FAOWATER Working Paper

The Rural Water Livelihoods Index

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1. Executive Summary

Overview

There are many indications that water is becoming an increasingly scarce resource, a point often made over the last 10 years (Falkenmark, 1997, SEI, 1997, Molden, 2007. Access to water is now recognised as a prerequisite for poverty reduction (Sullivan and Meigh, 2003), but in today's complex and changing world, competition for water from many different sectors can divert attention from its role in the improvement of human livelihoods (Llamas and Rogers, 2005). To better manage this vital resource, we need to develop ways of quantifying it which reflect this complexity, while providing robust representations of reality. Some 75% of the world's poorest people live in rural areas across the world, and for them, water access can literally mean the difference between life and death. The *Rural Water Livelihood Index* (RWLI) attempts to assess some of the more fundamental, water-related components which influence rural livelihoods, and which can support rural poverty reduction. In this way it can help decision makers target investments more effectively, ensuring funds get allocated to where there is most need.

Conceptually based on the Sustainable Livelihoods Framework (Scoones, 1998), the Capabilities and Entitlements approach of Sen (1985) and the *Water Poverty Index* (Sullivan, 2002), the RWLI is designed to employ existing data to calculate values for four key dimensions of the water-related conditions of rural livelihoods, namely:

1. *Access to basic water services*
2. *Crop and livestock water security*
3. *Clean and healthy water environment*
4. *Secure and equitable water entitlement*

The RWLI is calculated on the basis of components and indicator values representing each of these four dimensions. The resulting composite index reflects the values for these four dimensions, and on this basis, judgements can be made on how water management might be improved. Each of the four dimensions (components) of the RWLI are represented by two subcomponents, which are combined using a weighted average. In this report, this framework is applied at the national scale, but the approach can be used at any scale as long as appropriate data is available.

Objective

The purpose of the RWLI is to provide policy makers and planners at the national level an overview of where their country stands relative to others (much like the Human Development Index), and relative to themselves over time, to examine and monitor progress being made as a result of actions taken. This in turn will hopefully allow for *better targeted water-related interventions* to improve rural livelihoods. Through the measurement of these key components, it will be possible to assess which of the four dimensions are most likely to benefit from interventions. Appropriate interventions are context-specific and will have to be identified on a country-by-country basis since contexts differ so widely (i.e., responses to address the reported states will be country and site-specific). However, a general Response Matrix is being developed to provide planners and policy makers a conceptual framework to guide this process and at a macro-level the index values help national-level planners identify which sectors might be most in need of assistance.

Development

Much of the work in developing any global composite index is conceptual. With respect to the RWLI, a series of discussions were held between representatives of the United Nations Food and Agricultural Organization (FAO), the Oxford University

Centre for The Environment (OUCE) and the International Fund for Agricultural Development (IFAD) over the course of some ten months. These discussions built on earlier work on indicators originally carried out by several organisations working together on a DFID- funded project led by the UK Centre for Ecology and Hydrology (Sullivan et al. 2003).

Once the structure of the framework was agreed upon (after much debate), data were selected from existing sources, and on the basis of the resulting data collation, the RWLI values were calculated. This process involved:

- identifying and validating appropriate datasets,
- normalizing and aggregating the data,
- calculating the subcomponents to yield component scores,
- aggregating the subcomponents to calculate the final composite index values.

There is much data available from several sources in most countries, but its quality is very variable. In many cases, there are data gaps, but there also may only be information which is out of date. This clearly affects the quality of the results of any computation, including that of the RWLI. To avoid this being too problematic, countries which had too many data gaps or data reliability problems were excluded from this exercise. It is worth noting however that one of the final outcomes of any successful indicator development effort is to promote the generation of good quality, normalized data, so that the future indices generated from it will become more robust over time. Any index that becomes widely used tends to have the effect of encouraging the collection of better data , and the importance of standardizing data definitions (and collection methodologies), must not be underestimated.

After the data was collated, and the index calculated, a variety of statistical tests were conducted to validate the tool. Correlations between subcomponents and components were examined in order to determine which variables are most representative, as well as examining how much error variance is introduced by each variable, and how well the chosen components represent the final index value. In the final stages of the RWLI's development, a workshop was held at FAO with a variety of experts in order to determine which subcomponent and component combinations and weightings were most appropriate.

Findings and Future Development

The results obtained from this preliminary work on the development of this *Rural Water Livelihoods Index* illustrate that there is merit in the approach. The rural poor are often marginalised in many aspects of development, and this tool can help to focus attention on this group in order to give higher priority to their needs. The multivariate approach used here recognises that water-related decision making must be based on more than deterministic relationships, and to take this work further, as selection of pilot studies will be carried out based on data at the sub-national scale. While the national scale is clearly of use to international organisations and donor agencies, the sub-national scale is of much greater relevance to water managers and economic planners within the countries.

[1] We are beginning to see this happening in water quality indicators in the countries of the European Union, following the implementation of the EU Water Framework Directive (EU 2000)

2. Introduction

While hundreds of global indices and indicators have been created to date, very few of these are in use to support real decision making. In practice, there are only a few key indices of development which are widely used to measure progress, most notable of these being the Gross National Product (GNP), the Human Poverty Index (HPI), and the Human Development Index (HDI). Box 1 illustrates the HDI, and what has been achieved by its development. It is not the objective of this work to add yet another global indicator to the pile, but rather to produce a practical framework for measurement, specifically designed to address rural poverty. What is really needed is an objective, universal measure of water performance, calculated from a small number of specific dimensions of how water impacts on people's livelihoods. While such a measure has yet to be agreed upon, it is hoped that projects such as this will help to guide discussions toward a consensus on how such a measure may be derived.

Box 1: How the Human Development Index has changed the development process

The Human Development Index

Why was the Human Development Index created?
Prior to the Human Development Index, the process of development itself was measured in terms of changes in Gross Domestic Product (GDP). While this provided a crude assessment, it was realised that in many cases, rises in GDP were not evenly distributed across the economy. This meant that while some countries experienced rising GDP, this was achieved at the expense of social disruption or labour exploitation. To address this, an attempt was made to develop a way of coupling changes in GDP with changes in peoples' health and access to education. As a result, we are now able to assess the development process in a more holistic way, to understand more about how development impacts on the lives of ordinary people.

How is the HDI calculated?
The HDI is calculated as a composite index with three main components: Education (school enrolment and literacy), Health (life expectancy) and income (GDP, per capita values measured in terms of purchasing power). These are combined using a weighted average, and the weightings used have been determined in by an expert group. This allows the very variable situation across the world to be assessed and valid comparisons to be made.

What has the creation of the Human Development Index achieved?
By providing a better understanding of how peoples lives are impacted as development occurs, the HDI has galvanised global interest in the wellbeing of people in developing countries. Seeing how they themselves compared to other countries, has encouraged some governments to take direct action on the weaker aspects of their economy and society. The index has also helped to reveal to donor agencies, how their ODA efforts can be best used to really improve lives and livelihoods. A direct result of this has been the creation of the Millennium Development Goals (MDGs), and as a result, a concerted action has been made to address key social, economic and environmental issues which characterise global poverty.

The HDI captures both economic and social factors

The relationship between water and rural poverty is widely discussed in the development literature, and it is generally agreed that water of the appropriate quality, available at the right time is necessary to satisfy basic needs and enhance the productivity of land, labour, and other productive inputs. Many rural households throughout the world depend on subsistence agriculture and other activities such as small scale vegetable gardening, beer brewing, brick making, basketwork, textiles and other handicrafts that require water. These activities provide a much-needed source of income which is often used to support child education and household health. Better water access, for domestic, agricultural and agro-processing use, is likely to result in improved outcomes for poor households. Not only does this facilitate increased household productivity and health, but it is also likely to release labour into the household production system, which in turn may stimulate household income growth. For the rural poor, lack of access to water is often the factor limiting the potential to expand livelihoods, and time spent in water provisioning at the household level acts as a drag on micro-level economic growth.

The purpose of the *Rural Water Livelihoods Index* (RWLI) is to provide a framework for assessment of water-related components which influence rural livelihoods, and can support rural poverty reduction. In the work described here, this approach is applied at the national level, providing policy makers and planners with an overview of where their country stands relative to others, and relative to themselves with regard to rural water and rural livelihoods. This, in turn, will hopefully allow for better targeted water-related interventions to improve rural livelihoods. Through the measurement of key components, it will be possible to assess which sectors are likely to require interventions.

As a cost effective means of measuring rural progress in accordance with the above assumptions, it is necessary to identify suitable indicators from existing datasets. These indicators can then be combined into a composite index, much in the same way as with the Human Development Index (HDI) (UNDP, 1993, UNDP, 2006) and the Water Poverty Index (WPI) (Sullivan, 2002, Sullivan et. al., 2003). If administered at regular intervals, the RWLI can be used to measure progress towards the achievement of a reduction in those characteristics of rural livelihoods which are pervasive amongst the rural poor. Of course, appropriate interventions will have to be identified on a country-by-country basis since contexts differ so widely, and solutions are often going to be site specific. Clearly, national-level data will provide only a general indication of which sectors require attention, and more detailed work will be needed at the sub-national scale, to examine the various options more closely.
In terms of structure, the RWLI addresses four key aspects of rural livelihoods. These are:

1. *Access to basic water services*
2. *Crop and livestock water security*
3. *Clean and healthy water environment*
4. *Secure and equitable water entitlement*

These four dimensions of rural, water-related livelihoods have been obtained through an internal discussion among the team responsible for this report. It is an attempt to express the different ways in which rural people's lives can be affected by the different levels of availability of quality water (or by the excess of water in the case of floods). *Access to basic water services* includes access to clean and affordable water supply and to adequate sanitation. *Crop and livestock water security* is a measure of how agricultural activities are affected by climate variability and how resilient agricultural systems are to such variability, including droughts and floods. It is linked, in part, and where needed, with access to irrigation and livestock watering facilities. *Clean and healthy water environment* represents the water quality component of the index, in relation to human health and living conditions, while *secure and equitable water entitlements* are related to access to water, rights, and the degree to which the rule of law is present and equitably enforced.

Thus, the RWLI is a composite index of four major components, each of which is represented by two subcomponents[2]. The formula used to combine these components is designed to be simple and easy to use. If calculated periodically (for instance every five years) on the basis of accurate, locally generated data, the RWLI could indeed provide a globally accepted gauge of the state of rural livelihoods in relation to water resources at a national level, much in the same way that the HDI does now, in terms of general levels of economic and social development.. So too, as with the HDI, it is hoped that these country level comparisons will prompt national governments to adopt this approach as a way of providing an assessments of the condition of their water sector. This would enable decision makers, over time, to monitor and appraise their own situation, and thus be motivated to implement policies and programmes which will improve these key livelihood

[2] This structure is based on that of several widely used indices including the Human Development Index and the Water Poverty Index.

conditions, thus raising their RWLI scores. More importantly, in so doing, this will eventually bring about an improvement in the quality of life for the rural poor in their countries.

3. Background

3.1 Sustainable Livelihoods Framework

The sustainable livelihoods framework (Scoones, 1998, Carney, 1998) has been widely adopted by governments and donor agencies to improve the way rural peoples' lives are understood. In this context, and within the structure of the RWLI, the concept of poverty is based on the *livelihood entitlements* approach provided by Sen (1999), where poverty is the result of deprivation of such entitlements. In this work, it is our intention to provide specific snapshots of situations of rural water and rural livelihoods, by focusing on the resource pressures (and other drivers of change) which can give rise to and/or perpetuate rural poverty[3]. Table 1 provides an overview of some of the key assumptions upon which the RWLI is founded, and thus the rationale on which its creation and use are built.

Table 1: Framework of assumptions on rural livelihoods

Characteristic of rural livelihood	Characteristic manifestation amongst low income populations	Characteristic manifestation amongst high income populations
Agricultural Output (crops and livestock yield)	Low yields	High yields
Health and water access	Poor health and poor water access	Good health and good water access
Direct natural resource dependency	Very dependent directly on natural resources	Low dependence directly on natural resources
Vulnerability to flood and drought risk	High vulnerability	Low vulnerability
Knowledge and adaptive capacity	Traditional knowledge and adaptive capacity; low level of formal education	Sophisticated level of knowledge; high level of formal education

In any analysis of rural issues, consideration of agriculture is crucial. From a water perspective, this is especially important since agriculture takes up by far the greatest part of human water consumption (~70% of freshwater resources globally). In terms of drivers and pressures giving rise to water-related rural poverty, a number of components are thought to be important. These include three factors influencing the state of agricultural water use, namely *access, control*, and *management*.

Access describes the degree to which a household can obtain water. This may be from rainfall (in rainfed conditions), surface water sources, groundwater, surface or subsurface return flows from agriculture, or waste water from urban or peri-urban areas. In the context of access, water quality and reliability are also important. *Control* describes how well a household can move water from a source to the location at which the water will be applied. Elements within the control component might include farmer-operated canals and ditches, small pipelines, rights of way, and sharing arrangements with other farmers.

Management describes all activities relating to water provision. For the majority of water used by humans, this relates to farm-level decisions and practices regarding the application of water for crop and livestock needs. In the case of crops, farmers must determine the timing and amounts of irrigation deliveries, and the methods used for applying water on farm fields.

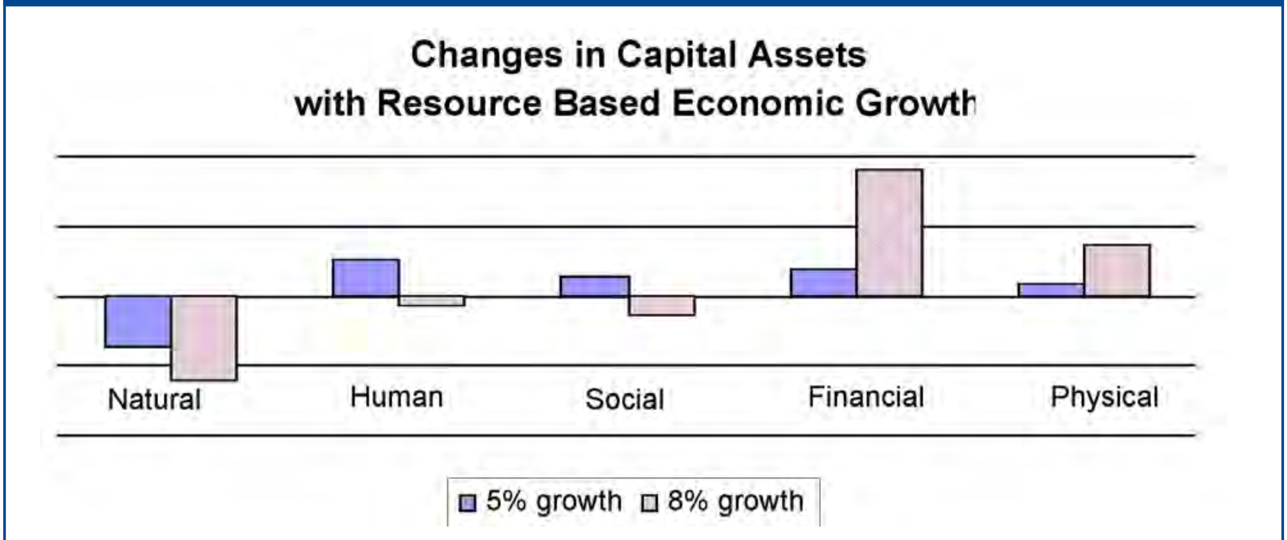
[3] While the widely used DPSIR framework has been used in discussions on indices elsewhere, we will not tie our work to this as we feel that it will not add value to what is being attempted here.

Economic outcomes depend on available inputs and the efficiency of their use. As in all economic systems, factors of production are needed by households to produce outputs which can then be either used or sold. The many different factors of production which exist can all be classed as *land, labour capital* or *entrepreneurial skill*. In the case of poor households, they predominantly only have labour as a factor of production, and usually their livelihoods are based around the sale of this labour. This may be a direct sale of labour to an employer, either in the agricultural or non agricultural sector, or it can be an imputed sale of labour through their own subsistence activities as described in both the farm and non farm sectors. This explains why the '*landless*' always tend to remain poor, as they have no access to the benefits (such as soil fertility, water retention etc) available from land. Similarly, the '*illiterate*' tend to remain poor, as they have no access to the benefits from education (such as ability to set up business, market goods etc). Furthermore, these groups, being by definition 'poor', also lack access to capital. In this context therefore, it is easy to see why the rural poor tend to remain poor.

The condition in which millions of poor people find themselves - faced by this lack of access to basic factors of production - has been well explained by Sen (1985, 1999) in his analysis of livelihood entitlements. In trying to focus attention on this issue of entitlements, the Sustainable Livelihoods Framework (Carney 1998, Scoones, 1998) clearly describes how household livelihoods depend on access to basic resources. In this approach, these resources are classified into *natural, human, financial, physical* and *social capital* types. Changes in the levels of these capitals will occur at a non-linear rate.

