CHAPTER 10

Monitoring water poverty: A vision from development practitioners

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ABSTRACT: The target of the Goal 7 of *Millennium Development Goals* (MDG) is to halve by 2015 the number of people without sustainable access to safe drinking water and basic sanitation. The last few years have witnessed a relevant increase in the international concern towards water sector in developing countries, and an investment increase is envisaged for the next decade. In view of increased investments, monitoring efforts are required for the sake of efficiency and sound decision making in the water and sanitation sector. Available methodologies for measuring water poverty and water access show some drawbacks when applied to practical tracking of the water sector performance. A case is made in this chapter for the adoption of EASSY (Easy to get at local level, Accurately defined, Standard and internationally applicable, Scalable at all administrative levels, Yearly updatable) variables locally collected for monitoring water and sanitation sector. Implementing EASSY indicators will certainly require a proper definition from the scientific community and academia, the involvement of donors and civil society, and government willingness to implement measures to collect them.

Keywords: Water and sanitation access; Human development; Water poverty; Monitoring indices

1 INTRODUCTION

Nowadays, reducing poverty is thought to be a responsibility of the governments and as an objective of donors support. This driving idea was heavily reinforced at the *UN Millennium General Assembly*, when the *Millennium Development Goals* (MDG) of halving the proportion of the world's population living in extreme poverty by 2015 was agreed by all member countries of the United Nations.

Traditionally, poverty reduction was focused on increasing economic growth at the national level. Whilst this may be necessary, it is not sufficient, since it neglects the distribution of assets and income. Poverty reduction is indeed a complex issue and many factors need to be taken into account, such as education, employment generation and food security, among many others. Water sector has also very much to do with poverty reduction strategy: goals and targets specific to water and poverty were also agreed at the *Millennium Assembly* and at the *World Summit on Sustainable Development*.

Goal 7 of the *Millennium Development Goals* deals with environmental sustainability and addresses the water supply issue directly. One of its targets, Target 10, is to "halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation", with 1990 being established as the baseline year. As a consequence, more attention was drawn from international donors to the water and sanitation sector by Target 10 and, in the past few years, several reports were written, attempting to assess the investment requirements for attaining it. Results obtained are disparate, the actual cost required to fulfill Target 10 being estimated in a range that spans from US$ 9,000 million to 30,000 million per year (Toubkiss, 2006), which to a certain extent reflects the utter difficulty that such forecast entails. Whatever the actual required investment would be, it can be foreseen that a relevant growth on investment for water and sanitation in developing countries is going to take place in the next few years. Moreover, increasing awareness in donor countries on aid efficiency and alignment with receiving countries priorities will lead to channeling of additional funds through national budgets. Then, sound water sector performance monitoring will be required for the sake of efficiency and for the effective resources allocation at the national level.

This chapter tackles the challenge of analyzing the current status of monitoring water poverty in developing countries. It is worth noting that the chapter will necessarily provide a biased vision from development practitioners, due to the experience of the authors in the Spanish NGO *Ingeniería sin Fronteras* (Engineering without Borders). The economic study of the current state of water and sanitation sector is addressed in Section 2, and a demonstration is provided as to the need for proper monitoring of water sector performance at the national level. Neither traditional indicators of water supply access are able to provide a sound methodology for water sector monitoring, as it is shown in Section 3. An analysis of characteristics of *Water Poverty Index* (WPI) (Sullivan, 2002; Lawrence *et al.*, 2002) for tracking the water and sanitation sector in developing countries is made in Section 4. The relationship between water poverty, human development and human poverty is analysed and it is seen that, even though WPI is the best tool available nowadays for measuring water poverty, it is still not appropriate for tracking the performance of water sector at the national level. Appendixes containing the detailed statistical analyses in which the conclusions are based in are included at the end of the chapter. Finally, the chapter ends with a discussion where it is concluded that there is a urgent need of EASSY (Easy to get at local level, Accurately defined, Standard and internationally applicable, Scalable at all administrative levels, Yearly updatable) variables for the sector, which could be included in sector information collection routines in low income countries. It is firmly believed that all stakeholders such as academia, governments, civil society and donors should reach a consensus as to the adoption of the above mentioned EASSY indicators.

2 THE IMPORTANCE OF MONITORING WATER SECTOR PERFORMANCE

According to OECD data, committed *Official Development Assistance* (ODA) for Water Sector amounted US$ 46,360 million between 1995 and 2004 (Jiménez, 2006). According to other estimations (Briscoe, 1999; Global Water Partnership, 2000), annual investment in Water and Sanitation in developing countries (excluding waste water treatment) amounted to US$ 16,000 million at that time. In the mid-1990s, the estimation of contributions coming from main agents was the following (Camdessus, 2003):

– Local public sector: 65–70%
– Local private sector: 5%
– International donors (including NGO's): 10–15%
– International private sector: 10–15%

Nevertheless, the situation has changed in later years. On the one hand, international donors and NGO's have increased their participation (OECD, 2006), and on the other hand, international private contribution has decreased from US$ 3,700 million average engagement in the late 1990s down to less than 2,000 millions in the last four years (World Bank, 2006). The contribution of local public sector must be considered as stationary at best (Camdessus, 2003), as many developing

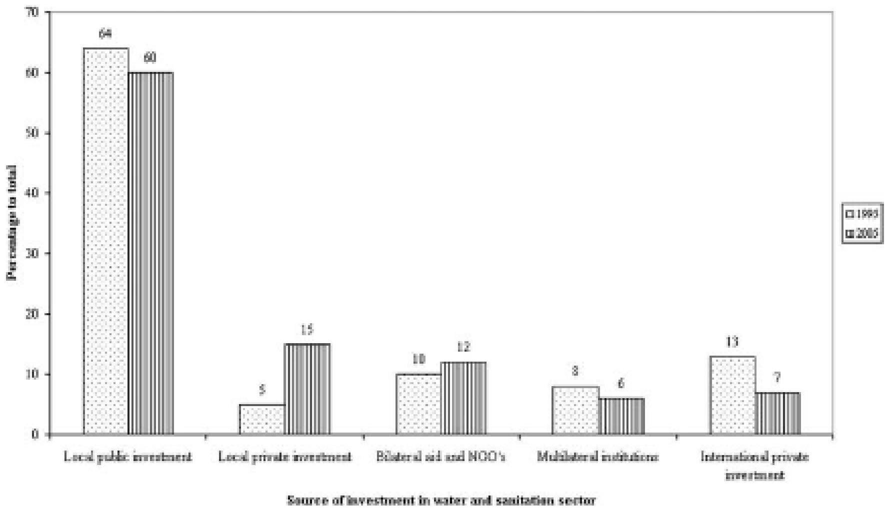

Figure 1. Water sector financing evolution (estimation).

countries have adopted economic plans that limited public expenditure, sometimes as a requirement to receive international aid.

Reducing infrastructure investments has been a normal mechanism to decrease public expenditure, while expecting that the international private investment would cover the shorfall.

This fact also explains the reduction of *World Bank* financial support for infrastructures in later years (World Bank, 2003). An estimation of actual sector financing is shown in Figure 1.

As Figure 1 shows, the total ODA contribution has increased up to around 20%, international private sector has decreased down to around 7%, local public sector remains at around 60%, and there is an important growth on local private sector to around 15%. This increase is due to their share of participation in operation and maintenance, as well as to the lack of response from national governments to the demographic pressure in large cities.

