agència Catalana de Cooperació al Desenvolupament (Generalitat de Catalunya), and the Agencia Española de Cooperación Internacional para el Desarrollo (Spanish Government) are gratefully acknowledged.

REFERENCES

1. Sullivan C (2002) Calculating a Water Poverty Index. World Development 30, 1195-1210.
2. Molle F, Mollinga P (2003) Water Poverty Indicators: conceptual problems and policy issues. Water Policy 5, 529-544.
3. Joint Monitoring Programme. Global Water Supply and Sanitation Assessment Report 2000. Joint Monitoring Programme for Water Supply and Sanitation. Geneva / New York: WHO / UNICEF 2000.
4. Sullivan C, Meigh J (2007) Integration of the biophysical and social sciences using an indicator approach: Addressing water problems at different scales. Water Resources Management 21, 111-128.
5. Joint Monitoring Programme. Progress on Drinking Water and Sanitation: Special Focus on Sanitation. Geneva / New York: WHO / UNICEF, 2008.
6. Harvey PA, Reed RA (2004) Rural Water Supply in Africa: Building Blocks for Handpump Sustainability. Water, Engineering and Development Centre. Loughborough University, Leicestershire.
7. Falkenmark M (1986) Fresh water – time for a modified approach. Ambio 15, 192-200.
8. Ohlsson L (2000) Water Conflicts and Social Resource Scarcity. Phys Chem Earth 25, 213-220.
9. Feitelson E, Chenoweth J (2002) Water poverty: towards a meaningful indicator. Water Policy 4, 263-281.
10. De Carvalho SCP, Carden KJ, Armitage NP (2009) Application of a sustainability index for integrated urban water management in Southern African cities: Case study comparison – Maputo and Hermanus. Water SA 35.
11. Joint Monitoring Programme. Meeting the MDG drinking water and sanitation target: a mid-term assessment of progress. Geneva / New York: WHO / UNICEF, 2004.
12. WHO/UNICEF. Core questions on drinking-water and sanitation for household surveys. Geneva WHO / UNICEF, 2006.
13. Jiménez A, Pérez-Foguet A (2009) Quality and seasonality of water delivered by improved water points in rural Tanzania. Journal of Environmental Management In revision.
14. Sullivan CA, Meigh JR, Giacomello AM, Fediw T, Lawrence P, Samad M, et al. (2003) The Water Poverty Index: Development and application at the community scale. Natural Resources Forum 27, 189-199.
15. OECD. OECD Core Set of Indicators for Environmental Performance Reviews. In: OECD (ed). Environmental Monographs. Paris: Organisation for Economic Co-operation and Development, 1993.
16. Savenije HHG (2000) Water Scarcity Indicators; the Deception of the Numbers. Phys Chem Earth 25, 199-204.
17. Henninger N, Snel M. Where are the poor? Experiences with the development and use of poverty maps. Washington, D.C.: World Resources Institute, 2002.
18. Cullis J, O'Regan D (2004) Targeting the water-poor through water poverty mapping. Water Policy 6, 397-411.
19. Sullivan C, Meigh J, Lawrence P (2006) Application of the Water Poverty Index at Different Scales: A Cautionary Tale. Water International 31, 412 - 426.
20. Mlote SDM, Sullivan CA, Meigh J. Water Poverty Index: a Tool for Integrated Water Management. 3rd WaterNet / WARFSA Symposium "Water Demand Management for Sustainable Development". Dar es Salaam, 2002.
21. Giné R, Pérez-Foguet A (2009) Improved method to calculate a Water Poverty Index at local scale. Journal of Environmental Engineering In revision.
22. Slottje DJ (1991) Measuring the Quality of Life Across Countries. The Review of Economics and Statistics 73, 684-693.