According to the conventional theoretical approaches to economic growth (Beckerman, 1995, Hamilton, 1995), in a sustainable system, any depletion of natural capital (e.g., quarrying) can be compensated by an increase in human capital, (for example through education funded from the proceeds of quarried stone). In practice however, this 'factor substitution' often does not occur, and this has led to a body of literature which contests this conventional view (Meadows, 1972; Daly, 1996). To illustrate this an example is shown in Figure 1 where two hypothetical scenarios of economic growth are presented. In the condition of 5% growth, the depletion of natural capital is at a lower level, and financial gains from it are distributed to bring about growth in human and social capital (e.g., healthier population with stronger institutions) and in physical capital (e.g., better infrastructure). In the second case, where a '*go for growth*' strategy is applied, driven by profit maximization, greater depletion of natural capital does generate a much higher level of financial capital, some of which is used to develop infrastructure (more physical capital), but in this case, no attention is given to social issues so human and social capital are both being depleted (though poorer health, social breakdown etc). The way in which these capital assets are distributed under conditions of economic growth is determined by political decisions, and thus it is important for policy-makers to be informed of the implications of the various choices open to them.

Figure 1: Hypothetical example of how the development process can impact livelihood assets

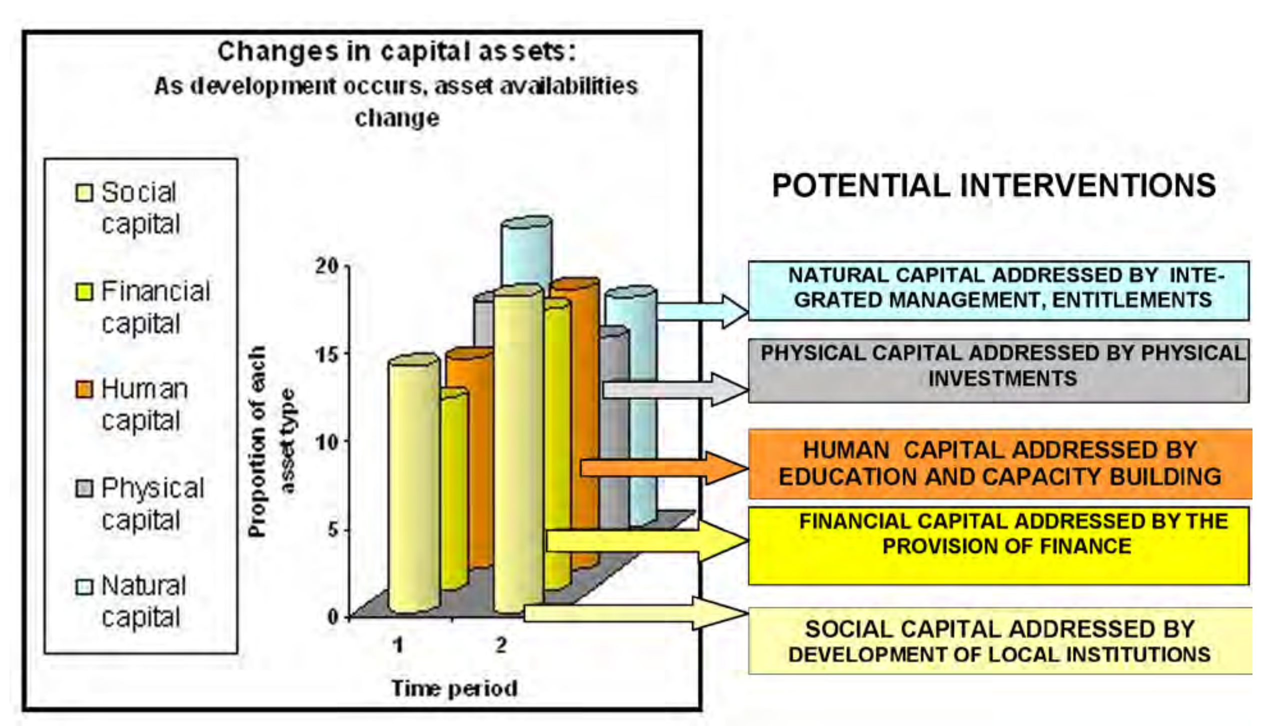


These concepts emphasize the importance of recognizing the need to promote an even development of all the livelihood capital types. The livelihoods of the poor must not be viewed only at a micro level, but also at the macroeconomic scale, to ensure that the benefits of their improvement act as a multiplier on the macro-economy as a whole. Since water is an essential prerequisite to many aspects of human development, better water provision will contribute a cross-cutting benefit to many sectors of the economy, promoting a balanced development trajectory overall. It is with this in mind that decision makers interested in water development would benefit from a tool to determine investment prioritization, thus maximizing potential benefits of development assistance, while also revealing other resource needs.

3.2 Linking livelihood capitals to policy responses

Livelihood capitals are interrelated, and may be jointly and even negatively influenced by the development process (as illustrated in Figure 2). To ensure that interventions taken by governments and donor agencies produce the desired effects, it is important to link the indicators used to measure progress, with the potential impacts policies may have. By combining a set of indicators through a multi-criteria framework, it is possible to assess which dimensions of livelihood characteristics most need to be addressed. When this is then linked to potential development interventions, it becomes possible to specifically address livelihood capitals in such a way as to promote pro-poor growth, in the context of sustainable, equitable water management, and rural development. This is illustrated in Figure 2.

Figure 2: Linking livelihood entitlements to potential interventions



Some efforts towards the development of an investment prioritisation tool such as the RWLI which seeks to link livelihoods capitals to water interventions (policy responses) have already been made (Sullivan, 2001, 2002). Specifically, the WPI, with funding from DFID, was developed and tested in Africa and Asia (Sullivan et al., 2002). The relevance of this approach to poverty alleviation has been discussed (Sullivan and Meigh, 2003, Molle and Mollinga, 2003, IISD 1999, Hoon et al, 1997) and subsequent work has been done by many researchers in many countries (Merz, 2003, Cullis and O'Regan, 2003, Dube, 2003, Yeh, et al., [in review]).

The interdisciplinary index structure used in the RWLI and WPI has been used as the basis of many other integrated indices which have subsequently evolved. In ongoing work in Canada, the WPI has been used as a basis for the *Canadian*

Water Sustainability Index (Morin, 2005) and it has also been used in a number of different contexts including the development of basin scale indicators (Sullivan et al., 2006b, Cook et al., 2007) and indicators of global water vulnerabilities (Meigh and Sullivan, 2003, Sullivan and Meigh, 2005, Sullivan et al., 2006c). With respect to climate change impacts in Africa, this approach has been discussed (Meigh et al., 2005), and its value as a tool for integrated catchment management has been highlighted (Wallace et al., 2003). The approach in index development and focus on water poverty has also been employed for rural poverty assessment in China (Cohen, 2007, Cohen and Sullivan, forthcoming). On this basis, an attempt is now being made to adapt this approach specifically to address generic, rural water related poverty issues, and to apply this RWLI to support water development investment strategies.

The main objective of the development of a tool such as the RWLI is to provide a means by which situations can be evaluated with a view to identifying optimal investment strategies. The overall goal is to improve human wellbeing in rural areas, within the constraints of ecological integrity. In keeping with the international commitments agreed at the World Summit on Sustainable Development (WSSD, 2002), this tool must take account of social, economic and ecological conditions within which human society must function. As discussed above, the analytical structure established within the Sustainable Livelihoods framework is considered to be particularly relevant in rural areas. What is novel about this approach is the linkages it develops between rural livelihoods, and hydrological and ecological scarcity.

Within this structure, the need to recognize the importance of access, control, and management of labour, land, and water resources are recognized. Since the objective of this tool is to assist in the provision of effective intervention mechanisms (policies, financial support, and technical assistance), to promote poverty alleviation, it is also considered important to include these within the structure of the proposed evaluative tool. In this way, this tool will also serve as a monitoring device, not only to evaluate general progress in rural poverty alleviation, but also (ex-post) to assess the impact of previously introduced intervention mechanisms.

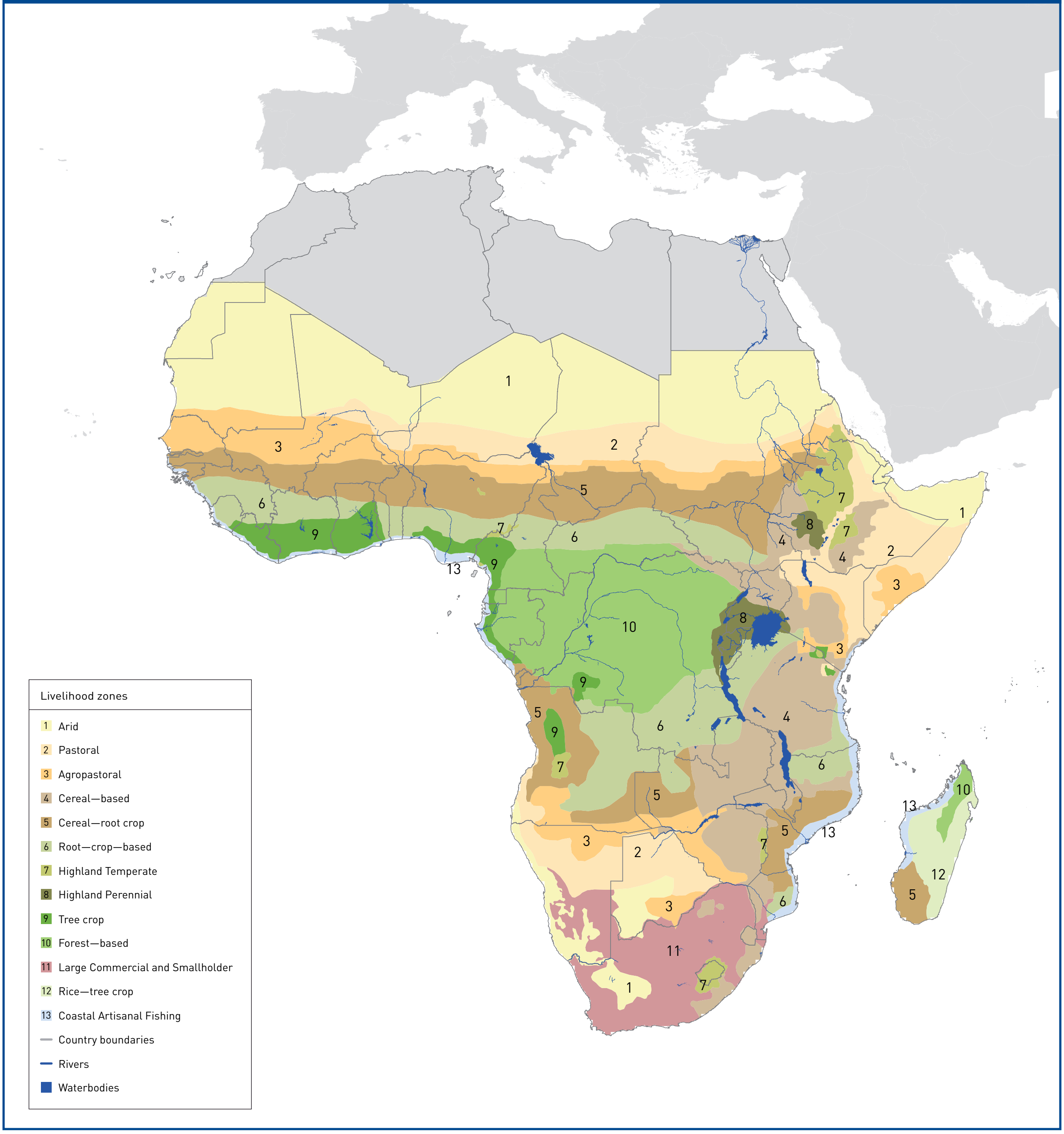
3.3 Mapping data from different sources

Using state of the art geographical information systems (GIS), it is possible to spatially relate factors influencing human wellbeing. RWLI values and component values can be mapped at the national level and overlaid with other data such as livelihood zones and poverty prevalence which tend to have less strictly defined political boundaries. This in turn will aid in the analysis of regional trends.

For example, on the basis of the literature review carried out by FAO for sub-Saharan Africa, it has been possible to identify specific agro-ecological zones where water vulnerability and water poverty may be high. This has been determined by correlating geographical areas identified by their agro-ecological characteristics with measures of food security (FAO AND IFAD, 2008). As a first stage in this process, a map of livelihood zones across Africa has been produced, and is shown in Figure 3 when this information is combined with the data on rural malnutrition, it is possible to identify those areas which are likely to have the potential to benefit from water interventions as a way of improving food security. This is shown in Figure 4

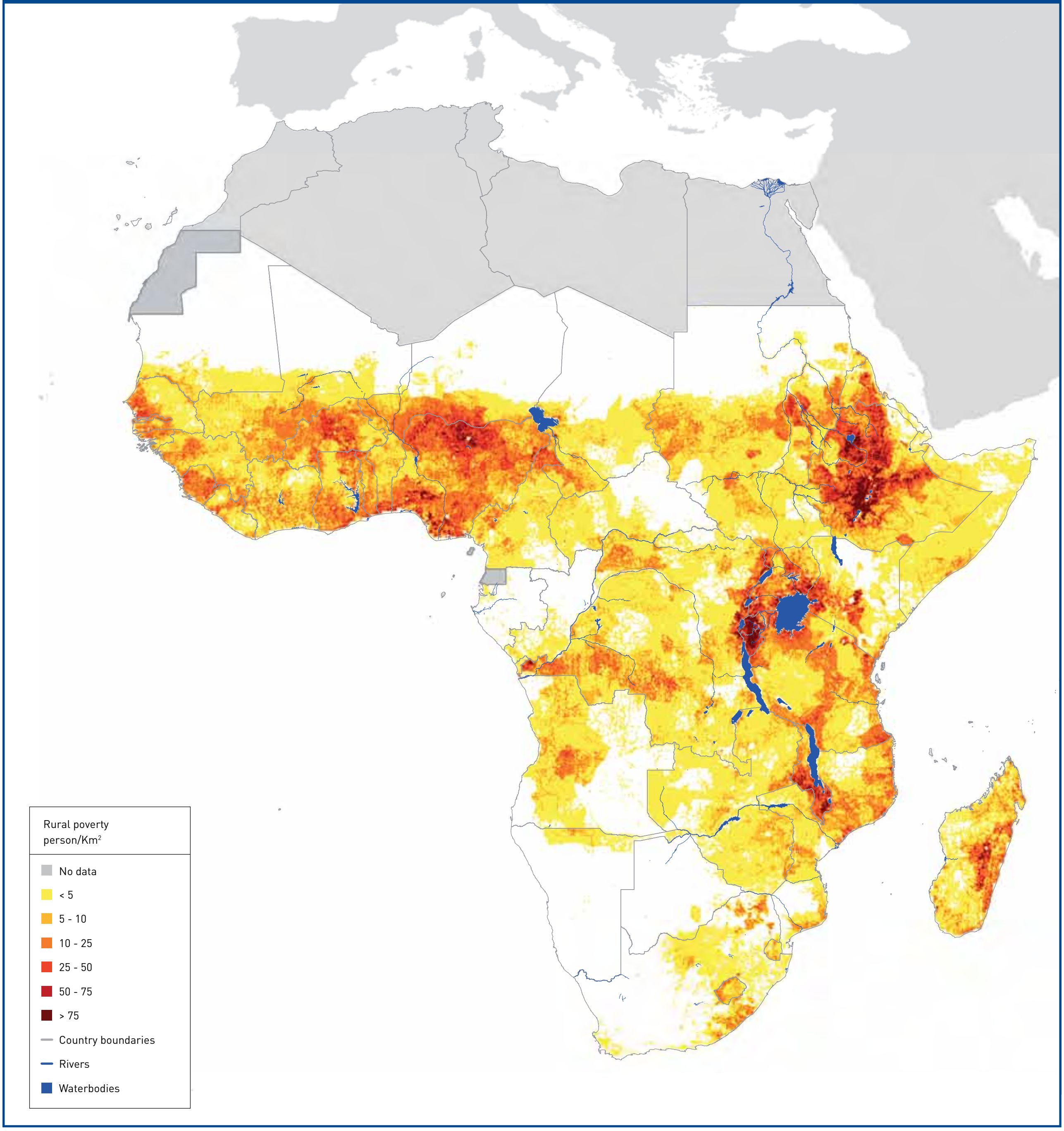
Given the information shown on the map inFigure 3, the areas most likely to benefit from water focused interventions have been identified as those which are characterized by Agropastoral, Cereal-based, Cereal-root crop zones. Together with the Highland Temperate zones of Ethiopia, these three livelihood zone types provide livelihood support for some 202 million rural people in Sub-Saharan Africa, and of these, some 78 million are classified as the rural poor. The vast majority of these rural poor are located in areas in Nigeria, Niger, Mali, Tanzania, Zambia and Kenya, and the Lake Victoria region and the countries of the Upper Nile. These countries are therefore the ones on which we shall be concentrating in terms of verifying the RWLI values and investigating the potential impact of specific targeted water interventions as they relate to the macro-level data the RWLI provides (in section 5.3).