International aid for water sector have attracted more attention from donors which are making an effort to improve aid effectiveness, as expressed in the *Rome Declaration on Aid Harmonization*, in February 2003, and the *Paris Declaration on Aid Effectiveness*, in March 2005. The European Union has adopted its own commitment in the *European Consensus on Development*, February 2006 (EU, 2006). Aid effectiveness improvement is based on the principles of:

– Ownership, meaning that partner countries exercise effective leadership over their development policies and strategies, and coordinate development actions.
– Alignment, meaning that donors base their overall support on partner countries' national development strategies, institutions and procedures.
– Harmonisation, meaning that donors' actions will become more transparent and collectively effective.
– Managing for results, meaning that they would have results-oriented frameworks.
– Mutual accountability, meaning that both donors and partners are accountable for results.

In practical terms, at least 85% of aid flows will be reported on government's budget and will use public financial management systems (*Paris Declaration*). That will lead to the fact that the great part of aid will be channelled through sectoral or general budget support, thereby considerably increasing the concerned ministry's budgets. Research evidence shows that so far budget support has not improved national accountability significantly (de Rienzo, 2006). Moreover, the OECD has committed to raise the amounts destined to aid with respect to the 0.25% of *Gross National Income* (GNI) which was registered last year (Gupta *et al.*, 2006). In keeping with that trend, the 15 wealthier countries of EU have agreed to spend 0.51% of GNI in 2010, and 0.70% in 2015 (UN, 2005). Furthermore, United Nations has declared the decade 2005–2015 "*International Decade for Action: Water for Life*" (UN, 2004). The Resolution states that the main goal of the Decade should be a greater focus on water-related issues at all levels and on the implementation of water-related programmes in order to achieve internationally agreed water-related goals (UN, 2006). With this background, it is to be expected that funds for water sector channelled through national governments in aid recipient countries will increase. According to our estimates, this means that around 70% of total financing for the water and sanitation sector in those countries, and around US$ 20,000 million a year will be channelled through national governments (Jiménez, 2006).

This context highlights a very important problem for NGO and development agencies in the field, namely, how to monitor national government's policies in a short term basis to ensure an effective expenditure of funds. As an example, the last revision of the *Global Budget Support* for Tanzania (years 1995–2005), states that "poverty impacts remain uncertain for the last half decade, the most relevant period, because there has been no household survey since 2001" (Lawson & Rakner, 2005). Thus, the ability for tracking the performance of national governments remains crucial to fight water poverty and increase access to services, water and sanitation included.

Sectoral Budget Support such as water or health is usually based on annual reviews done jointly by donors, government and other actors (private, civil society) where performance is to be assessed. The main problem is the inexistence of reliable and objective indicators to make this assessment. Continuing with the same example as above, *Joint Water Sector Review* in Tanzania 2006 occurred without having a set of appropriate indicators and therefore, being impossible to measure results. A too big time-lag between funds disbursement and outcome measurement should be avoided, since that would prevent political accountability regarding poverty reduction decisions. That is why, from development practitioners' perspective, there is a strong need to set international indicators that fulfil some requirements:

- Sensitivity in short term period, that allows performance monitoring.
- Possibility to be measured in a bottom-up approach, allowing the establishment of regional trends.
- Easy to measure and cost-limited, allowing those to be integrated in the sector information system in low income countries.

3 TRACKING WATER SECTOR PERFORMANCE USING MDG INDICATORS

The most important monitoring task in the water sector is being carried out at the international level by the WHO and UNICEF *Joint Monitoring Programme for Water Supply and Sanitation* (JMP), whose main goal is to track the fulfilment of the *Millennium Development Goals*. The target being "to halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation" (UN, 2003; WSSD, 2002), the most suitable indicator for it is the number of people having "access to improved" water sources (WHO/UNICEF, 2000, 2005). Improved and not improved sources are defined in Table 1.

According to the *Water Supply and Sanitation Collaborative Council* (WSSCC) task force, people are said to have access to improved water supply if they have access to sufficient drinking water of acceptable quality, as well as sufficient quantity of water for hygienic purposes.

There are several examples of how these definitions can be differently interpreted. Only recently have countries like Mozambique recognized rope pump water points as *improved access* (WaterAid, 2005), even if it fits into the definition given above. In rural Tanzania, "the basic level of service for domestic water supply in rural areas shall be a protected, year-round supply of 25 L/day of potable water per capita, through water points located within 400 m from the furthest homestead

Table 1. Improved and not improved water sources (WHO/UNICEF, 2005).

	Improved	Not improved
Water supply	Piped connection into dwelling, plot, or yard	Unprotected well
	Public tap or standpipe	Unprotected spring
	Borehole	Vendor—provided water
	Protected dug well	Bottled water
	Protected spring	Tanker truck—provided water
	Rainwater	River, stream, pond, or lake

and serving 250 persons per outlet" (Government of Tanzania, 2002). However, this very water point would serve 500 people in a radius of not more than 500 m in Mozambique (Government of Mozambique, 1995). On the other hand, whatever the definition, access is usually calculated through household surveys, thus including personal interpretation about what *access* means and therefore not as objective as police provisions say. Much more could be discussed about this issue, since the coverage figures produced by technology indicators do not give enough information about the quality of the water provided or about its use (WHO/UNICEF, 2000). Similar analysis could be made with the indicator for sanitation access, but many of its limitations and drawbacks are described elsewhere (WHO/UNICEF 2005). Then, even though these are the most widely used indicators relating to water and human poverty, as the above examples show, they have not proven to be accurate enough, leading to difficulty in interpretation of available figures. Independently of the results provided by this short analysis, tracking water sector policy and performance is not only related to access, but to several other aspects that need to be measured, as *Integrated Water Resources Management* approaches indicate (European Union, 2006). Next Section focuses on the characteristics of *Water Poverty Index* (WPI) for that purpose.

4 TRACKING WATER SECTOR PERFORMANCE AT NATIONAL LEVEL USING WPI

WPI is an aggregated indicator with a broader scope than those of MDG, defined by a large number of scientists in consultation with concerned stakeholders (Sullivan *et al.*, 2003). It contemplates five subcomponents: *Resources*, *Access*, *Use*, *Capacity* and *Environment*, thus being a much more comprehensive approach ever used for measuring water poverty.

This section deals with the applicability of the index for water sector monitoring at the national level through two different approaches:

– Sections 4.1 and 4.2 show the results of an analysis of the relationship between WPI and the most relevant country development indicators, such as the *Human Development Index* (HDI), the *Human Poverty Index* (HPI), the *Gross Domestic Product* (GDP) per capita expressed in *purchasing power parity* (PPP) in current international dollars, and the *Falkenmark Index* (FI). This provides an overview of the added information provided by WPI, as well as new ideas for its definition. Section 4.3 studies the ability of WPI index to differentiate among countries in terms of key indicators. Some limitations are identified: narrow ranges of variation and population concentration (especially in the *Environment* subcomponent of the WPI). Detailed analysis is presented in the statistical annex.
– Section 4.4 makes an overview of WPI applications at different scales, including an analysis of key issues identified for monitoring use.

4.1 *Water poverty and human development*

This subsection is intended to provide insight into the relationship between *Water Poverty Index* (WPI), and *Human Development Index* (HDI). Detailed figures are provided in Appendix 1.

The relationship between WPI and HDI has been pointed out recently (Mukherji, 2006). The author concluded that the water poverty of a nation is not related to water scarcity but, rather, with the development level and per capita GNP. As analysis shows, there are many different HDI situations for a given value of the WPI resources index. This confirms that the initial conditions in terms of water resources have not been significant for countries development.