Figure 3: Livelihood zones in sub-Saharan Africa



Source: FAO and IFAD, 2008

Figure 4: Distribution of rural poverty in sub-Saharan Africa



Source: FAO and IFAD, 2008

4. The structure and computation of the RWLI

4.1 The unavoidable tradeoffs in designing a composite index

The construction of composite indices is a difficult task. Since the strength of the representation (meaning) of any component within any index of this sort is influenced by the total number of components, it makes sense to try and minimize this number as far as possible (that is, so each subcomponent's influence is not washed out by too many competing subcomponents). For example, if an index such as the RWLI has four components and each is equally weighted at 0.25 then any one component has as much as a 25% influence on the composite score. If a given component consists of two subcomponents which are equally weighted at 0.5 each, then each subcomponent accounts for as much as 12.5% of the index score. If, on the other hand, a given component is made up of ten subcomponents then each, assuming they are equally weighted at 0.1, contributes a mere 1.25% to the composite score. This example makes it clear that the more subcomponents one adds to an index the less important each of them becomes. In general, the use of an excessive number of components or sub-components leads to a reduction in contrasts in the computation of the index between regions or countries to be compared, and a tendency for different components to compensate each other, leading to small differences in the index scores. Three to five components, each of them being computed on the basis of one or two sub-component can be considered a good tradeoff where the multiple dimensions of the issue are adequately taken into account without excessive complexity, and where differences between scores remain significant.

When addressing the issue of poverty, however, it is nevertheless still important to try to capture a holistic representation of the multidimensional nature of what is being measured. That is, in the interest of ensuring that the data used is meaningful with respect to the composite index, there is a necessary compromise between the depth of data captured and the range of data included. In the case of the RWLI, as a country-level index, the compromise is further complicated because only datasets for which enough global data is available, can be used. This causes some distortion in the final structure of the RWLI, as it is necessary to use existing data. In some cases, where some data is not available, an attempt was made to remedy this using either the most recently available data, or by expert judgement. Other cases simply had to be dropped as being too data poor. Taking all of this into consideration, the RWLI was constructed to be a composite index of four major components (or indicators), each of which is represented by two subcomponents[4]. Table 2 provides more detail on the components and subcomponents and data sources used for each, with additional information provided in Appendix 1.

4.2 RWLI data requirements & calculations

Based on the theoretical rationale presented above, and on the necessary compromise between depth of information covered and the influence of any given data source, the RWLI's components and subcomponents have been carefully chosen by means of multiple consultation sessions, with a variety of water, rural poverty and development experts. Finally, taking into account data availability, the index was calculated based on the structure and sources outlined in Table 2.

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4 The value of such a structure is that it provides a consistent, repeatable framework which can be replicated through the application of appropriate indicators at any scale. It is important to note that all efforts should be made to ensure representation of any particular scale is made through the use of data at that scale (Sullivan and Meigh, 2006) and that when the RWLI is calculated in the future, data based on the same unit of calculation must be used.

Table 2: RWLI: Components, subcomponents, indicators and data sources

Component	Sub-component	Indicator	Data used and computation method	Data Sources*	Year/s Used
1. Access to water & sanitation services	1.1 Access to water supply	Improved drinking water coverage – Rural population (+)	Access to safe drinking water is estimated by the percentage of the population using improved drinking water technologies (which are those more likely to provide safe drinking water than those characterized as unimproved). Improved drinking water sources comprise: Household connection; Public standpipe; Borehole; Protected dug well; Protected spring; Rainwater collection. The results were normalized.	JMP (WHO & UNICEF)	2004
	1.2 Access to sanitation	Improved sanitation coverage – Rural population (+)	Access to sanitary means of excreta disposal is estimated by the percentage of the population using improved sanitation facilities (which are more likely to ensure privacy and hygienic use). Improved sanitation facilities comprise: Connection to a public sewer; a septic system; Pour-flush latrine; Simple pit latrine, or a Ventilated improved pit latrine. The results were normalized.	JMP (WHO & UNICEF)	2004
2. Crop & livestock water security	2.1 Livestock security	Inter-annual variation of cattle holdings (-)	After the 15 year trend was removed, the coefficient of variation of cattle holdings (in heads of cattle from 1992-2006) was calculated. The results were inversed and then normalized.	FAO	1992-2006
	2.2 Crop production reliability	Inter-annual variation of cereal production (-)	After the 15 year trend was removed, the coefficient of variation of cereal production (1992-2006) was calculated. The results were inversed and then normalized.	FAO	1992-2006
3. Clean & healthy water environment	3.1 Pressure on water resources	Water withdraw as a % of total renewable water resources (-)	Water Withdrawal as Percentage of Total Renewable Water Resources. Renewable resources are the total resources that are offered by the average annual natural inflow and runoff that feed each hydrosystem (catchment area or aquifer). The results were inversed and then normalized.	FAO	1998-2002
	3.2 Diffuse (agricultural) water pollution risk	Intensity of nitrate consumption (-)	Nitrogen (N Total Nutrients) consumption (metric tons) divided bv arable land (i.e cultivated land). The results were inversed and then normalized.	FAO	2003- 2005

Component	Sub-component	Indicator	Data used and computation method	Data Sources*	Year/s Used
4. Secure & equitable water entitlement	4.1 Severity of rural poverty	Percentage of undernourished people (-)	The percentage of undernourished people at national level is a indication of the number of people who are unable to reach even the most basic poverty line. The results were inversed and then normalized.	FAO	2000-2002
	4.2 Prevalence of corruption	Corruption Perceptions Index (-)	The Corruption Perceptions Index (CPI) is calculated using data from 14 sources originated from 12 independent institutions. All sources measure the overall extent of corruption (frequency and/or size of bribes) in the public and political sectors and all sources provide a ranking of countries. Evaluation of the extent of corruption in countries is done by country experts, non resident and residents (in the CPI 2007, this consists of the following sources: ADB, AFDB, BTI, CPIA, EIU, FH, MIG, UNECA and GI); and resident business leaders evaluating their own country (in the CPI 2007, this consists of the following sources: IMD, PERC, and WEF). The results were normalized.	TI	2006-2007

Notes: (1) When a high score of the indicator means a bad situation (represented by (-) in Table 2), the inverse of the result is used in the computation of the component. (2) See 4.4 for discussion on normalization.

Table 2: RWLI: Components, subcomponents, indicators and data sources Data Sources - Abbreviations	
FAO	Food and Agricultural Organization of the United Nations
JMP	Joint Monitoring Program (WHO & UNICEF JMP for Water Supply & Sanitation)
TI	Transparency International
UNICEF	United Nations Children's Fund
WHO	World Health Organization

With respect to the indicators and data sources above, it is important to bear in mind that the objective of any index is to provide an insight into the *essence of a situation*, rather than a specific measure of it (Sullivan et al, 2006a).When the complexity of a situation means simple measures are inappropriate, an index-based approach such as this can provide some useful insights to support decision-making.

4.3 Compiling a national level database to support the calculation of the RWLI

The data used to calculate the RWLI is shown in Table 2, and this provides the foundation of the database used to calculate the index values. The starting point in the compilation of this database was a list of all 192 UN member countries. Data representing the selected variables as shown in were sought from a variety of key sources. In cases where countries were missing two or more subcomponent values, they were removed from the list (they were mostly small countries). In the remaining country set of 158 countries, data gaps were filled using a variety of methods as illustrated in Table 3 below.

Table 3: Dealing with missing data

Sub-component	Countries with missing data	Data used and computation method
1.1 Access to water supply	Kuwait, Lithuania, New Zealand, Poland, Portugal,	In cases, where data was missing, replacement values were identified on the basis of an average score calculated from the scores for this variable for four countries presenting "similar" conditions. The exception to this rule was if a country reported 100% coverage for their national values, it was inferred that rural coverage was also 100%. In a few instances, expert judgement was used to fill the missing values. (See Appendix II for details).
1.2 Access to sanitation	Denmark, France, Greece, Ireland, Israel, Italy, Kuwait, Lithuania, Malta, New Zealand, Norway, Poland, Portugal, Romania, Saudi Arabia, United Kingdom	In cases, where data was missing, replacement values were identified on the basis of an average score calculated from the scores for this variable for four countries presenting "similar" conditions. The exception to this rule was if a country reported 100% coverage for their national values, it was inferred that rural coverage was also 100%. In a few instances, expert judgement was used to fill the missing values. (See Appendix II for details).
2.1 Livestock security*	Lesotho, Maldives, Niger, Sierra Leone	In cases, where data was missing, replacement values were identified on the basis of an average score calculated from the scores for this variable for four countries presenting "similar" conditions.
2.2 Reliability of crop production*	Czech Republic, Iceland	In cases, where data was missing, replacement values were identified on the basis of an average score calculated from the scores for this variable for four countries presenting "similar" conditions.
3.1 Pressure on water resources	Bosnia and Herzegovina, Croatia, Maldives, Slovakia, Solomon Islands	Only a few countries had missing data for this variable, but to address this, the value of Total Renewable Water Resources per capita was calculated (based on FAO data), and the normalised values were used to replace missing data. To verify the validity of this approach, this per capita value was correlated with the normalised value of the water withdrawal as a percentage of total renewable resources, and this proved to be a positive value of 0.713 indicating the appropriateness of this measure for filling the missing data.
3.2 Diffuse (agricultural) water pollution risk	Afghanistan, Bhutan, Botswana, Cape Verde, Central African Republic, Chad, Comoros, Congo (Republic of the), Democratic Republic of the Congo, Djibouti, Dominican Republic, Gambia, Guinea-Bissau, Haiti, Iraq, Lao (People's Democratic Republic of), Lesotho, Liberia, Mali, Mauritania, Rwanda, Sierra Leone, Solomon Islands, Somalia, Swaziland, Tajikistan, Turkmenistan, Uzbekistan, Zambia	Due to several missing values for this measure (29) and the country specific nature of fertiliser application, the normalised average global value for nitrogen consumption per unit of arable land was used for all of these countries.
4.1 Severity of rural poverty	Australia, Austria, Barbados, Belize, Bhutan, Canada, Cape Verde, Comoros, Cyprus, Denmark, Djibouti, Fiji, Finland, France, Germany, Greece, Guinea-Bissau, Iceland, Ireland, Israel, Italy, Japan, Maldives, Malta, Netherlands, New Zealand, Norway, Oman, Portugal, Qatar, Solomon Islands, South Africa, Spain, Sweden, Switzerland, United Kingdom, United States of America	4.1 Missing values for OECD countries were filled by expert judgement based on the assumption that OECD countries have minimal rural under-nourishment and thus these have been given a normalised score of 99/100. For non-OECD countries replacement values were identified on the basis of an average score calculated from the scores for this variable for four countries presenting "similar" conditions.
4.2 Prevalence of corruption	Fiji	There was only one case in which data was missing; the replacement value was identified on the basis of an average score calculated from the scores for this variable for four countries presenting "similar" conditions.

4.4 Combining the indicators into a composite index

The overall structure of the RWLI is based on the principles of *Multi-Criteria Analysis* (Saaty, 1980, Hyde et al., 2004, Nijkamp, 1990), and as a *composite index*, it is generated from the weighted average of four major components, each in itself being constructed from a selection of representative variables. Weights are composed of measures of importance associated with each component (variable) score (See section 4.5). But before data are to be combined, they first need to be normalized, and then weighting needs to be considered. To overcome problems of incommensurability, data must be normalized so that each component (domain) has a common distribution and is not scale dependent. The normalization process also facilitates easy identification of the best and worst areas, according to the RWLI approach. How the data has been normalized in this work is shown in Box 2.

Box 1: How the Human Development Index has changed the development process

Normalizing Component Scores

In order to combine components which are based on different units of measurement, the scores need to be 'normalized' before combination. This means putting them on the same scale. In this study, scores for each indicator are calculated by the formula:

$x_i - x_{min} / x_{max} - x_{min}$

where x_i , x_{max} and x_{min} are the original values for location i, for the highest value country, and for the lowest value country respectively.

The score for any one indicator then lies between 0 and 100.

The maximum and minimum values are usually adjusted so as to avoid values of 0 or 100.

The aim is to get values in the range 0 to 100 for each indicator.

For the calculation of the RWLI, data from the sources outlined in table 2 were normalized in this way to calculate sub-component scores for each country. The scale for normalized data was designed to range from 0-100, with high numbers indicating favourable conditions. After all the data was collated, the scores were then combined through the formula:

$$RWLI_i = \frac{\sum_{j=1}^{N} w_j X_{ij}}{\sum_{j=1}^{N} w_j}$$

Where RWLIi is the *Rural Water Livelihoods Index f*or location i, Xij refers to component j of the RWLI structure for that location, and wi is the weight applied to that component.

The equation can be restated as:

$$RWLI_i = \frac{W_{aws}AWS_i + W_{cls}CLS_i + W_{che}CHE_i + W_{see}SEE_i}{W_{aws} + W_{cls} + WV_{che} + W_{see}}$$

Where:

RWLI = the Rural Water Livelihoods Indexvalue for location i
AWS = Access to water and sanitation services for location i
CLS = Crop and livestock water security for location i
CHE = Clean and healthy water environment for location i
SEE = Secure and equitable water entitlement for location i

Each of these four main components was calculated on the basis of a number of sub-components. Each of these components is illustrated in the following equations.

Access to water and sanitation services

$$AWS = \frac{w_{ws}WS + w_{s}S}{w_{ws} + w_{s}}$$

Where:

WS = Access to water supply

S = Access to water sanitation

w_{ws} and w_{s} = the respective weights assigned to WS and S for the computation of AWS

Crop & livestock water security

$$CLS = \frac{w_{LS}LS + w_{CP}CP}{w_{LS} + w_{CP}}$$

Where:

LS = Livestock security

CP = Reliability of crop production

w_{LS} and w_{CP} = the respective weights assigned to LS and CP for the computation of CLS

Clean & healthy water environment

$$CHE = \frac{w_{P}P + w_{WPR}WPR}{w_{P} + w_{WPR}}$$

Where:

P = Pressure on water resources

WPR = Diffuse water pollution risk

w_{P} and w_{WPR} = the respective weights assigned to P and WPR for the computation of CHE

Secure & equitable water entitlement

$$SEE = \frac{w_{SP}SP + w_{C}C}{w_{SP} + w_{C}}$$

Where:

SP = Severity of rural poverty

C = Prevalence of corruption

w_{SP} and w_{C} = the respective weights assigned to SP and C for the computation of SEE

4.5 Weighting of components: risks and benefits

The issue of weightings is highly controversial due largely to the subjectivity inherent in assigning weightings. While the application of weights facilitates an indication of importance of the different variables, it also leaves the results open to manipulation. However, the calculation of an index through the combination of any set of data implies in any case a system of weighting. Putting weights into the formula makes this explicit, and thus more transparent. To ensure that this is the case, the issue of weighting must be explained to users and stakeholders. This is particularly true since weightings modify the relative importance of specific components, and the determination of the importance of any part of an index is a political decision. For the provision of baseline values of the RWLI, an equally weighted index may be the most neutral choice. It is important to note that if comparisons are to be made between scores for different locations or situations, the weightings used must be the same in all cases.

Weights are effectively multiplicative factors which are applied to each component. When totalled, weights must equal 100 (%). A weight of 30% means that the specific domain score for that particular component is multiplied by 0.3.
Five approaches to allocation of weights are discussed below:

- entirely arbitrary
- determined by consensus
- determined by policy relevance
- empirically driven
- driven by theoretical considerations

Arbitrary Weights

When weights are chosen without reference to theory or empirical evidence, or even when equal weights are selected, this is classed as 'arbitrary'.

Weights determined by consensus

In this case, policy makers and stakeholders could simply be asked for their views and the choices obtained by consensus.

Weights determined by policy relevance

Components can be weighted in accordance with public expenditure on particular areas of policy.

Weights driven by theoretical considerations

In the theoretical approach, account is taken of the available research evidence which informs the theoretical model of what is being examined, and weights are assigned according to this. (e.g., if deriving an index of susceptibility to Malaria, the theory suggests that the presence of specific mosquito types is essential to the transmission of Malaria. This would imply that this would have the greatest weight, while other issues, such as presence of standing water, would be less important, and so would have less weight).

Empirical approaches to weighting

There are two sorts of approaches that might be applicable here. First, analysis of an existing survey might generate weights. Here one might construct a proxy for the issue being examined, and multivariate predictive modeling can be used to derive weights. Second, factor analysis (Senior, 2002) to extract a latent 'factor' representing the issue can be used, assuming that the analysis permitted a single factor solution.

Weighting scheme used for RWLI

In this scoping study, we have examined how others involved in index development have dealt with this (Murphy, 1999; Noble et al., 2000) and have decided, that for our purposes, the most effective approach is to allocate weightings in such a way as to ensure that each of the four major components are equally weighted, while at the same time, each of the sub-components is given an equal weight within that component. It is important to note that if the number of sub-components changes, for example if data is missing, this alters the implicit weight of the other sub-components. For this reason, in this exercise, all missing data were replaced by estimates or proxies, and countries with too much missing data were excluded. Excluded countries are shown in Appendix V. Hence, an equal weighting schemes was used in which each component accounts for up to _ of the total RWLI value (and each subcomponent up to 1/8 of the value).

In the spreadsheet provided as an annex to this report, these weights can be changed to provide local input into the design of the tool, but the resulting RWLI values could then not be used for comparison with other places (unless of course the same weighting scheme was used). This highlights the importance of establishing the *baseline condition* for the purpose of international and inter-temporal comparison[5]. Such comparisons are essential in the use of indices, as the computed scores represent a fixed statistical snap-shot of a condition, and to be used in a dynamic situation, they need to be recalculated under new conditions, using the same methodological framework.

The use of weights to allow prioritisation is important, as it recognises the site-specificity of both water resource and socio-economic conditions. In order to make such prioritisation, weights within the structure can be changed, but the total weight must always remain at 1. In the current default baseline structure, the major components are all constructed from 2 sub-components, and each of these is allocated 0.5 of the weight. It is possible to change one to 0.8, for example, but in this case, the weight (importance) of the other is reduced to 0.2, thus totalling 1 for that component.

As long as the weighting process is explained to users and stakeholders, and the selected weights made clear, the process is robust. In this exercise, a meeting of experts from a number of institutions participated in the process of allocating the weights for this prototype RWLI model. As a result of the discussions, the decision was made to allocate equal weights to all components, as the baseline structure.

[5] The approach adopted in this study will allow for inter-temporal comparison only if the extremes used in the normalization of the different components do not vary with time.

5. Results

The calculation of the RWLI in the manner described above resulted in a score for each country on both the components and subcomponents. These scores are presented in detail in Appendix III, and the distribution of RWLI scores across all countries are shown in Figure 6:

While Figure 5 shows the frequencies of RWLI scores across all 158 countries, Figure 6 shows the frequencies of the four component scores. As can be seen in these figures, the distribution is relatively normal across the spectrum of RWLI scores (~45 – 96), but there is a greater spread of scores across the 0-100 scale for the four components than for the aggregated index (which is to be expected).

These national results can be used to provide a global picture of RWLI values, as shown in the map in Figure 7. More detailed visual presentations of results are provided in Section 5.1, 5.2 and the appendices.

Figure 5: RWLI scores - frequencies

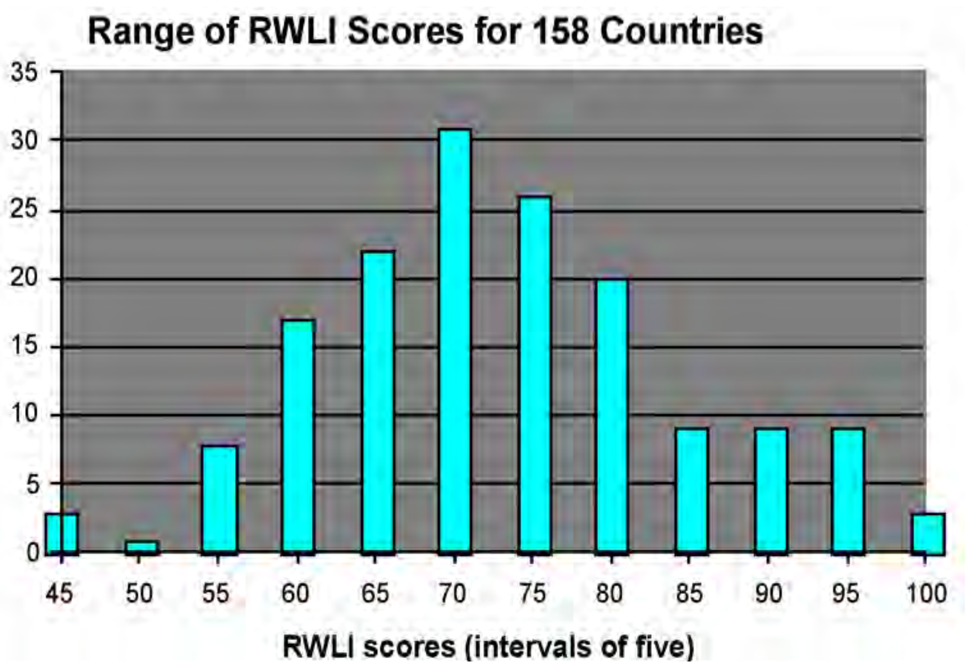


Figure 6: RWLI Component scores – frequency analysis

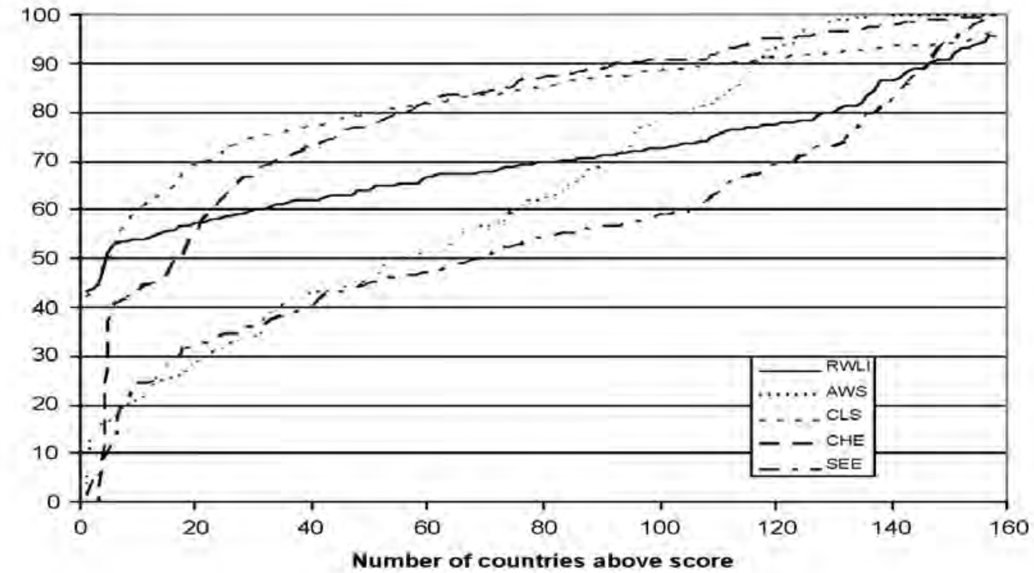
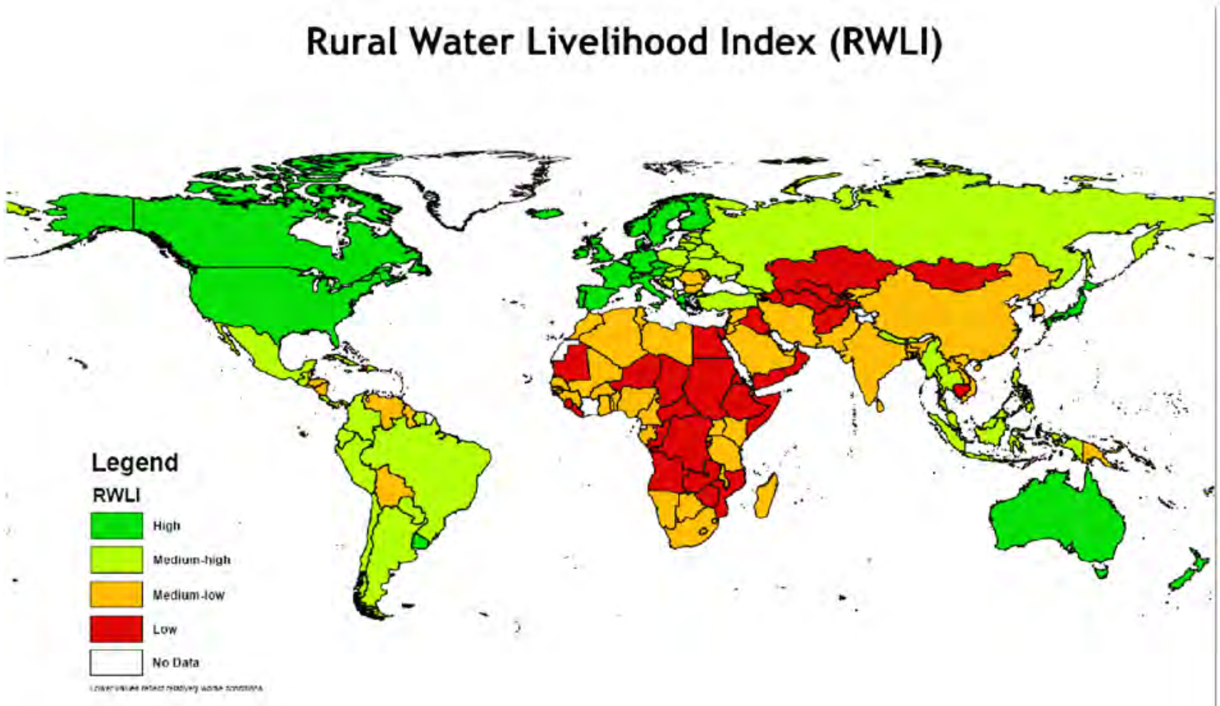


Figure 7: RWLI scores for 158 countries



5.1 Testing the validity of selected RWLI components

In order to check the validity of the selected components, correlations were calculated between the different variables. The correlation matrices between both the components and subcomponents are shown in Table 4

Ideally, there should be a low correlation between the four components of the index. While some correlation can be expected, as all components are usually correlated with the overall development level of a country, an excessive correlation between two components would indicate that these components illustrate the same dimension of the rural water problem in the countries, and should perhaps be combined into one single component. Table 5.1 shows a relatively low correlation between the components of the RWLI except in the case of components 1 and 4 for which a correlation of 0.77 has been obtained, which is not optimal. This result can be explained in part by the indicators used in computing Component 4 (undernourishment and level of corruption) which are somewhat general and not directly related to water issues. The lack of other sources of relevant data at this stage to represent Component 4 prevents us from using more appropriate indicators.

Interestingly, the correlation with the Human Development index (HDI) is relatively high, while it is slightly lower for the GDP. It is very low for both the GINI index and the water resources per capita indicator (often used to represent the water situation in a country), indicating no relation between RLWI and these two indicators.

5.2 Visualisation and mapping of results

While the final values of the RWLI for each country are certainly informative, the analysis of the four components is also an important source of interesting findings, which is why the additional four maps are provided here (Figures 9 to 12). This helps to reveal the strengths and weaknesses of the various components which give rise to the final value of the index itself. This can also be accomplished by presenting the RWLI data through a multi-axis radar graph as shown in Figure 8 which also serves to highlight that while the RWLI scores might be similar for two or more countries, there are relevant differences in the component scores.

Table 4: A correlation matrix for the RWLI components and subcomponents

Components (using correlation coefficient)

	1	2	3	4
1				
2	-0.04			
3	-0.36	0.14		
4	0.77	0.10	-0.25	
RWLI	0.78	0.34	0.15	0.84
TRWR/pop	0.02	0.07	0.08	0.12

RWLI against various data and indices

	RWLI
TRWR/pop	0.12
HDI	0.71
GINI	-0.32
GDP	0.66

Subcomponents (using correlation coefficient)

	1.1	1.2	2.1	2.2	3.1	3.2	4.1	4.2
1.1								
1.2	0.76							
2.1	-0.09	-0.07						
2.2	-0.01	0.04	0.13					
3.1	-0.20	-0.24	0.12	0.26				
3.2	-0.32	-0.34	0.00	-0.13	0.21			
4.1	0.64	0.63	0.05	0.07	-0.19	-0.24		
4.2	0.60	0.65	0.12	0.02	0.01	-0.34	0.52	
RWLI	0.72	0.74	0.22	0.29	0.26	-0.08	0.70	0.76

Key

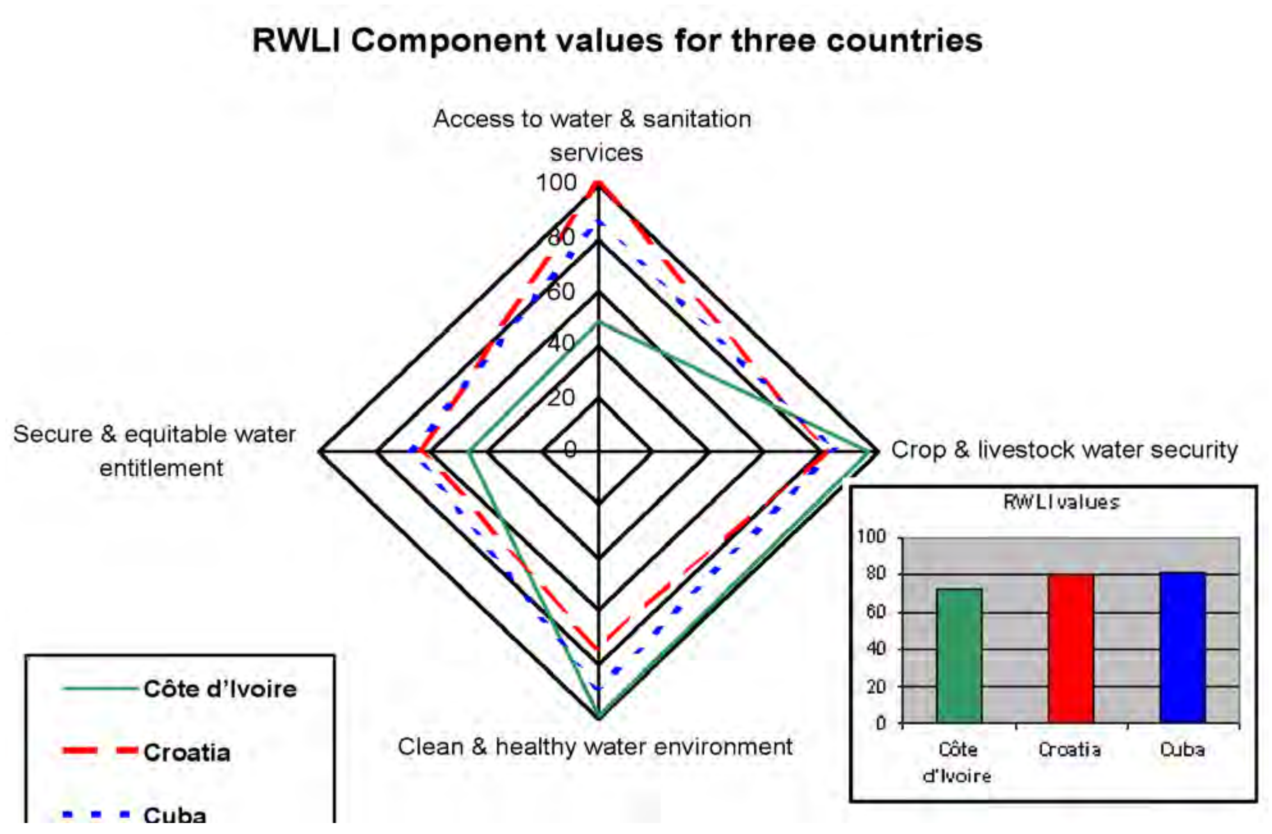
Correlation	Negative	Positive
Small	_0.3 to _0.1	0.1 to 0.3
Medium	_0.5 to _0.3	0.3 to 0.5
Large	_1.0 to _0.5	0.5 to 1.0

Notes

TRWR/pop	Total Renewable Water Resources per capita (FAO)
HDI	Human Development Index (UNDP)
GINI	Gini Index - Inequality in income/expenditure (WB)
GDP	Gross Domestic Product (per capita, in USD) (WB)

Source: Cohen 1988

Figure 8: Visual presentation of RWLI & component scores for three countries with similar RWLI scores



This method of presentation can be used to examine and compare specific countries of interest. It enables comparisons to be made both *between* and *within* countries, as illustrated in Boxes 3 and 4.

5.3 Illustrative case studies

Nine countries from Africa are selected here as illustration of the RWLI approach. Full details of all countries included in this study are shown in Appendix 3, but the cases shown here provide some insights into how the tool can be used. Looking at Box 3a, it is interesting to note that while Nigeria has a much higher RWLI score than Egypt, there are significantly more people in Egypt who have good access to water and sanitation. In contrast also to Nigeria and all the other countries in the group, Egypt scores extremely poorly on the *Clean and Healthy water environment* component, due to its very low scores in terms of water quality and pressure on water resources. In spite of this it scores well on the other components.

In the case of Ethiopia, high scores on the component *crop and livestock security,* and *clean and healthy water environment*, are weakened by very low scores on *secure and equitable water entitlement*, and almost negligibly on *water and sanitation services*. These latter two components are clearly the ones to be addressed first in making improvements in the water sector in that country. While Eritrea has a good water environment, all other scores are very low, and many issues need to be addressed if improvements are to be made in that country.

Looking at part b of Box 3, both South Africa and Sudan have a reasonably even level of development on all four components, with *secure and equitable water entitlement* being their weakest aspect. This aspect is also extremely low for both Burundi and Somalia, although they both do have reasonable scores on *crop and livestock security*, and *clean and healthy water environment*.