According to the WPI methodology (Sullivan, 2002; Lawrence *et al.*, 2002), the sub-index of resources is computed by taking into account internal water resources and external water inflows in each country. Resources are expressed on a per capita basis (Lawrence *et al.*, 2002). However, as pointed out by Sullivan *et al.*, (2003), the variability of water resources is a factor that is often overlooked in water and poverty analyses. The key factor on defining the contribution of resources in the overall water poverty of a given community (both at national or local scale) should be the *actual resource availability* rather than the quantity of water resources. Water is fugitive (Savenije, 2002) and either costly infrastructures or good hydrogeological conditions are required for water storage. This is why an interesting relationship to be studied would be the one existing between WPI and exploitable water resources (instead of total water resources). Exploitable water resources are defined as "the water resources considered to be available under specific economic and environmental conditions" (FAO, 2003). The computation of exploitable water resources contemplates factors such as dependability of the flow, extractable groundwater, and minimum flow required for non-consumptive use. Unfortunately, estimations of exploitable water resources are not easy and needed data are only available for a limited number of countries in the AQUASTAT database (FAO), most of them being either developed countries or developing countries of semi-arid or arid regions.

Traditionally, the key indicator for water poverty is the access to *improved* sources of water. *Access* is the second sub-index integrated to the WPI methodology, accounting for three indicators, namely, *percentage of safe water access*, *percentage of sanitation access* and an *index of irrigation* (Lawrence *et al.*, 2002). Analysis shows (see Appendix 1) that there is a fair linear relationship between HDI and WPI *Access* sub-index, with a correlation coefficient of 0.75. Extreme poverty cannot be overcome without adequate access to water (Sullivan *et al.*, 2003), so this relationship between HDI and WPI *Access* appears to be meaningful.

The WPI *Capacity* sub-index is the one which shows the best relationship versus HDI, with a correlation factor of 0.88 (see Appendix 1). Quantitative indicators for the *Capacity* sub-index are: *GDP per capita*, *under-5 mortality rate*, *UNDP education index* and *Gini coefficient* (Lawrence *et al.*, 2002). Then, the high degree of correlation between WPI *Capacity* and HDI can be expected since the sub-index is based on the same data that contribute to the HDI. It is obvious that assessing the capacity of people to manage their own water resources is crucial for a sound assessment of water poverty. However, a discussion could be opened as to whether current WPI *Capacity* sub-index is really giving added information to the WPI or just mimicking HDI. It is worth noting that no specific information about water sector itself is considered for WPI *Capacity* estimation at a national level. Data such as the number of water technicians per capita, the people with university degree in water sector, or the number of water management entities could perhaps enhance the *Capacity* sub-index by adding sector-specific information.

No relation is found between WPI *Use* sub-index and HDI (see Appendix 1). Misuse of water is common in some developed countries (e.g. Spain scores 9.8), and some medium and low HDI countries can score better in this factor, like Sudan (14.6) or Mauritania (14.3). Mukherji (2006) found a direct relation between WPI *Use* sub-index and per capita GNP to a given threshold (about US$ 10,000 PPP), after which the relation become reverse as a possible indicator of efficiency achieved after a certain level of development.

Values of the WPI *Environment* sub-index display considerable scatter when plotted against HDI (Appendix 1). It is seen that only highly developed countries are able to score high values (i.e. 14 or above) in this factor (in particular, those of temperate and humid climatic conditions, as can be derived from a closer look at the WPI database), while almost every situation is possible under a value of 13. There is a clear *preference* of countries to get 11 points, whatever their level of development (Appendix 1). As a consequence, no clear conclusion about environmental conditions and its relationship with poverty or development appears to be possible below a WPI value of 13.

Further analysis of HDI–WPI relationships has been performed using Factorial analysis with the same dataset used previously by Mukherji (2006). A detailed presentation of the analyses done is shown in Appendix 2. Main results show the follows: First, it is worth stressing that *Use*, *Environmental* and *Resources* components of WPI contribute in a similar amount to the description of the variability of the dataset. *Capacity* and *Access* components, which are highly correlated, contribute also in a similar amount; however, both contribute in the same factor. Specific contribution of *Access* component of WPI has been found, but marginal. Almost null contribution of factor specifically related with *Capacity* component has also been found.

It is also remarkable the high correlation between *Capacity* component of WPI and HDI. This could be used in two different manners. Firstly, as an argument to redefine that component, provided that the results are almost identical to the HDI itself. Note that this supports the previously introduced notion that the *Capacity* component should be revised in order to include specific information related to water and sanitation sector. And conversely, provided that HDI and *Capacity* component are so much correlated at state level, HDI distributions at smaller geographical scales (local, regional, etc.) could be used to approximate *Capacity* component at those scales if other data is unavailable. Although the correlation using data at other scales has not been checked, the hypothesis seems reasonable. The same analysis could be applied to *Access* component of WPI and HDI, however it is worth noting again that *Access* component contribution is small but much higher than that associated to *Capacity* component (compare sixth and seventh unrotated factors in Table 3 of the Appendix 2).

Finally, another result of the analysis concerns the contribution of *Falkenmark Index* (FI), introduced in the analysis following a previous work by Mukherji (2006). It can be concluded that the correlation between *Falkenmark Index* and *Resources* component of WPI is strong enough to consider only one of both at a first level description. In that situation more than 90% of the variability of the overall system is kept, and variability of all variables is explained in, at least in 85% of cases. However, for a detailed comparison between countries, its inclusion could be considered, as it provides more information about the variability of the system than, for instance, *Access* or *Capacity* components (especially if HDI is available).

4.2 *Water Poverty and human poverty*

Relationship between WPI and the *Human Poverty Index* (HPI) has been analysed with factorial analysis, following same steps of previous subsection (Appendix 3). Also the decimal logarithm of the *Gross Domestic Product* (GDP) per capita has been included.

Results show that the inclusion of logarithm of GDP and HPI modifies neither the statistical behaviour nor the conclusions of the analysis of just WPI and HDI presented in previous subsection. On the other hand, logarithm of GDP, has the same behaviour as HDI, consequently it shows also a high correlation with *Capacity* and *Access* of WPI. Instead, HPI tends to discriminate cases (countries) more relevantly than FI, although the specific contribution of HPI to the overall variance is much lower than that of FI.

In any case, it is worth noting that WPI has much lower statistical correlation with HPI than with HDI or GDP. Or, in the same direction, WPI is more strongly related to HDI and GDP than to HPI. A corollary is that HPI provides more complementary information to WPI than HDI or GDP. Appendix 3 presents details and further analyses of results.

4.3 *Water Poverty Index and population distribution*

Previous sections have focused on the analyses of WPI and its relationships with other indices using data at country level. All countries have been treated as equally relevant cases from a statistical point of view. However, population varies significantly among different countries, thus the capacity of discrimination of the different variables as regards to people will be distinct from that indicated previously. In this subsection, results from a first approach to the influence of countries' population are presented as a tracking indicator for WPI usefulness at the state level. Firstly, a comparison between

HDI and WPI was made in terms of population distribution among index's values. Secondly, analysis was deepened to the WPI sub indices. Detailed analysis is presented in Appendix 4.

WPI concentrates population in a short range: 2,822 million people, i.e. 45% of world population, lay in 1/20 of the index scale. Country's concentration without considering their population shows more even distribution, yet 51% of the countries fit into 3/20 of the WPI scale, and three values are taking more than 15% of the total number of countries each. In both cases, *Human Development Index* gets a better distribution of countries along the index scale, with a maximum of 28% of population in 1/20 of the scale, and only one case of 1/20 of the scale with more than 15% of countries.