[6] Here it is worth noting that a few countries, such as Iceland, are inadvertently penalized for relatively high rates of fertilizer consumption per arable land; though in fact, they may apply the fertilized in an environmentally responsible, efficient fashion.

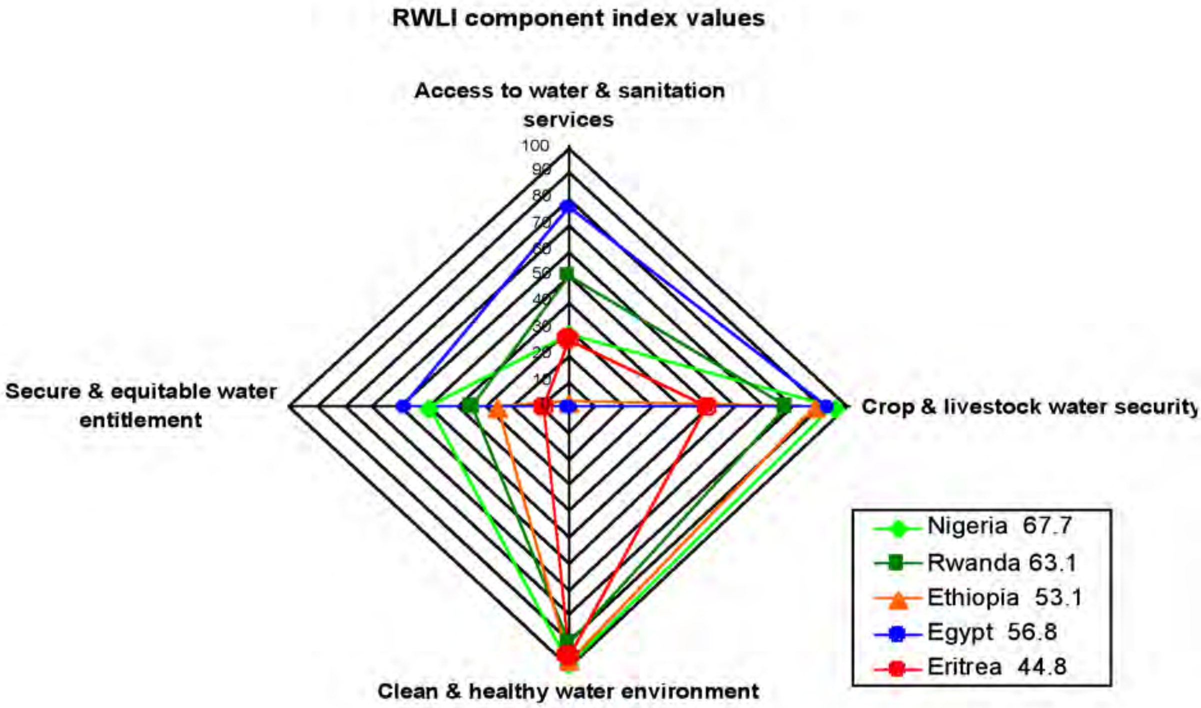
In the examples of large countries from Asia provided in Box 4a, Japan scores well on all dimensions, although less well on the water quality measure due to a high level of application of fertiliser[6]. The other large countries shown all have relatively poor scores on *water and sanitation access*, and on *secure and equitable water entitlement*. These are the areas of the water sector in those countries which would need to be improved in priority.

Taking the smaller Asian countries in Box 4b, Malaysia, Thailand and Bhutan all score reasonably well on all components, while Laos, Cambodia and Sri Lanka do less well, primarily due to *low water and sanitation access*. While Sri Lanka has much better level of water and sanitation than the latter two, it scores particularly poorly on *secure and equitable water entitlement*. Overall however, it is interesting to note that both India and Sri Lanka have almost identical RWLI scores.

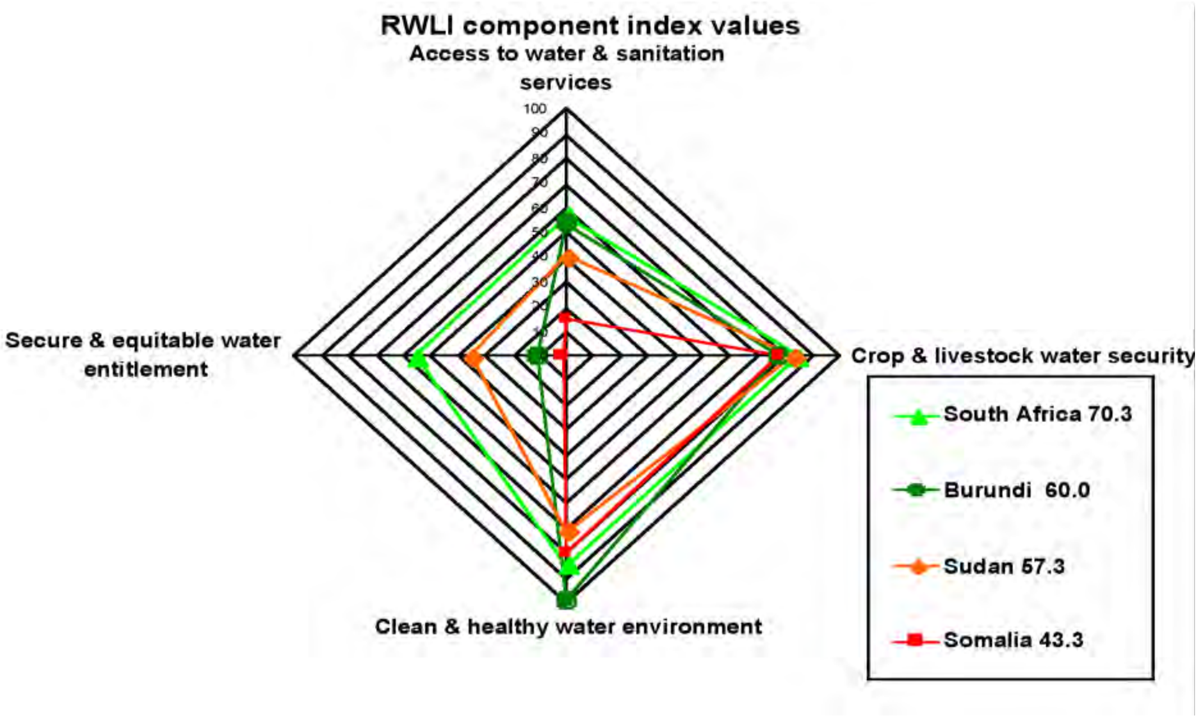
At this stage it is important to point out once more that the results presented here suffer from substantial limitations in the choice of available datasets for computation of the four components, with implications in terms of their relevance. Also, the national level rural values provide no insight into the local detail of the water situation within the country, and to achieve this, sub-national level data would be needed. Furthermore, since this is the first iteration of this tool, it is expected that there will be some opportunity to make some changes and refinements to it, before the tool is finalised for operational use.

Box 3 Comparing selected countries in Africa

Box 3a

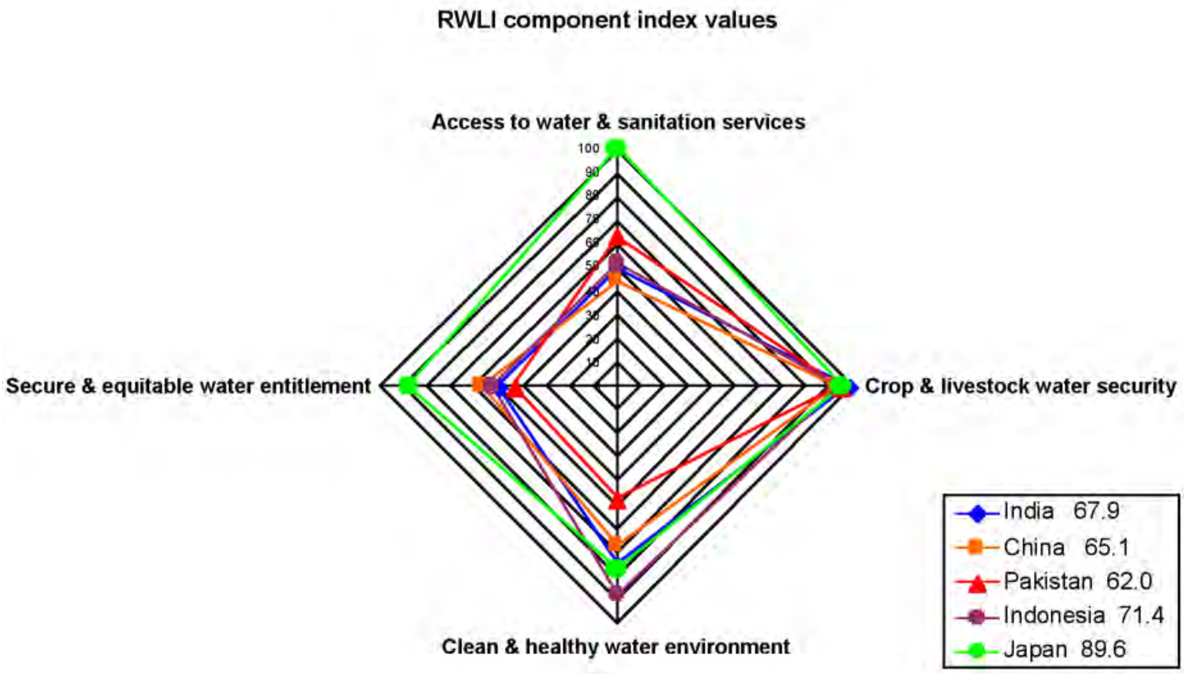


Box 3b

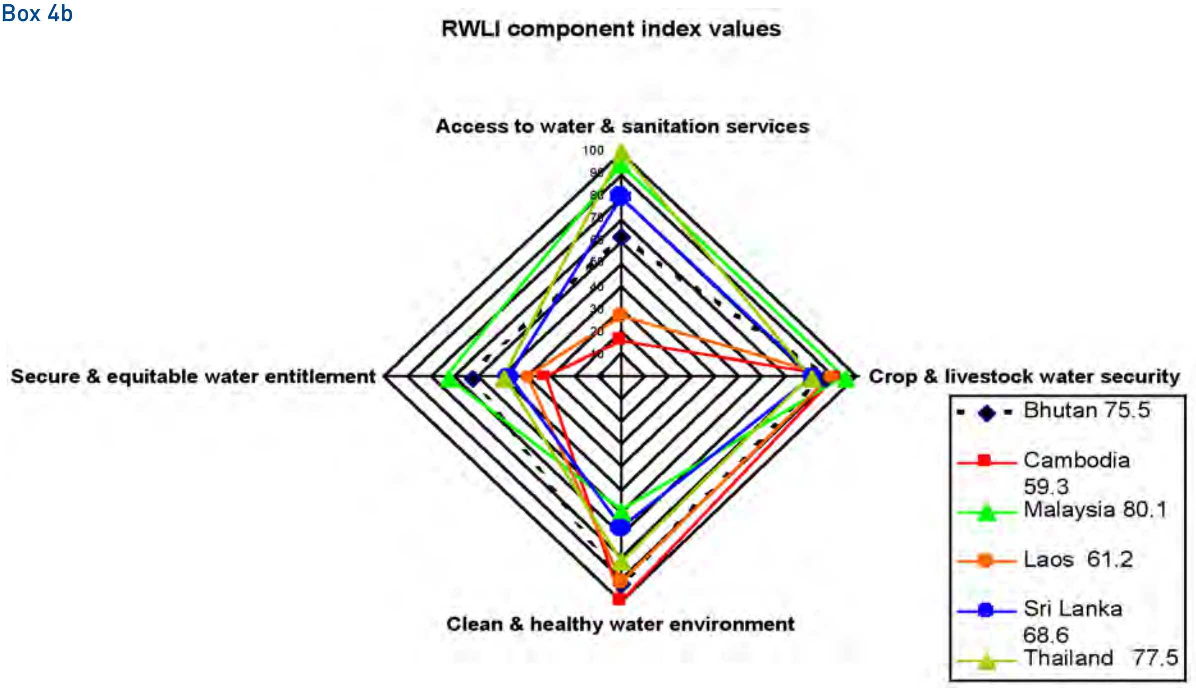


Box 4 Comparing selected countries in Asi4

Box 4a



Box 4b



In addition to the use of these multi-axis graphs, mapping can also be used to provide more detailed insight into the overall conditions. Figure 9, 10, 11 and 12 provide a global display of the national values for each of the RWLI's four components organized in four categories (low, medium-low, medium-high and high), and again, the same approach could be applied at the sub-national scale, if the appropriate data was available.

Figure 9: Global map of RWLI Component 1

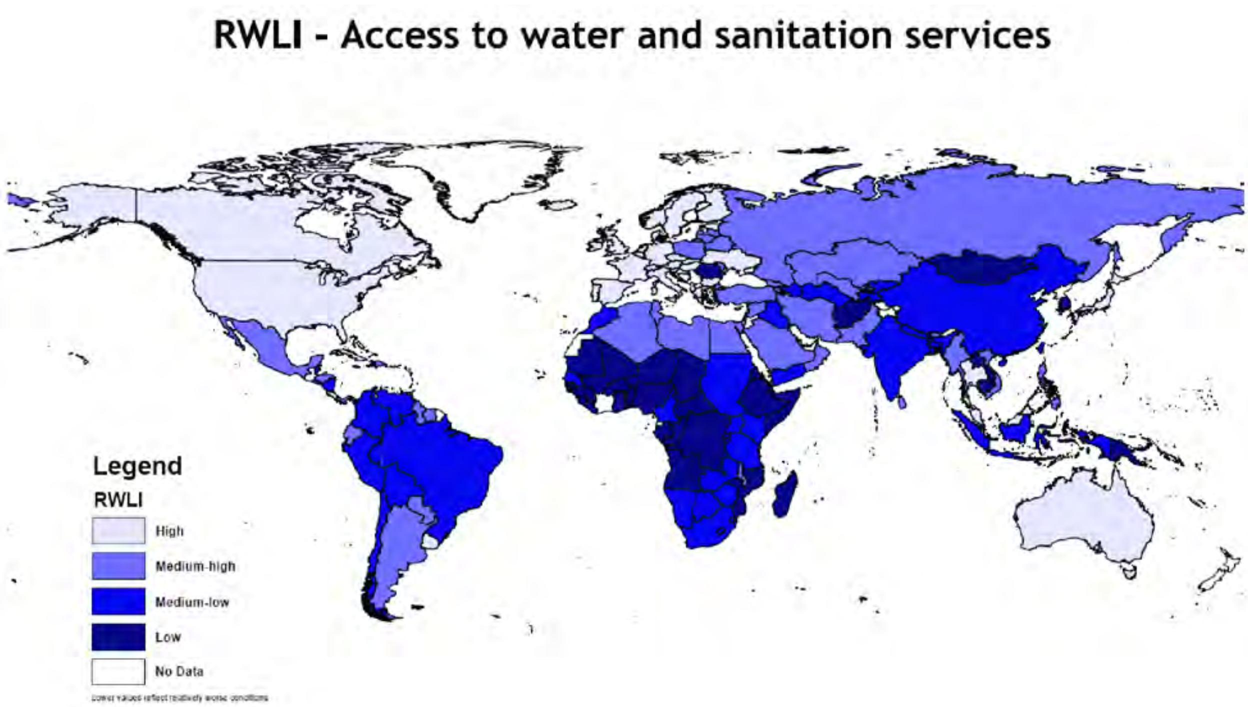


Figure 10: Global map of RWLI Component 2

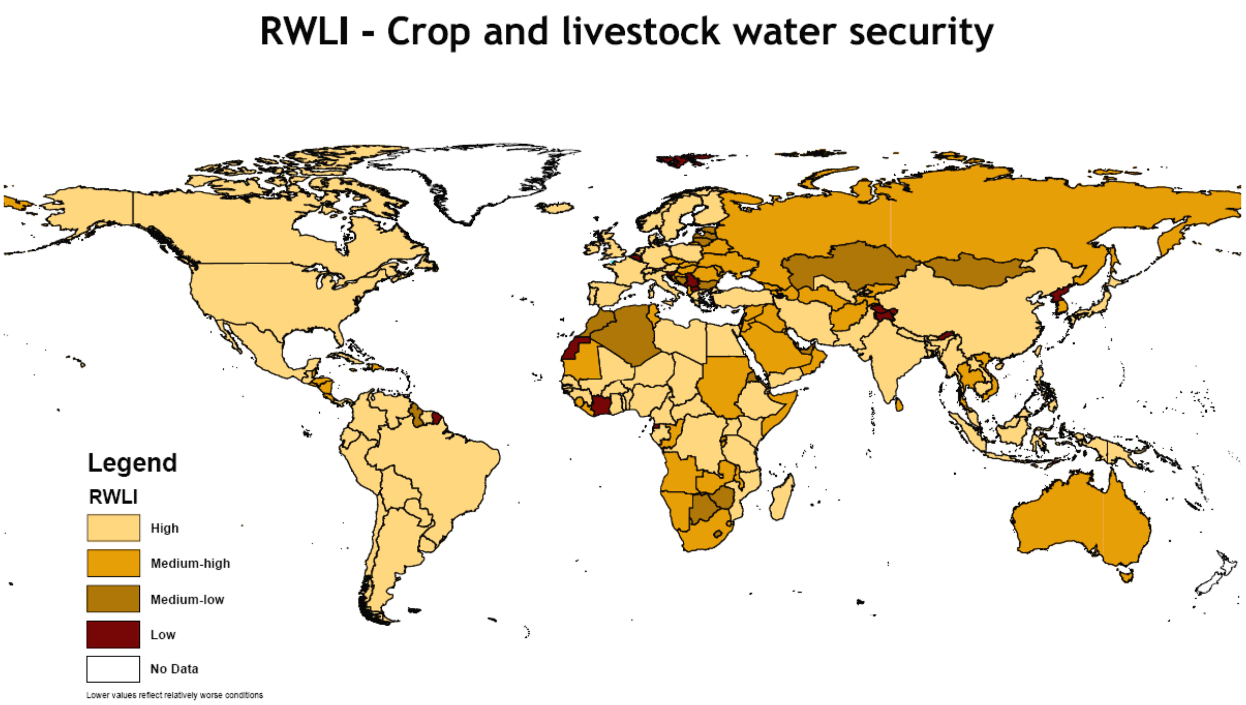


Figure 11: Global map of RWLI Component 3

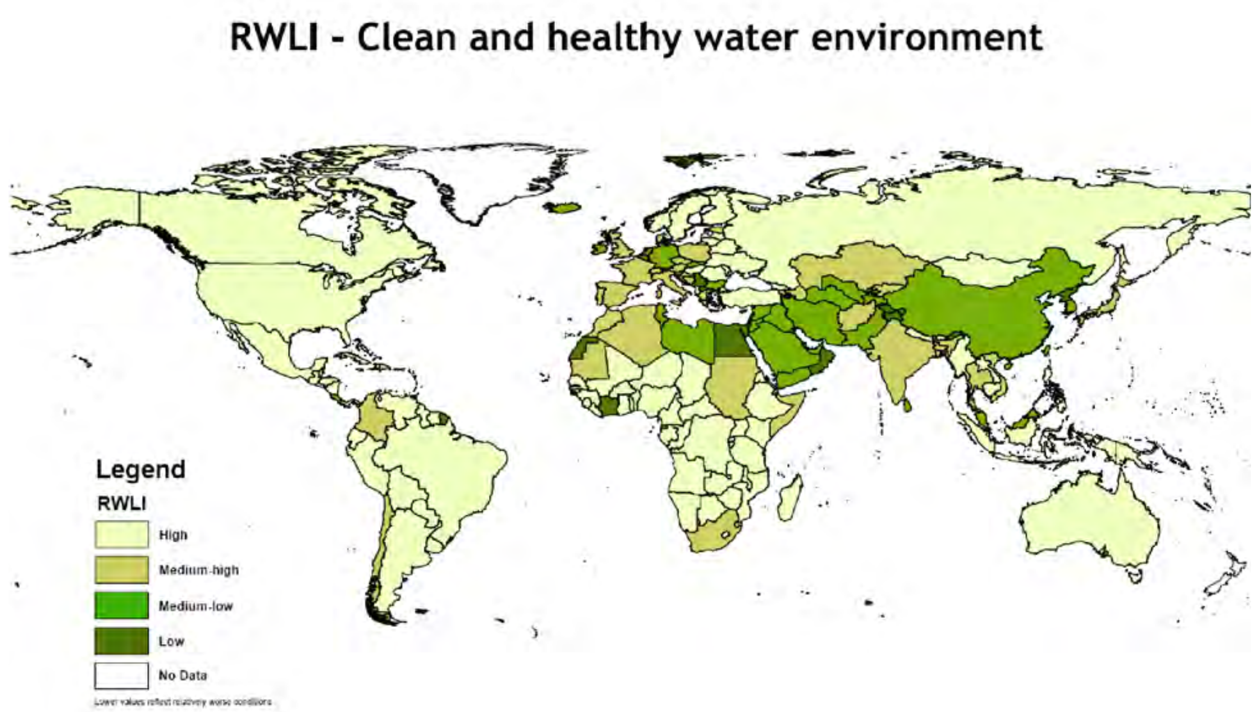
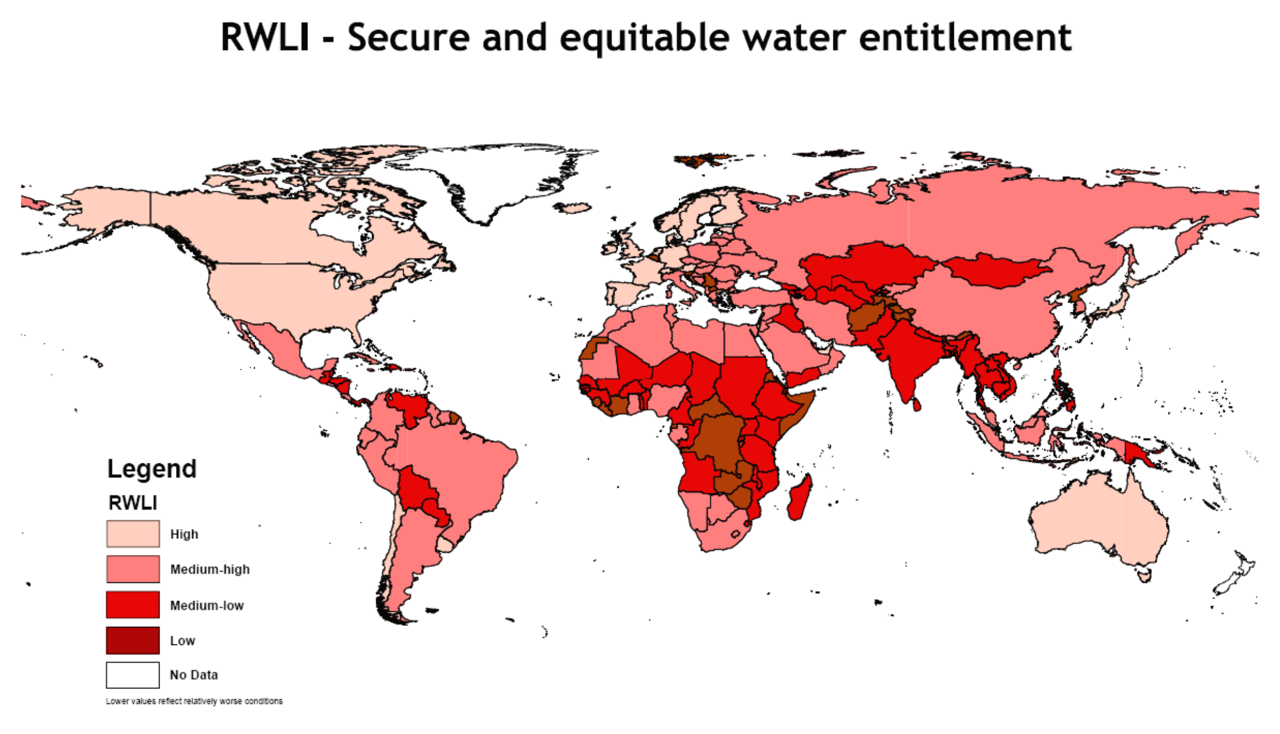


Figure 12: Global map of RWLI Component 4

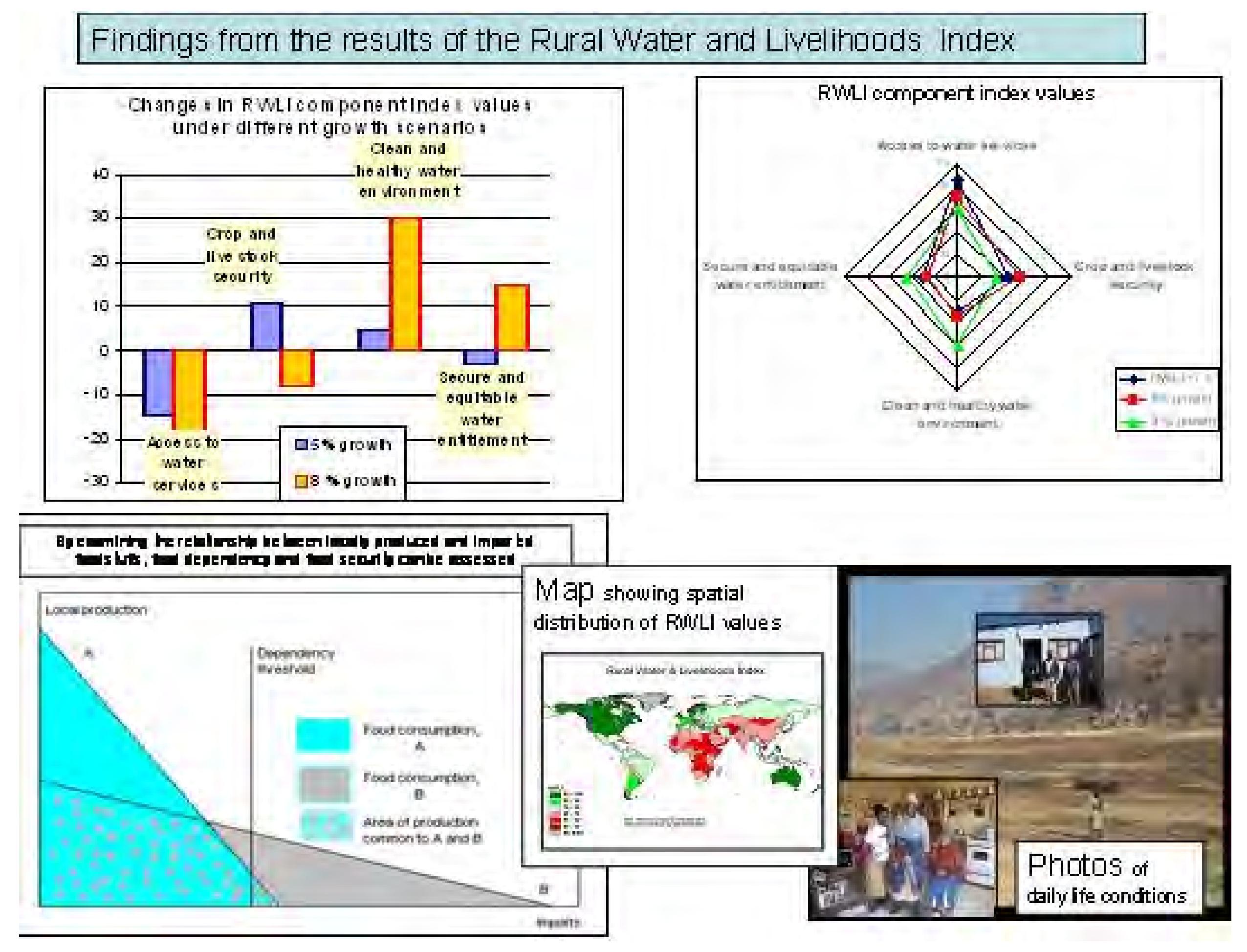


5.4 Presenting an information matrix for the RWLI

Indices are expressed in terms of a single number, and it is clear that this falls short of what may be needed for meaningful decision making. In order to strengthen the value of index scores therefore, we propose that the information is expressed both as its numerical value, and also in some graphical format within a comprehensive matrix of information. Suggested components of this information matrix are shown in Figure 13 and include::

1. *Index scores* – on a scale of 1 to 100, with low scores indicating more extreme deprivation conditions.
2. *Table of index values and related graphical representation* (for communities, grid cells etc.)
3. *Geographical representation* of spatially distributed information (mapped data only)
4. *Graph to indicate food dependency* (based on WHO nutritional thresholds). This would show the proportions of food (in nutritional terms) produced internally (to the area, region) and proportions imported from outside. A location with a higher dependency on imported food will be more vulnerable to shocks than other areas, and as such, increased water provision for food production will have an increased potential benefit.
5. *Comparisons with other global indices* such as the HDI

Figure 13: An example of how information on the RWLI can be presented



6. Discussion -practical issues in the application of the RWLI

There are a number of issues which arise in the use of a tool such as the RWLI. As previously mentioned, the need for transparency and inclusion of users and stakeholders should, where possible, be promoted. The issue of scale is also important, and again, application of this approach at the sub-national scale is anticipated in future work. Since the purpose of indices is to provide information to decision makers, it is important to also supply some supporting material on how this information can be used for action and implementation. Section 6.1 discusses the use of a response matrix, while Section 6.2 discusses the scale issue.

6.1. Indices for action – a Response Matrix

Through the measurement of the RWLI's four components, it is possible to assess which sectors are likely to benefit from pro-poor, water-related interventions. However, appropriate interventions will have to be identified on a case by case basis since contexts differ so widely (i.e., responses to address the reported states will be country and site-specific). In order to assist country-level planners with these tasks, a general Response Matrix has been developed to provide planners and policy makers a conceptual framework to guide the process see Tab;e 5

Table 5: Potential Response Matrix to Improve RWLI Component Scores `

	I. Investments in hydraulic infrastructure	II. Investments in other rural infrastructure	III. Capacity building	IV. Policies	V. Finance
1. Access to basic water services	wells, pipes, pumps, water fountains, compost latrines, water harvesting facilities	Clinics biogas (if climate/conditions appropriate)	training in hygiene, in management and maintenance of community water supply systems and sanitation facilities,	pricing and WSS cost recovery policy that favours the poor	Subsidies for latrine development, incentives/ subsidizes for private investment in rural infrastructure?
2. Crop & livestock water security	dams, irrigation schemes, wells, pumps	markets, roads, seeds, schools, livestock health care services	farmer field school for soil moisture management, for irrigation infrastructure management etc.	trade and tariff policies that favour local production	local credit, subsidies for small infrastructure development
3. Clean & healthy water environment	water treatment plants	water reuse facilities, nitrogen buffers, reed beds,	capacity building in environmentally sustainable agricultural practices, in secure wastewater treatment	environmental law, enforcement, polluter pays principle	
4. Secure & equitable water entitlement	supply enhancement through dams		Strengthen regulatory bodies	adapt water law, enforce smallholder protection and the rule of law	

Table 5 provides some examples of how different responses and interventions are required in different places, even if the problem may be the same. Decisions regarding crop and livestock water management, for example, will depend on a farmer's ability and education, available information, and the type of irrigation equipment available (if any). These types of decisions will be influenced by the human and financial capital within the household, and the natural, physical and social capital within the livelihood zone. By developing an integrated index related to these capital types, it is possible to assess conditions of rural poverty more holistically, resulting in more effective intervention mechanisms and less policy failure.

It is well known that policy and market failures are often at the root of poor development strategies (Daly 1999) and many of these have occurred due to the lack of adequate information about conditions being addressed. This is often due to the use of inappropriate, neoclassical analytical techniques which may be based on unrealistic assumptions about the conditions being examined. By providing a more comprehensive information set to decision makers, an integrated index such as that presented here will have the potential to result in more effective poverty alleviation in rural areas. Interventions considered to be appropriate in this context will include rural development policies, investments, financial support, capacity building and technical assistance (as illustrated by the five areas identified in Figure 2.

The effectiveness of interventions will vary across livelihood zones and agro-ecological zones. Through the use of the RWLI it is hoped that the more effective interventions pertaining to water resources will be identified for different locations, and interventions can be prioritized for the greatest social benefit. In essence, the RWLI values should provide a preliminary snapshot of information about the state of water-related livelihood conditions in rural areas. It is then up to policy makers and planners to determine how they can best seek to improve their RWLI scores.

6.2 Scale issues in applications of the RWLI

While it can be useful for donor agencies and governments to have access to national level measures, it is more useful for policy makers to have information at the sub-national scale. The extent to which this approach can be adopted or adapted for use at local scale remains to be seen. While the overall framework and approach can be used as a starting point, local adaptation would need internalization by local decision makers to suit their information needs. An example of the kind of resolution which may be possible at this sub-national scale is shown in Figure 14 where the livelihood zones in Zambia are displayed. If data are appropriately disaggregated from sub-national administrative units, a similar index can be calculated and applied to livelihood zones. So too, it is hoped that the devised Response Matrix (Table 5) will indeed provide national-level planners a useful rubric with which they can raise their country's RWLI scores. Since water is most usually managed locally, this would clearly increase the robustness, reliability and usefulness of the method. It is expected, however, that decision makers may make better use of components and sub-components of the index than of the index itself.