A separate study of population and countries distribution against each WPI sub-indices was made in order to shed light as to why WPI minimizes the differences in the final result. The resolution of WPI drops dramatically by the *Environment* sub-index, whilst *Resources* and *Access* sub-indices show the highest resolution. This seems to reflect the fact that *Resources* and *Access* are apparently the WPI components which are easier to quantify by traditional indicators and variables. On the contrary, environmental conditions are more difficult to quantify by objective indicators in the WPI. Sullivan & Meigh (2007) state, from a comparative study of pilot sites at local scale, that further work needs to be done in order to identify variables to represent the *Environment* component, particularly in urban areas. This improvement is also needed at the national scale.

4.4 *Application of Water Poverty Index at different spatial scales*

Several methodological applications of WPI at different scales have been published in recent years (Lawrence *et al.*, 2002; Sullivan *et al.*, 2003; Cullis & O'Reagan, 2004; Heidecke, 2006; Sullivan & Meigh, 2007). These include national, district, basin and community levels. The authors have analyzed in detail the particularities of the application of WPI methodologies at different scales, and the suitability of the index to make comprehensive assessment of the water sector in a given region has been demonstrated.

The above mentioned WPI methodology was applied to the case of Benin at regional scales (Heidecke, 2006). In that work, the performance of the WPI was analyzed in terms of the accuracy of the data integrated to the WPI. The calculation of the WPI would be influenced by the quality of the datasets, which may vary with their countries of origin. A straightforward conclusion which can be derived is that WPI results can only be as accurate as the data involved in the calculation (Heidecke, 2006). This is an event that a proper evaluation of the WPI should always contemplate. Most variables included in WPI calculation need to be collected from country official departments (either at local, regional or national scales) but many of that variables are defined differently among countries. Then, countries with loose definitions with respect to, for instance, water access or sanitation might score better than others with a stricter regulation, which might not necessarily reflect the actual situation of those countries. This fact is a common drawback for all water indicators and has been also pointed out recently by Sullivan & Meigh (2007).

Some problems have been reported when applying WPI for monitoring purposes. For instance, at a national scale, current WPI cannot be used for tracking the water sector performance of a given country since the WPI definition used is related to the rest of the countries (Lawrence *et al.*, 2002). This national WPI methodology is able to produce a ranking of water poverty for all countries. However, the increase of WPI in a country during a given time period may not reflect a real improvement but could actually be due to the worsening of other countries.

The ability of tracking the time evolution of water poverty in particular areas, where a given action or program is (or has recently been) implemented is crucial for development practitioners. Cullis & O'Reagan (2004) applied the WPI methodology to study the water poverty status in South Africa. *Access* and *Capacity* sub-indices needed to be computed with the last census available which has not been updated since 1996, which entails that the impact of actions developed to improve both subcomponents since 1996 could not be reflected in the final WPI results.

From our point of view, the main challenges facing the application of the index at various scales are as follows:

1. Data collected to compute the sub-indices are not consistent between different spatial scales, meaning that spatial comparison is only possible between the same scale units (two countries, two regions, or two communities). The contribution of a given improvement in one scale may not be reflected in the upper level, thus it is not integrative as to be up-scaled in a bottom-up procedure. In fact, variables at the community scale can be quite qualitative whereas variables at national scale are based on quantitative assessment of international organizations and research centers, which makes it very difficult to establish the relationship between different scales.
2. The possibility to update national WPI data, as currently defined, is very time-distanced. The fact that some data sets are based on household surveys, or similar national level data collection routines make very difficult to asses the improvements made in a given country in a given period.

5 CONCLUSIONS: THE NEED OF EASSY INDICATORS

There is an urgent need for having adequate performance indicators to track improvement in water sector in developing countries. The volume of funds channeled through local public entities represents around 60% of total investment in the sector, and will increase in the next years with the majority of funds from international cooperation being channeled through the public sector.

The *Water Poverty Index* has proved to be highly reliable to describe the water situation, since, unlike other deterministic water-resource assessment models, it explicitly contemplates the importance of political, institutional and environmental issues. Recognizing this fact, some constraints have been described in this chapter about WPI as a practical tool to be widely used by development practitioners.

Comparison with other relevant country development indicators, as HDI and HPI, has helped to understand WPI itself and relationships between its sub-indices. Factorial analyses of data presented by Mukherji (2006) and some additional indicators have been presented. WPI has been confirmed to display a higher correlation with HDI and logarithm of GDP than with HPI or *Falkenmark Index*. Highest correlations have been found between HDI and *Access* and *Capacity* sub-indices of WPI. Also a high correlation between *Access* sub-index and WPI as a whole has been observed. A detailed look at the results has shown that contributions of *Environmental*, *Use* and *Resources* sub-indices of WPI are *equilibrated*, i.e. they describe variability in a similar amount and in complementary aspects of the data. Instead, *Capacity* and *Access* sub-indices both represent fundamentally the same variability; different from ones of three previously cited sub-indices, but equivalent to that of HDI and GDP. A reduced contribution of *Access* sub-index by itself, apart from that included in HDI and WPI *Capacity* sub-index, has also been identified, with a weight less than 20–25% of other sub-indices. Thus, as a general rule, HDI can be used to accurately approximate *Capacity* sub-index, at least at state level while its non-sector-focus nature is unsolved; and even more, *Access* sub-index can be also approximated by HDI, if a small reduction in WPI variability is admissible. On the other hand, a preferred relationship of *Falkenmark Index* with *Resources* sub-index has been confirmed. Extension of these analyses to sub-state WPI applications could confirm these trends and could open the discussion about the information contained in the variables definition.

Finally, with respect to WPI statistical analysis, world population histograms among WPI fractions at country level have been presented (see Appendix 4). It has been found that a narrow range of variation of the WPI *Environment* sub-index concentrates, not only number of countries, but also world population, situation more evident among Aid recipient countries. Thus, WPI methodology at state scale shows reduced sensitivity to discriminate country and population situations, especially in relation with environmental issues. The application of WPI at national level is based on internationally available data to rank countries, which make its use for monitoring national water policy performance not possible, since some variables are based on census repeated every 5 to 10 years in the best case scenario or in the information contained in world atlases. Moreover, ranking does not give direct information on the performance of a given country but its comparison with others performance.

The application of WPI at other scales (basin, region, community) has been proved to be valid and meaningful, but since the variables used at different levels are not exactly the same, the establishment of comparisons is not straightforward. This might happen as well within the same geographical level in a given country, when variables are not accurately defined (thus allowing different interpretation) or are taken from different years. Actual differences on the variables used at different scales makes impossible to define a nested bottom-up index that could be integrative. On the other hand, even the use of very simple practical indicators, such as those defined for tracking the *Millennium Development Goals*, need further improvement in definition and application to ensure appropriate implementation.

Given the importance of tracking water sector's performance on a yearly basis, it is crucial to include water sector-specific data collection routines, as it is implemented in other basic social sectors such as health. This entails that, in the short term, information has to be easily available at the local level at a reasonable cost, even if some measurement of some variables, such as resources or environment, have to be oversimplified. Including routine data collection at the lowest appropriate level would enable at the same time a better tracking of transparency and accountability at all levels, as well as national awareness on the importance of systematic data collection. Existing data provided by international institutions has the advantage of making a first cut comparison possible, but it suffers from the lack of reliable country owned information.

The adoption of EASSY (Easy to get at local level, Accurately defined, Standard and internationally applicable, Scalable at all administrative levels, Yearly updatable) variables for monitoring water sector performance will certainly require a proper definition from the scientific community, the involvement of donors and civil society, and government willingness to implement measures to collect them. It will be needed to complement other geographical, environmental and hydrological information systems in order to define an internationally agreed reliable and updatable *Water Sector Indicator* that can be useful to monitor national water sector's performance over time and space.