6.3 Limitations and caveats

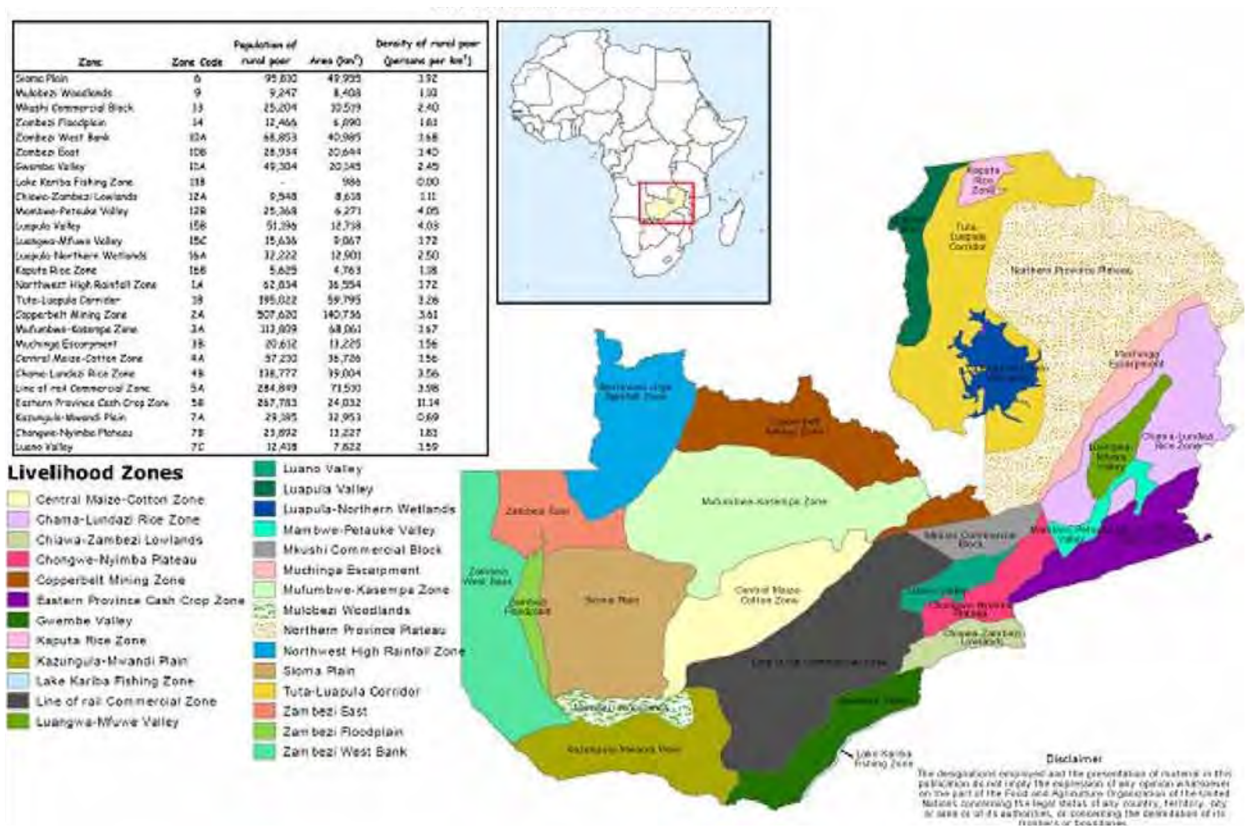
There is no doubt that the development and computation of an index provides valuable information to support decision making. There are, however, many words of caution which must be stated in the context of index construction. Important issues to recognise include:

Structure of the index – what is included depends on the objective of the work, and the knowledge and efforts of those involved in the index creation. As such, it essential that as many views as possible are taken into account in the development of such an index, but it is recognised that in the interests of simplicity, other usefully information is not captured. Consequently, this tool should be used in conjunction with others, when used for decision support.

Variable selection

It is inevitable that when an item is selected to represent a condition, it will not always serve that purpose to the same degree, for all locations. An example of this is provided by the selection of the level of fertiliser application by area as an indication of water quality. The rationale for this is that it is known that fertiliser does make its way into aquatic systems, thus leading to pollution, but of course its impact is very varied, due to both biophysical variability (e.g., soil type, slope etc.) and socioeconomic factors (farmer efficiency, farming practice etc.). In the RWLI, this generates an anomaly when applied

Figure 14: Sub-national assessments of livelihoods in Zambia



Zone	Zone Code	Population of rural poor	Area (km²)	Density of rural poor (persons per km²)
Sioma Plain	6	95,830	49,955	1.92
Mulobezi Woodlands	9	9,247	8,408	1.10
Mkushi Commercial Block	13	25,204	10,519	2.40
Zambezi Floodplain	14	12,466	6,890	1.81
Zambezi West Bank	10A	68,853	40,985	1.68
Zambezi East	10B	28,954	20,644	1.40
Gwembe Valley	11A	49,304	20,145	2.45
Lake Kariba Fishing Zone	11B	-	986	0.00
Chiawa-Zambezi Lowlands	12A	9,548	8,618	1.11
Mambwe-Petauke Valley	12B	25,368	6,271	4.05
Luapula Valley	15B	51,396	12,718	4.03
Luangwa-Mfuwe Valley	15C	15,636	9,067	1.72
Luapula-Northern Wetlands	16A	32,222	12,901	2.50
Kaputa Rice Zone	16B	5,625	4,763	1.18
Northwest High Rainfall Zone	1A	62,034	36,554	1.72
Tuta-Luapula Corridor	1B	195,022	59,795	3.26
Copperbelt Mining Zone	2A	507,620	140,736	3.61
Mufumbwe-Kasempa Zone	3A	113,809	68,061	1.67
Muchinga Escarpment	3B	20,612	13,225	1.56
Central Maize-Cotton Zone	4A	57,230	36,726	1.56
Chama-Lundazi Rice Zone	4B	138,777	39,004	3.56
Line of rail Commercial Zone	5A	284,849	71,530	3.98
Eastern Province Cash Crop Zone	5B	267,783	24,032	11.14
Kazungula-Mwandi Plain	7A	29,385	32,953	0.69
Chongwe-Nyimba Plateau	7B	23,892	13,227	1.81
Luano Valley	7C	12,438	7,622	1.59

to Iceland, for example, where a high rate of fertiliser is applied to a small area, mostly due to greenhouse horticulture. The relatively small area involved in this agricultural activity has the effect of magnifying the imputed water quality impact. Further work specifically on this case would be needed to clarify this, but at this point, this simply serves as an illustration of a known weakness. It is hoped that this is taken to be the first iteration of this tool, and over time, its structure can be improved by the refinement of sub-components, or acquisition of new data used to represent them.

Data

As with any model, the quality of outputs depends on the quality of inputs. The data used in this exercise represents the best available data for each component. The quality and age of this data is highly variable, and it has to be noted that there is a high degree of uncertainty resulting from the use of some of this data for some of the countries. There is much variation in both the definition of how things are measured, and the scale and sampling procedures that may have been used in obtaining the raw data. A further source of error may arise through data interpolation, used by data holders to update figures when new data is not available. Ideally, the quality of the dataset used to compute the RWLI could be improved, if individual countries would be able to provide missing data, instead of their values being represented by estimations.

This variability in the quality and updating frequency of the data affects the quality of the RWLI. This could be reduced in time through the generation of a more standardized dataset for the purpose of water management and monitoring. The establishment of a standardized approach for water monitoring and measurement would be a great step forward. Other forms of data collection such as through schools, additions to census questions, etc. can also be considered as part of efforts to improve data coverage and quality.

Mathematical implications of ways of combining data

There are different ways to combine data, and it is possible that further work can be done to investigate this more fully. The overall structure of the RWLI could possibly be improved using an exponential distribution for data normalization, rather than a normal one. Some additional work is involved to do this, which is beyond the scope of this study, and it is important to note that the use of a different distribution for the data normalization process will have implications on the types of statistical tests which can be used to further analyse the results.

Exponential transformation involves ranking the scores for each component. The ranking standardises the component scores to a scale of 0 to 1 (or 0 to 100). These ranks are then transformed to an exponential distribution, using the formula

$$X = -K*\log\{1 - R*[1 - \exp(-100/K)]\}$$

Where K = constant (that proportion of cases which are likely to be above a score of 0.5 (on a scale of 0-1)

This has the effect of transforming the ranked component scores to a value between 0 (least deprived) and 100 (or 1) (most deprived), on an exponential basis, meaning that more stressed scores are given greater emphasis, and so when combined, are not cancelled by other component scores indicating less deprivation. This technique is widely used in the development of financial market indicators (Murphy 1999), and has potential for application to this type of tool, although further work to investigate the implications of this would be needed.

Another approach to combining large numbers of sub-components consists in selecting the lowest of all sub-components as the value of the component, rather than computing a weighted average. This avoids the smoothing effect obtained when using large numbers of indicators. This technique is especially useful with regard to water quality issues, where a large number of substances with different pollution thresholds must be monitored, and where any of these pollutants alone is sufficient to affect the quality of the water.

Human error

Human error is inevitable when dealing with large datasets and data collection and manipulation. There will have been errors in the interpretation of original surveys used to generate the data used, and in the recording of this information. There may also have been other errors in data selection, or in the choice of scaling dimensions when normalizing the scores.

7. Conclusions

This report represents a first attempt to generate a tool specifically designed to quantitatively examine rural livelihoods and their links with water provision. The RWLI builds on earlier work on water and poverty, and can be taken as a step in the process of development of an effective and robust tool to capture issues relating to a number of the targets of the Millennium Development Goals, particularly goals 1 and 7, as they relate to water.

Current water sector indicators used for the measurement of progress towards the Millennium Development Goals are inadequate to really indicate the impact of changes taking place at the household level. Targets relating to both water supply and sanitation provide a crude insight into general coverage, but do not really provide suitable differentiation so that real differences in water related wellbeing can be assessed. Without taking account, for example, of time spent in water collection, having access within a certain distance of a dwelling does not really adequately reflect the degree of hardship that may be experienced in connection with household water provision. While this report does not attempt at this stage to measure change at that level, we do suggest that a more integrated framework for development assessment would be a worthwhile and useful tool. By attempting to develop a systematic yet simplified approach to this problem, we suggest a pragmatic, yet feasible measure.

There is much interest in developing greater food security in rural areas, and improving rural incomes and quality of life. Not only will this provide support to those rural populations, but it will also serve to relieve pressure on urban areas which currently act as magnets for the rural poor. By more effectively supporting rural livelihoods through better water provision, a greater degree of national and international security can be achieved.

There is no doubt that there are many different ways of measuring both states (conditions) and the process of change. It is essential that any attempt to seriously monitor progress needs to start with a firm baseline, and must be built from accessible and reliable data. In the path of modern human development, we have seen such tools evolve, specifically the development of *Systems of National Accounting*[8], and in the establishment of the Human Development Index. Since the agreements reached at the Rio Summit on Sustainable Development (UNCED, 1992), later reinforced in the WSSD in Johannesburg (WSSD, 2002), we are politically committed to the principles of sustainability and equity, as the foundation for our human future. As such, to achieve this, we need an integrated and holistic approach to how we evaluate our progress and the degree to which we are managing our resources in a sustainable way. The approach suggested here has the strength of being developed from existing data, and also is designed to be simple and easy to use. While these are indeed advantages, they are often also said to be disadvantages, as existing data is not always of the best quality, and simplicity can sometimes be interpreted as meaning 'incomplete' While both of these are to some extent valid criticisms, we believe that with concerted efforts by all interested parties and institutions, a reliable and robust measure of water and livelihoods can be generated, to realistically and cost-effectively provide support for development strategy and policy making.

[7] This is particularly true where areas are impacted by political and environmental refugees

[8] This is the system of national accounting that all countries use following the implementation of the approach in the UN system since 1973. This has achieved an international normalization of definitions and measures which enable economic and financial systems to be consistently assessed.

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Appendix I: Notes on adjustments made to raw data

1. Access to water & sanitation services

1.1 Access to water supply

Missing Data
For three countries, Libya, Oman and Saudi Arabia, there was no listed data for 2004. Consequently, 2000 data (the most recent prior year for which data was available) was used for 2004.

1.2 Access to sanitation

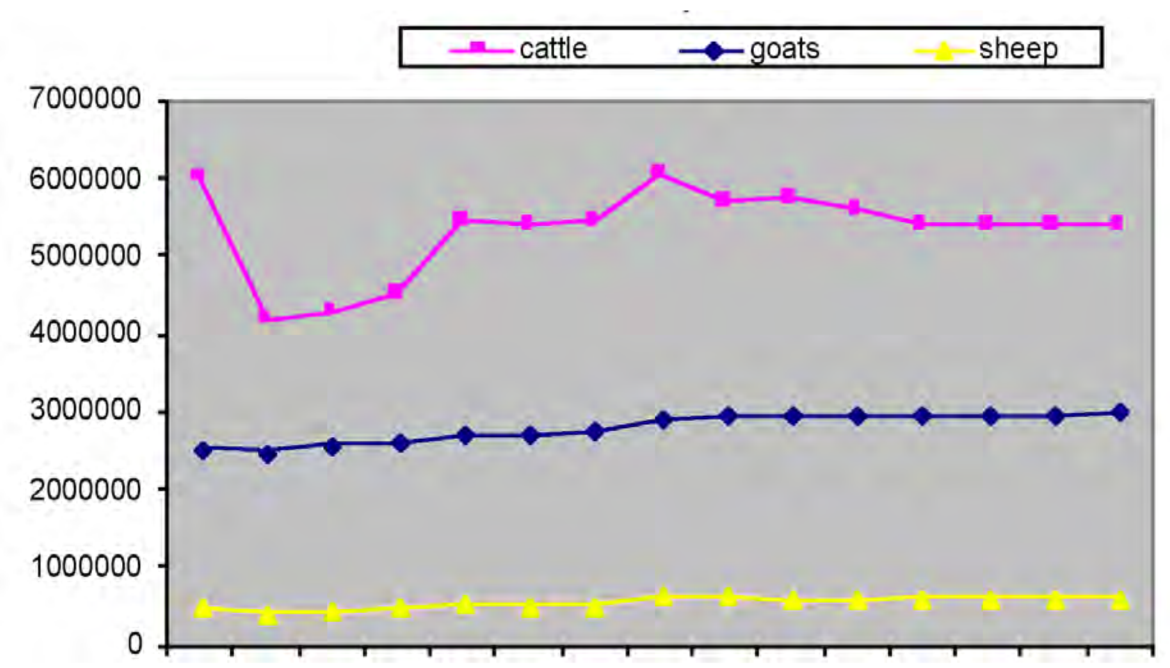
Missing Data
For two countries, Iran and Oman, there was no listed data for 2004. Consequently, 2000 data (the most recent prior year for which data was available) was used for 2004.

2. Crop & livestock water security

2.1 Livestock Security

Initially, data on cattle, sheep and goat holdings were to be used to calculate the variance in livestock holdings. However, given the water-related nature of the RWLI, and the intention of the Crop & Livestock Security component to provide a gauge of the relative security of livestock holdings in relation to water resources and water management, it was determined that cattle provided the best gauge of variation due to water-related difficulties. This is highlighted in the case of Zimbabwe; as can be seen in the figure below cattle holding dipped significantly in step with the drought the country suffered in the early 1990s. Since goats are more hardy animals (with respect to water scarcity), it is not surprising that goat holdings may be increased in face of water scarcity, hence to include goats and sheep would be to provide a smoothing effect to the variability the component seeks to capture. Consequently, only cattle holding were used to calculate sub-Component 2.1.

Cattle and Goat Comparison - Zimbabwe



Missing Data

Missing data for cattle holdings were filled with average of nearest three years (within the 1992-2006 data range). If more than two data points were missing for any given country within the years 1992-2006 the data were not used and the country's data marked as missing.

2.2 Crop production reliability

Missing Data

The value of cereal production for Eritrea in 1992 was missing but all other years (1993-2006) had values. As such, the average of the values for the years 1993-1995 were used to fill the missing data for Eritrea in 1992.

3. Clean & healthy water environment

3.1 Pressure on water resources

Though it was possible to fill in some of the missing data, it was determined that the benefit did not outweigh the cost of compromising the dataset as a whole. No missing data was filled.

Outliers

A number of countries withdraw far more water than the total quantity of their renewable water resources and drastically skew the global distribution of this measure. Hence, these 13 countries had negative values for 3.1 - therefore the values after normalization were negative and were changed to the lowest possible score, zero. (Specifically, these countries included: Bahrain, Barbados, Egypt, Israel, Jordon, Kuwait, Libya, Oman, Qatar, Saudi Arabia, United Arab Emirates, Uzbekistan and Yemen.)

3.2 Diffuse (agricultural) water pollution risk

Missing Data

For Nitrogen Consumption: Data for Cambodia and Lithuania were not available for 2005. In order to fill this data gap, the average of the 2003 and 2004 values were taken for the 2005 data (the raw data held only zeros - instead of "-9999" for missing data, yet it is highly unlikely the N Consumption fell to zero, and therefore more likely that there was an error in original data entry). Marshal Island also had a N consumption value of zero but this was considered likely and left as zero.

For Arable Land: It was not possible to fill in missing data because for the five countries without data for 2005 no data was provided for any prior years.

Outliers

Once the calculated data were scaled six outliers were identified: Bahrain, Egypt, Iceland, Kuwait, Singapore, and Trinidad and Tobago. Since each of their normalized scores were negative numbers they were replaced with values of zero.

4. Secure & equitable water entitlement

4.1 Severity of rural poverty

Adjusted Data

The only adjustment to the raw data was in cases where the value provided was "→2.5"% in which case these values were replaced with a value of 2 before being normalized.