ACKNOWLEDGEMENTS

The authors want to express their gratitude to *Ingenieria sin Fronteras* (Engineering without Borders), a partnership of *Spanish Non-Governmental Organizations* dedicated to cooperation for development, which seeks to put technology at service of human development, in order to build a fairer world society. Thanks are also given to the *Marcelino Botín Foundation* and particularly to Prof. Ramón Llamas for the invitation to take part of this Forum. Victor Vázquez, Quique Peña and Juan Manuel Galindez have contributed to this work by providing constructive comments and suggestions to the first draft of the manuscript.

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APPENDIX 1 WATER POVERTY INDEX VERSUS HUMAN DEVELOPMENT INDEX

Appendix 1 illustrates the relationship between *Water Poverty Index* (WPI), and *Human Development Index* (HDI), from data included in the UNDP Report (2005) and Lawrence *et al.* (2002). A total of 146 countries are considered. Donors and aid recipient countries have been separately identified.

Figures 2 to 7 present HDI versus WPI relationships. As Figures 2 to 4 show, there is a well-defined linear relationship between HDI and WPI ($R^2 = 0.66$) which becomes more strongly correlated with WPI *Access* component ($R^2 = 0.75$), and WPI *Capacity* ($R^2 = 0.89$). On the other hand, Figures 5 to 7 show no correlation among HDI and the *Resources*, *Use* and *Environment* WPI components.

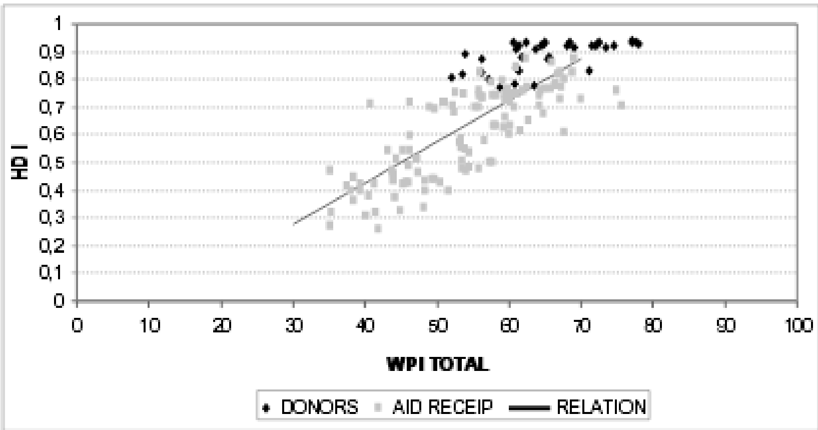

Figure 2. Human Development Index versus Water Poverty Index.

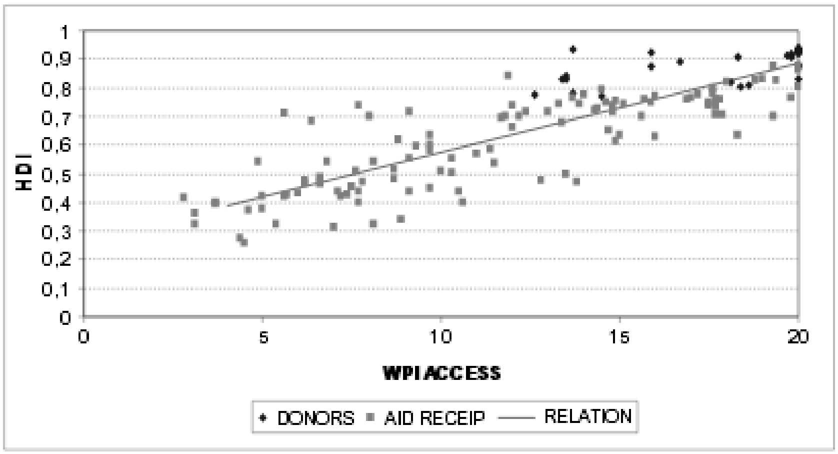

Figure 3. Human Development Index versus Access component of Water Poverty Index.

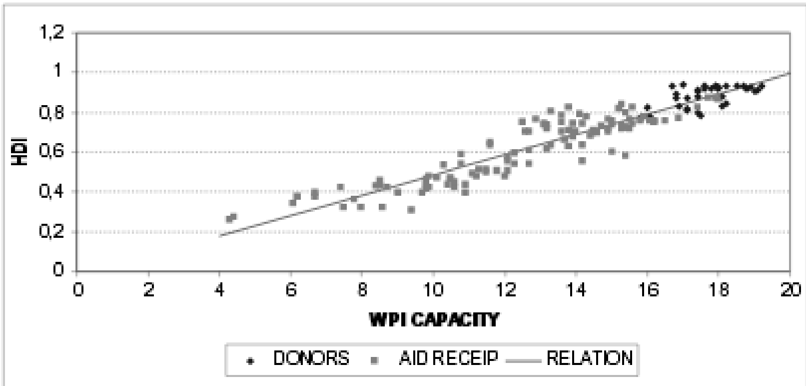

Figure 4. Human Development Index versus Capacity component of Water Poverty Index.

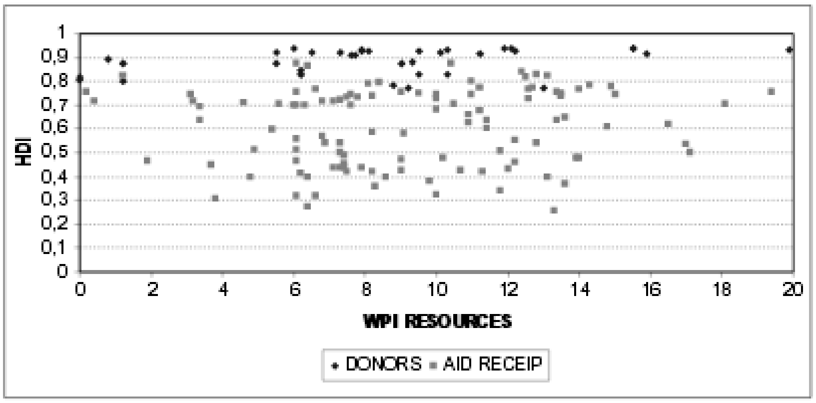

Figure 5. Human Development Index versus Resources component of Water Poverty Index.

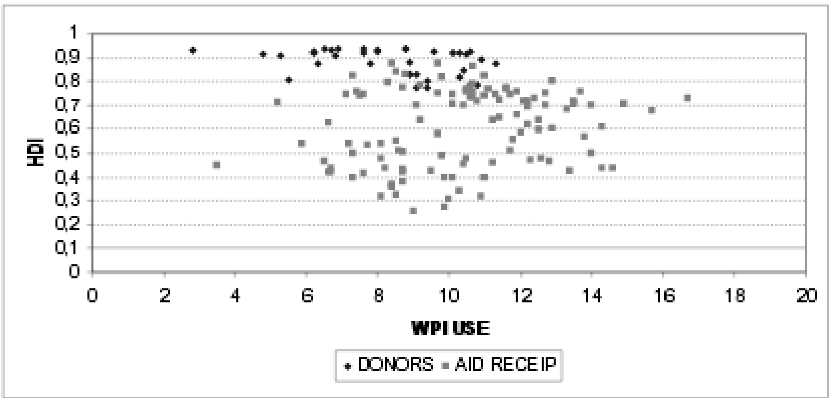

Figure 6. Human Development Index versus Use component of Water Poverty Index.

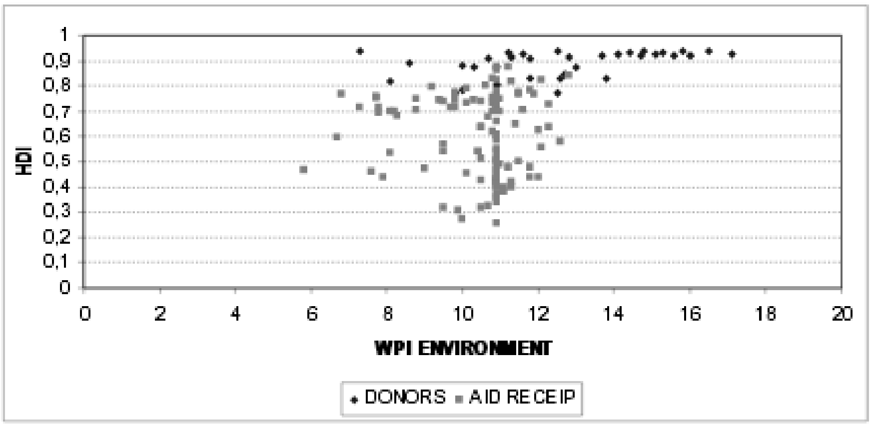

Figure 7. Human Development Index versus Environment component of Water Poverty Index.

APPENDIX 2 FACTORIAL ANALYSIS: WATER POVERTY INDEX AND HUMAN DEVELOPMENT INDEX

Appendix 2 provides a factorial analysis of HDI—WPI relationships using with the dataset previously used by Mukherji (2006). Table 2 presents the correlation matrix. Boldfaced numbers indicate correlation higher than 0.8 and underlined numbers correspond to relationships shown in Figures 2 to 7. Relationships between HDI and WPI, WPI–*Capacity* and WPI–*Access* are reflected here. The table shows the relatively high correlation between *Access* and *Capacity* subcomponents, and *Access* and overall WPI.

Table 3 presents the factors (linear combination of initial variables) that explain the variability of the dataset. It is worth noting that the first three factors account for about 83% of the variability, a proportion that rises up to more than 99% when six factors are considered. The most redundant factor is the last one, with a nil contribution to the total variance. It corresponds, as expected, to the linear relationship between WPI and its five components. Next one, number seven, can also be deemed irrelevant. Furthermore, two more, numbers six and five, represent less than the 5% of the total variance each, because of which the relevance of their contributions can be also neglected.

Table 4 summarizes the communality of the set of factors considered (the variability of each variable explained by these factors). Results considering 3 to 6 factors are presented. Values lower than 0.9 are in boldface. Note that the variability of all initial variables can be explained by six factors (at least in 97% of cases), with five factors in a 90% and with four factors in an 87%. Considering only three factors, that threshold drops down to 60%. Therefore, the approximation of the eight variables with only the first four factors can be considered statistically acceptable (a global variance of 92%, and at least 87% of each variable contribution). Factors appearing in fifth and sixth positions complete the description of the variability of the dataset, with a 99% of global variance and a 97%, at least, of variance of each variable.

Before analyzing the relationship between factors and the initial variables, a rotated set of factors is computed for each case (sets of 3 to 6 factors). They are computed using *Varimax* criteria, responding the aim of a simple identification of the factors in terms of the variables. Table 5 summarizes the percentage of the total variance explained by the set of rotated factors. Main factor retains the 43–45% of total variance, regardless of the number of factors considered. The second to fifth factors have a similar weight, amounting between 13 and 15% of total variance each. The sixth factor only represents 2.5%.

Table 6 includes the definition of each set of rotated factors in terms of the initial variables. Only values higher than 0.1 are listed. Boldfaced numbers are used for coefficients higher than 0.8 and other punctual representative values. Results allow for a clear interpretation of all factors found. The first factor includes *Capacity* and *Access* components of WPI, WPI itself and HDI. The second factor is directly related to *Resources* component of WPI, although it also includes the *Falkenmark Index* if less than five factors are extracted (the *Falkenmark Index* constitutes the core part of the fifth factor). The third and fourth factors are specifically related to *Environmental* and *Use* components of WPI and, finally, the sixth factor (the one with the lowest relevance) is related to Access component of WPI. It is reminded that the *Access* component is already part of the first factor, where it contributes more significantly than in the sixth one. Note that the first factor includes *Capacity* and *Access* components of WPI, HDI, and WPI, but later one has null contribution, so three main variables amount for a 43–45% of the total variance.

Table 2. Correlation matrix. Data from Mukherji (2006).

	WPI–RES	WPI–ACC	WPI–CAP	WPI–USE	WPI–ENV	WPI–TOT	HDI–2001	FI
WPI–RES	1.000							
WPI–ACC	0.057	1.000						
WPI–CAP	−0.056	**0.821**	1.000					
WPI–USE	−0.014	−0.053	−0.109	1.000				
WPI–ENV	0.275	0.275	0.282	−0.278	1.000			
WPI–TOT	0.457	**0.855**	0.767	0.123	0.468	1.000		
HDI–2001	0.031	**0.868**	**0.941**	−0.117	0.318	**0.809**	1.000	
FI	0.585	0.144	0.108	−0.037	0.056	0.345	0.108	1.000

Table 3. Variance explained by the factors.

Factor	% of total variance	% accumulated
1	47.578	47.578
2	20.616	68.194
3	14.794	**82.989**
4	9.700	**92.689**
5	4.340	**97.029**
6	2.331	**99.360**
7	0.640	100.000
8	0.000	100.000

Table 4. Variation of each indicator explained by the 3, 4, 5, 6-factorial analysis.

Communality	3 Factors	4 Factors	5 Factors	6 Factors
WPI–RES	0.859	**0.870**	0.992	1.000
WPI–ACC	0.883	0.890	**0.896**	1.000
WPI–CAP	0.907	0.928	0.932	0.982
WPI–USE	0.802	0.981	0.999	1.000
WPI–ENV	**0.601**	0.937	1.000	1.000
WPI–TOT	0.962	0.989	0.996	0.998
HDI–2001	0.937	0.947	0.948	0.969
FI	**0.687**	**0.874**	0.999	1.000

Table 5. Contribution of each rotated factor to total variation. Cases obtained from 3, 4, 5, 6-factors.

% of Total variance	3 Factors	4 Factors	5 Factors	6 Factors
Total	82.989	92.689	97.029	99.360
1	44.450	43.505	43.519	43.212
2	22.498	21.350	14.329	14.221
3	16.041	14.471	13.131	13.203
4		13.363	13.126	13.113
5			12.924	12.944
6				2.667

Table 6. Normalized coefficients of the factors expressed in terms of the initial variables. Cases obtained from 3, 4, 5, 6-factors analysis are included.

	1	2	3	4	5	6
HDI–2001	**0.958**		0.136			
WPI–CAP	**0.944**		0.113			
WPI–ACC	**0.937**					
WPI–TOT	**0.874**	0.445				
WPI–RES		**0.920**	0.112			
FI		**0.824**				
WPI–USE			**−0.890**			
WPI–ENV	0.308	0.248	**0.667**			
HDI–2001	**0.964**		0.107			
WPI–CAP	**0.957**					
WPI–ACC	**0.937**					
WPI–TOT	**0.831**	0.371	0.340	0.215		
FI	0.131	**0.908**	−0.157			
WPI–RES		**0.858**	0.352			
WPI–ENV	0.221		**0.923**	−0.175		
WPI–USE			−0.144	**0.980**		
HDI–2001	**0.964**		0.107			
WPI–CAP	**0.947**	−0.130				
WPI–ACC	**0.942**					
WPI–TOT	**0.843**	0.387	0.273	0.187	0.158	
WPI–RES		**0.930**	0.150		0.325	
WPI–ENV	0.213	0.143	**0.955**	−0.150		
WPI–USE			−0.131	**0.990**		
FI		0.301			**0.948**	
HDI–2001	**0.973**		0.106			
WPI–CAP	**0.963**	−0.101				−0.174
WPI–ACC	**0.914**					**0.394**
WPI–TOT	**0.834**	0.377	0.279	0.185	0.165	0.148
WPI–RES		**0.935**	0.149		0.321	
WPI–ENV	0.210	0.142	**0.956**	−0.150		
WPI–USE			−0.131	**0.991**		
FI		0.300			**0.949**	

APPENDIX 3 FACTORIAL ANALYSIS: WATER POVERTY INDEX AND HUMAN POVERTY INDEX

Appendix 3 focuses on the relationship between WPI and the *Human Poverty Index* (HPI) through factorial analysis, following same steps of Appendix 2. Also the decimal logarithm of the *Gross Domestic Product* (GDP) per capita, expressed in PPP terms at current international dollars, is included in the analysis, referred to as LG10_GDP. Data of both indicators refer to year 2004. Also updated HDI data from 2004 are used. All new data were obtained from *EarthTrends* data service (see http://earthtrends.wri.org). Analyses including HPI have been done involving 120 countries, and with also LG10_GDP with just 107 countries. Table 7 presents the main rotated factors of the system obtained with a seven-factor analysis. Partial contributions to total variance are included, as well as the total value represented by the seven factors, i.e. 98.799%.

First conclusion of analyses is that the inclusion of logarithm of GDP and HPI modifies neither the statistical behaviour nor the conclusions of the analysis of just WPI and HDI presented in Appendix 2. A strong relationship between HDI, Logarithm of GDP, and *Capacity* and *Access* components of WPI has also been found. Moreover, the second to fifth factors are related respectively with FI and *Environment*, *Resources* and *Use* components of WPI, with around 9–12% of contribution to total variance each. And finally, the *Access* component appears, apart from its contribution on the first factor, leading the seventh factor, with less than 2.5% of contribution to total variance, and less than a quarter of that from fifth and higher factors, which represents the *Environment*, *Resources* and *Use* components of WPI (compare 2.267 with 9.568 and so on in Table 7). Thus, its specific contribution can be easily neglected.

Main difference with Appendix 2 is found when analysing HPI, which have a negative influence on the first factor and it appears leading the sixth factor. Sixth factor contribution represents 4% of total variance, about 40% of any from higher factors (compare 3.912 with 9.568 and so on in Table 7), so its contribution can be considered not negligible.

HPI appears leading a specific factor when five-factor (or greater) analyses are computed. This factor appears first, with fewer factors, than that representing FI. Thus, HPI tends to discriminate cases (countries) more relevantly than FI. However, the specific contribution of HPI to the overall variance is much lower than that of FI (note that part of HPI contribution is also represented by HDI and others in factor 1).

Apart from the role of HPI and GDP, note that new HDI data, from 2004, present higher correlations with WPI's *Capacity* and *Access* components than those obtained in Appendix 2 with data from 2001. It can be caused by the number of countries considered, which has been reduced in these analyses. In any case, this fact confirms that HDI can approximate robustly both components of WPI, especially the *Capacity* one, at least when considering states.

Table 7. Coefficients of the rotated factors, obtained with a seven-factors analysis. Contribution of each one to total variation is also included.

% of Total Variance 98.799	1 49.829	2 11.798	3 10.809	4 10.615	5 9.568	6 3.912	7 2.267
HDI–2004	**0.967**					−0.173	
WPI–CAP	**0.964**						−0.111
LG10–GDP	**0.946**		0.183	−0.135			
WPI–ACC	**0.901**						**0.418**
WPI–TOT	**0.847**	0.174	0.280	0.170	0.323		0.186
HPI—2004	**−0.797**					**0.597**	
FI		**0.953**			0.299		
WPI–ENV	0.236		**0.950**	−0.167	0.115		
WPI–USE			−0.144	**0.987**			
WPI–RES		0.486	0.144		**0.861**		

APPENDIX 4 WATER POVERTY INDEX AND POPULATION DISTRIBUTION

Appendix 4 analyzes the ability of the WPI to represent differences among countries. Firstly, a comparison between HDI and WPI is made in terms of population distribution among index's values. Secondly, analysis is deepened to the WPI sub indices.

Figure 8 shows the world population distribution (UNDP, 2005) among the index fraction for both HDI and WPI (data from Lawrence *et al*., 2002). It can be seen that WPI concentrates population in a short range: 2,822 million people, i.e. 45% of world population, lay in 1/20 of the index scale. Analyzing the number of countries in each fraction of both indices, it is noticeable that countries concentration without considering their population shows a more even distribution, yet 51% of the countries fit into 3/20 of the WPI scale, and three values are taking more than 15% of the total number of countries each. In both cases, HDI gets a better distribution of countries along the index scale, with a maximum of 28% of population in 1/20 of the scale, and only one case of 1/20 of the scale with more than 15% of countries.

To deepen in this analysis, population distribution of water sector's aid recipient countries (excluding China and India) against WPI values has been made. As can be seen in Figure 9, WPI lacks the ability to discriminate the countries situation among developing countries. Considering 2,653 million people as the rest of aid recipient countries population (after excluding China and India), 29.63% of them lay in 1/20 of the scale, and 3 consecutive fractions include 65% of

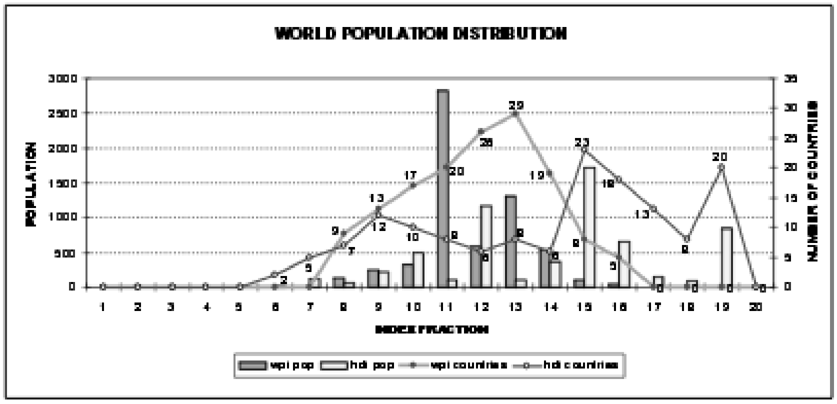

Figure 8. Population distribution and number of countries distributions among fractions of the *Human Development Index* and the *Water Poverty Index*.

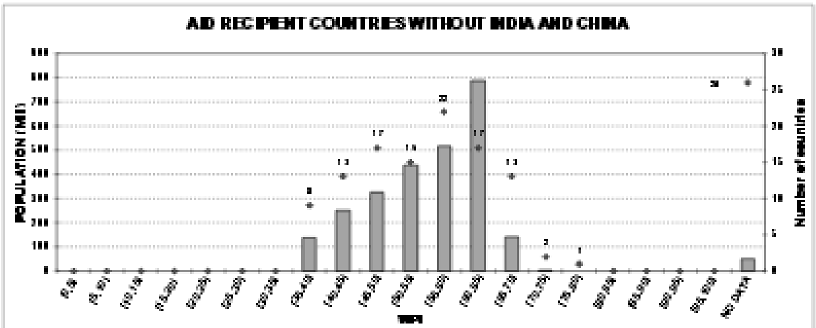

Figure 9. Population and number of countries distribution among fractions of the *Water Poverty Index* (aid recipient countries without China and India). Population is given in millions units.

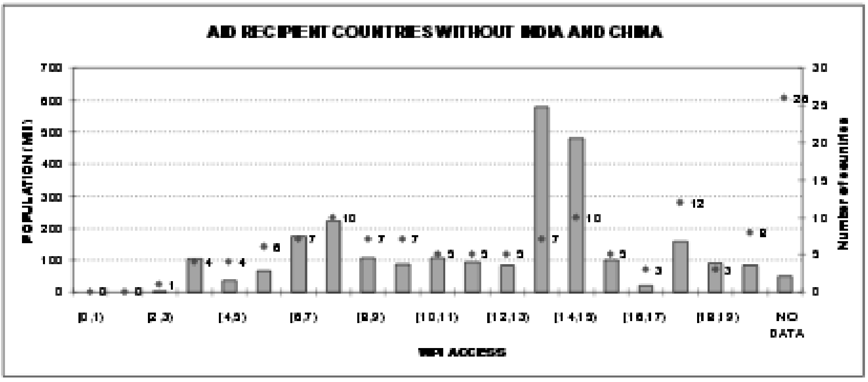

Figure 10. Population and number of countries distribution among fractions of the WPI-*Access* component (aid recipient countries without China and India). Population is given in millions units.

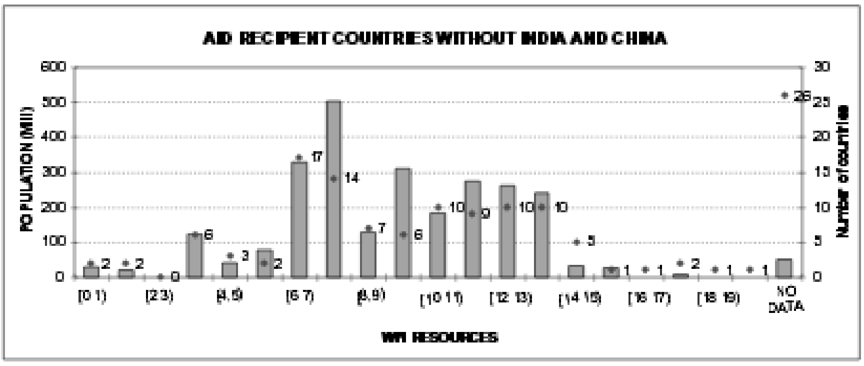

Figure 11. Population and number of countries distribution among fractions of the WPI-*Resources* component (aid recipient countries without China and India). Population is given in millions units.

the population. Only 8 out of 20 fractions of the index scale include some country or the other. In terms of number of countries, the WPI performs better, but we still find almost 29% of countries represented in 10% of the scale, and almost 50% of them among four consecutive fractions.

A separate study of population and countries distribution against each WPI sub-indices is presented, in order to shed light as to why WPI minimizes the differences in the final result. Figures 10 to 14 show the population distribution over the range of possible values in the 5 independent components of the WPI. Figure 10 shows that *Access* sub-index classifies the world population along almost every possible value. None of unity ranges of the sub-index includes more than 10 countries. The *Resources* sub-index seems to have resolution enough to show differences between the countries. Computed values range from 0 to 18, and world population distributes over all possible situations (Figure 11). *Capacity* and *Use* sub-indices distribute world population less than *Resources* and *Access*, lacking resolution to represent the actual differences among different countries. It can be seen in Figures 12 and 13 that in neither case sub-indices vary over their full range. *Capacity* component starts at 4 and ends at 19 (i.e. 75% of the full range) and *Use* component starts at 3 and ends at 17. The *Environment* sub-index is actually the component responsible of minimizing the differences in WPI values between people. Figure 14 shows how 2 consecutive fractions of the *Environment* sub-index (of a total of 20 fractions) are covering 66.41% of the population and 54.81% of countries. All countries lay between WPI-*Environment* values of 5 and 13, and one single fraction includes 55 countries.

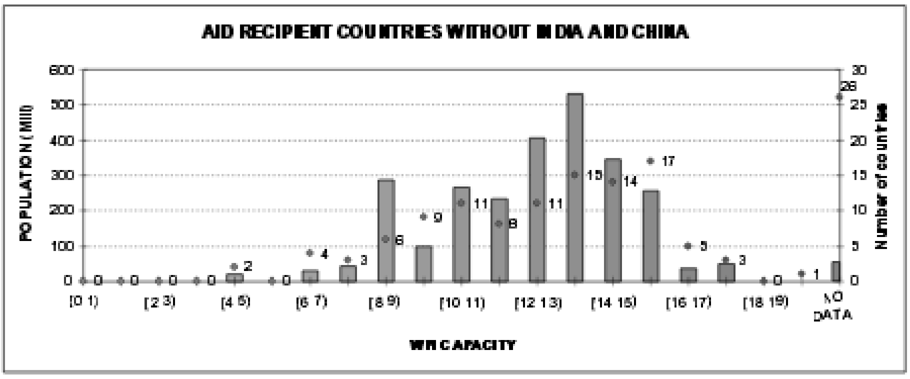

Figure 12. Population and number of countries distribution among fractions of the WPI-*Capacity* component (aid recipient countries without China and India). Population is given in millions units.

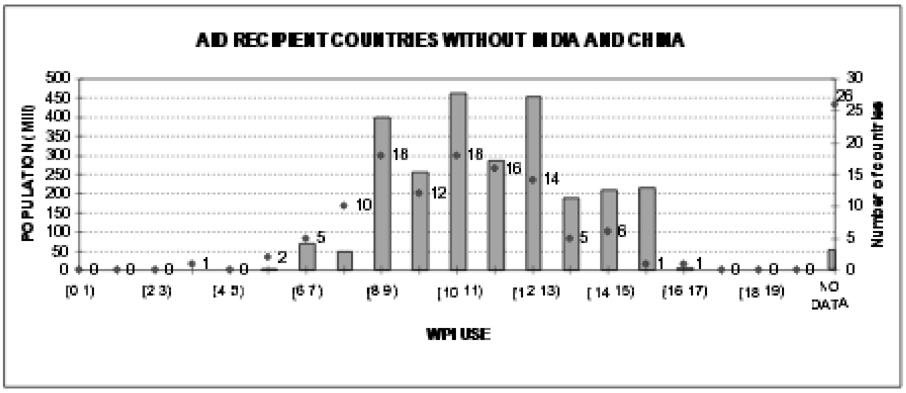

Figure 13. Population and number of countries distribution among fractions of the WPI-*Use* component (aid recipient countries without China and India). Population is given in millions units.

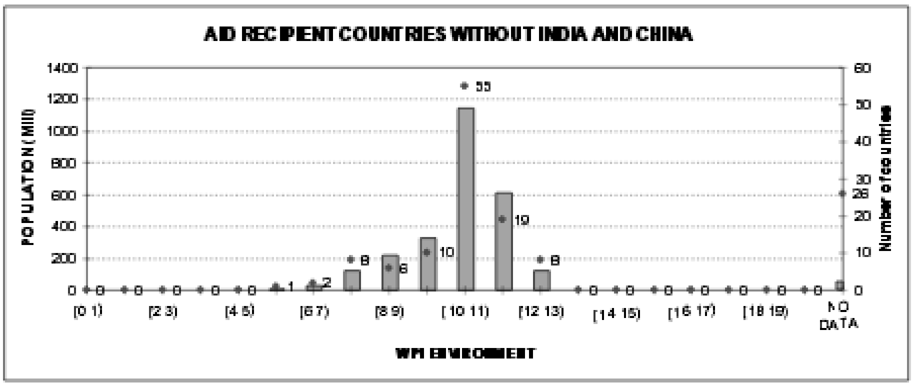

Figure 14. Population and number of countries distribution among fractions of the WPI-*Environment* component (aid recipient countries without China and India). Population is given in millions units.