4.2 Prevalence of corruption

Missing Data

The missing CPI data were for countries for which TI does not collect data. No suitable alternatives could be found and so the missing data was not filled in during the initial calculations.

Appendix II: Notes on missing data

Country with missing data filled in (during final aggregation stage*)	Countries whose values were used to fill in missing data (average of four) for a given subcomponent
Barbados	Cuba, Guyana, Jamaica, Trinidad and Tobago
Belize	Guatemala, Guyana, Honduras, Jamaica
Bhutan	China, Mongolia, Myanmar, Nepal
Cape Verde	Cote d'Ivoire, Ghana, Senegal, Togo
Comoros	Madagascar, Mauritius, Myanmar, Sri Lanka
Cyprus	Croatia, Greece, Italy, Turkey
Czech Republic	Bulgaria, Germany, Poland, Romania,
Djibouti	Egypt, Eritrea, Ethiopia, Sudan
Fiji	Australia, New Zealand, Papua New Guinea, Sri Lanka
France	Germany, Italy, Spain, United Kingdom
Guinea-Bissau	Central African Republic, Cote d'Ivoire, Mauritania, Senegal
Iceland	Denmark, Finland, Norway, Sweden
Kuwait	Oman, Qatar, Saudi Arabia, United Arab Emirates
Lesotho	Botswana, Namibia, South Africa, Zimbabwe
Lithuania	Estonia, Latvia, Republic of Moldova, Russian Federation
Maldives	Malaysia, Mauritius, Myanmar, Sri Lanka
Malta	Austria, Cyprus, Italy, Spain
New Zealand	Australia, Canada, United Kingdom, United States of America
Niger	Benin, Burkina Faso, Chad, Mali
Oman	Egypt, Kuwait, Saudi Arabia, United Arab Emirates
Poland	Belarus, Republic of Moldova, Romania, Slovakia
Qatar	Iran, Saudi Arabia, United Arab Emirates, Yemen
Romania	Azerbaijan, Belarus, Republic of Moldova, Russian Federation
Saudi Arabia	Egypt, Libya, Pakistan, United Arab Emirates
Sierra Leone	Guinea, Liberia, Mali, Senegal
Solomon Islands	Mauritius, Papua New Guinea, Philippines, Sri Lanka
South Africa	Botswana, Lesotho, Namibia, Zimbabwe

*That is, this technique for filling in missing data was conducted after each of the subcomponent's had themselves been calculated in order to assign values where none had been calculated in the first place (see Appendix I).

Note: for any given subcomponent, only countries with original values were used to fill in missing values. Thus, while there is some overlap in the listings above, a country whose missing data had already been filled for a given subcomponent was never used to fill other missing data for that same subcomponent.

Appendix III: Alphabetical list of RWLI and component scores

Key				
RWLI	**1**	**2**	**3**	**4**
Rural Water & Livelihoods Index	Access to water & sanitation services component	Crop & livestock water security component	Clean & healthy water environment component	Secure & equitable water entitlement component

Table of RWLI & Component values

Country	RWLI	1	2	3	4
Afghanistan	43.97	24.64	73.36	73.28	4.61
Albania	79.57	88.38	81.41	91.92	56.56
Algeria	69.78	79.49	68.68	73.07	57.89
Angola	58.71	22.99	83.84	99.77	28.24
Argentina	81.23	80.00	90.19	95.35	59.38
Armenia	67.36	68.66	79.45	83.85	37.46
Australia	93.34	100.00	83.28	95.58	94.50
Austria	92.37	100.00	94.19	83.92	91.38
Azerbaijan	60.38	43.98	81.97	70.35	45.22
Bangladesh	65.44	50.76	95.77	81.20	34.03
Barbados	71.34	100.00	63.49	42.06	79.80
Belarus	76.52	79.90	82.92	88.87	54.38
Belize	67.51	51.23	75.30	93.54	49.96
Benin	67.26	29.97	90.36	99.75	48.97
Bhutan	75.47	62.06	85.89	90.95	62.99
Bolivia	69.80	41.82	91.94	99.47	45.99
Bosnia and Herzegovina	73.10	93.63	69.38	71.75	57.65
Botswana	65.22	55.72	60.89	90.38	53.87
Brazil	71.74	43.37	89.40	96.02	58.20
Bulgaria	69.35	96.25	58.84	61.77	60.54
Burkina Faso	65.35	25.70	91.99	96.32	47.40
Burundi	60.08	53.57	77.63	98.73	10.40
Cambodia	59.31	16.06	89.88	99.39	31.92
Cameroon	67.16	39.16	89.99	99.43	40.05
Canada	95.06	98.92	91.01	95.19	95.13
Cape Verde	61.96	43.08	57.54	87.50	59.73
Central African Republic	60.64	32.73	93.81	91.16	24.88
Chad	56.78	18.49	87.77	90.90	29.96
Chile	78.09	56.82	88.36	83.59	83.59
China	65.14	44.35	92.28	67.14	56.79
Colombia	72.58	60.00	90.46	82.61	57.25
Comoros	69.91	53.29	89.18	90.75	46.41
Congo (Republic of the)	55.50	20.33	80.79	91.17	29.73
Costa Rica	75.14	93.96	84.54	50.98	71.09
Côte d'Ivoire	72.52	48.80	96.42	98.95	45.92
Croatia	79.78	100.00	81.73	74.04	63.35
Cuba	81.43	85.06	85.28	88.59	66.80
Cyprus	80.12	100.00	70.15	77.26	73.07

Country	RWLI	1	2	3	4
Czech Republic	83.61	98.45	83.62	78.61	73.75
Democratic Republic of the Congo	51.08	21.45	87.16	91.16	4.53
Denmark	94.26	100.00	93.45	84.11	99.50
Djibouti	65.04	51.19	86.43	88.00	34.55
Dominican Republic	72.85	81.03	83.46	83.10	43.80
Ecuador	78.43	84.54	87.09	89.10	52.97
Egypt	56.87	76.67	92.13	0.00	58.67
El Salvador	72.06	51.70	84.45	92.18	59.91
Eritrea	44.84	25.84	49.63	95.15	8.75
Estonia	80.92	97.38	62.42	84.13	79.76
Ethiopia	53.12	2.06	87.52	97.64	25.26
Fiji	74.16	49.28	81.57	96.48	69.33
Finland	95.59	100.00	92.86	89.99	99.50
France	89.30	99.75	93.81	77.26	86.38
Gabon	71.12	34.14	91.36	99.93	59.06
Gambia	68.97	59.24	87.63	90.98	38.02
Georgia	73.31	76.82	77.92	93.59	44.89
Germany	88.12	100.00	93.70	69.26	89.50
Ghana	71.02	33.90	94.85	98.69	56.63
Greece	86.51	100.00	92.63	83.93	69.50
Guatemala	77.36	86.23	90.28	89.68	43.26
Guinea	62.18	17.61	95.43	99.46	36.22
Guinea-Bissau	62.96	31.66	88.92	90.89	40.39
Guyana	70.16	69.83	59.89	98.33	52.57
Haiti	57.35	30.95	91.25	87.64	19.56
Honduras	70.70	65.61	79.17	95.23	42.79
Hungary	82.56	91.14	76.65	88.08	74.38
Iceland	84.73	100.00	90.72	49.96	98.25
India	67.97	50.24	97.06	74.83	49.74
Indonesia	71.41	51.66	93.99	87.20	52.81
Iran	70.79	79.67	87.60	60.43	55.47
Iraq	53.71	45.11	73.84	62.86	33.02
Ireland	87.02	99.00	91.95	69.50	87.63
Israel	74.05	98.75	81.05	37.53	78.88
Italy	86.69	99.00	94.30	80.19	73.25
Jamaica	78.39	77.28	83.23	96.80	56.24
Japan	89.68	100.00	94.30	76.77	87.63
Jordan	69.56	88.24	79.50	43.41	67.10
Kazakhstan	60.07	60.09	49.83	83.72	46.63
Kenya	63.85	39.25	86.94	96.66	32.54
Kuwait	55.06	80.83	73.39	0.00	66.01
Kyrgyzstan	64.87	55.64	79.05	73.21	51.56
Lao People's Democratic Republic	61.28	26.74	88.63	90.72	39.04
Latvia	72.47	82.80	41.98	95.24	69.84
Lebanon	77.18	93.30	83.91	72.23	59.30
Lesotho	65.51	51.47	65.39	90.34	54.83
Liberia	54.43	25.10	78.09	91.15	23.39
Libya	67.27	79.96	86.71	45.55	56.88
Lithuania	78.08	81.62	62.39	97.04	71.25
Madagascar	61.13	25.34	85.03	97.53	36.60

Country	RWLI	1	2	3	4
Malawi	67.37	61.92	76.41	94.84	36.29
Malaysia	80.14	94.14	94.00	59.30	73.13
Maldives	53.56	56.62	43.02	57.67	56.95
Mali	63.08	32.60	92.72	87.90	39.11
Malta	77.44	99.88	88.08	44.82	77.00
Mauritania	59.36	21.12	80.73	83.71	51.87
Mauritius	73.62	96.91	52.93	76.84	67.81
Mexico	75.92	62.28	93.46	86.91	61.01
Mongolia	56.11	28.20	55.54	99.01	41.69
Morocco	63.14	50.54	66.38	76.03	59.60
Mozambique	58.32	16.67	89.85	99.70	27.06
Myanmar	78.56	72.65	96.03	98.39	47.18
Namibia	67.39	44.48	70.78	99.02	55.29
Nepal	73.83	57.74	94.05	97.23	46.31
Netherlands	89.24	100.00	94.49	65.49	97.00
New Zealand	90.34	99.86	91.42	70.57	99.50
Nicaragua	66.94	45.19	84.93	97.73	39.89
Niger	58.86	14.56	89.19	96.74	34.96
Nigeria	67.79	28.25	94.62	98.23	50.07
Norway	93.51	100.00	91.90	87.00	95.13
Oman	54.02	64.73	81.62	0.00	69.74
Pakistan	62.01	63.41	93.98	47.06	43.57
Panama	72.91	62.94	87.58	96.79	44.35
Papua New Guinea	63.02	31.39	90.50	94.05	36.14
Paraguay	73.44	61.92	85.15	98.90	47.80
Peru	71.67	45.29	91.55	94.45	55.38
Philippines	72.00	68.75	89.61	86.86	42.79
Poland	76.59	69.08	89.29	80.50	67.50
Portugal	88.62	100.00	90.91	82.19	81.38
Qatar	62.36	100.00	69.31	7.89	72.24
Republic of Korea	61.93	34.22	76.19	64.17	73.13
Republic of Moldova	69.99	68.52	70.14	88.88	52.41
Romania	66.41	29.48	80.58	91.21	64.38
Russian Federation	76.53	77.79	75.62	98.48	54.22
Rwanda	63.15	50.63	77.48	90.38	34.10
Saudi Arabia	64.13	67.62	82.48	44.61	61.80
Senegal	69.00	43.51	88.53	95.71	48.26
Sierra Leone	56.07	33.58	79.10	91.05	20.57
Slovakia	77.27	98.41	73.92	66.98	69.76
Solomon Islands	59.83	38.07	79.79	74.85	46.60
Somalia	43.35	14.66	77.40	79.95	1.41
South Africa	70.37	57.00	84.56	84.75	55.17
Spain	86.49	100.00	85.87	77.46	82.63
Sri Lanka	68.62	79.72	80.77	66.80	47.17
Sudan	57.31	40.60	82.90	70.86	34.89
Suriname	77.93	72.46	87.34	95.12	56.79
Swaziland	62.67	45.29	75.86	79.62	49.90
Sweden	95.99	100.00	91.83	93.28	98.88
Switzerland	93.87	100.00	93.77	84.70	97.00
Syria	68.67	82.90	81.18	55.75	54.84

Country	RWLI	1	2	3	4
Tajikistan	46.57	42.44	77.28	53.75	12.83
Thailand	77.56	99.48	79.75	81.79	49.20
Togo	61.43	20.23	87.63	99.14	38.72
Trinidad and Tobago	67.37	93.26	74.99	45.78	55.46
Tunisia	69.57	71.85	70.32	68.61	67.50
Turkey	81.49	81.63	92.92	85.23	66.17
Turkmenistan	53.73	48.38	76.39	41.31	48.82
Uganda	70.99	44.87	92.59	99.72	46.78
Ukraine	77.11	91.34	74.58	85.10	57.42
United Arab Emirates	65.67	97.42	45.02	43.35	76.88
United Kingdom	90.94	99.50	93.43	77.57	93.25
United Republic of Tanzania	63.97	41.97	85.67	96.55	31.67
United States of America	91.03	100.00	92.67	85.68	85.75
Uruguay	90.95	99.48	88.75	93.84	81.72
Uzbekistan	57.03	65.85	86.14	41.17	34.97
Venezuela	70.29	56.34	92.96	88.69	43.19
Viet Nam	67.81	62.99	83.90	78.82	45.53
Yemen	53.82	43.22	89.28	49.87	32.93
Zambia	57.89	41.55	75.27	90.34	24.40
Zimbabwe	58.10	56.95	63.05	87.62	24.80

Appendix IV: RWLI Ranking compared with HDI and GDP

Table of RWLI & Component values

RWLI 2008			HDI		GDP	
Rank	Country	2008 value	2005 value	Difference in rank (1)	2005 value	Difference in rank (1)
1	Sweden	96.0	0.956	-5	39,637	-7
2	Finland	95.6	0.952	-8	36,820	-9
3	Canada	95.1	0.961	-1	34,484	-13
4	Denmark	94.3	0.949	-9	47,769	-2
5	Switzerland	93.9	0.955	-2	49,351	1
6	Norway	93.5	0.968	5	63,918	5
7	Australia	93.3	0.962	4	36,032	-6
8	Austria	92.4	0.948	-7	37,175	-2
9	United States of America	91.0	0.951	-3	41,890	2
10	Uruguay	90.9	0.852	-29	4,848	-43
11	United Kingdom	90.9	0.946	-5	36,509	-1
12	New Zealand	90.3	0.943	-5	26,664	-9
13	Japan	89.7	0.953	5	35,484	-1
14	France	89.3	0.952	4	34,936	-1
15	Netherlands	89.2	0.953	7	38,248	6
16	Portugal	88.6	0.897	-8	17,376	-10
17	Germany	88.1	0.935	-2	33,890	0
18	Ireland	87.0	0.959	13	48,524	13
19	Italy	86.7	0.941	1	30,073	0
20	Greece	86.5	0.926	-1	20,282	-4
21	Spain	86.5	0.949	8	25,914	-1
22	Iceland	84.7	0.968	21	53,290	20
23	Czech Republic	83.6	0.891	-3	12,152	-7
24	Hungary	82.6	0.874	-6	10,830	-9
25	Turkey	81.5	0.775	-41	5,030	-27
26	Cuba	81.4	0.838	-16		n.a.
27	Argentina	81.2	0.869	-5	4,728	-28
28	Estonia	80.9	0.860	-9	9,733	-6
29	Malaysia	80.1	0.811	-22	5,142	-20
30	Cyprus	80.1	0.903	7	20,841	7
31	Croatia	79.8	0.850	-9	8,666	-5
32	Albania	79.6	0.801	-24	2,678	-43
33	Myanmar	78.6	0.583	-77		n.a.
34	Ecuador	78.4	0.772	-37	2,758	-38
35	Jamaica	78.4	0.736	-48	3,607	-26
36	Chile	78.1	0.867	2	7,073	-5
37	Lithuania	78.1	0.862	1	7,505	-2
38	Suriname	77.9	0.774	-30	2,986	-30
39	Thailand	77.6	0.781	-23	2,750	-34
40	Malta	77.4	0.878	12	13,803	12

RWLI 2008			HDI		GDP	
Rank	Country	2008 value	2005 value	Difference in rank (1)	2005 value	Difference in rank (1)
41	Guatemala	77.4	0.689	-58	2,517	-36
42	Slovakia	77.3	0.863	7	8,616	5
43	Lebanon	77.2	0.772	-28	6,135	-1
44	Ukraine	77.1	0.788	-17	1,761	-40
45	Poland	76.6	0.870	14	7,945	7
46	Russian Federation	76.5	0.802	-9	5,336	-1
47	Belarus	76.5	0.804	-5	3,024	-19
48	Mexico	75.9	0.829	5	7,454	8
49	Bhutan	75.5	0.579	-62	1,325	-43
50	Costa Rica	75.1	0.846	9	4,627	-6
51	Fiji	74.2	0.762	-24	3,219	-13
52	Israel	74.1	0.932	32	17,828	27
53	Nepal	73.8	0.534	-67	272	-88
54	Mauritius	73.6	0.804	2	5,059	3
55	Paraguay	73.4	0.755	-22	1,242	-40
56	Georgia	73.3	0.754	-22	1,429	-34
57	Bosnia and Herzegovina	73.1	0.803	3	2,546	-19
58	Panama	72.9	0.812	9	4,786	4
59	Dominican Republic	72.8	0.779	-4	3,317	-4
60	Colombia	72.6	0.791	0	2,682	-14
61	Côte d'Ivoire	72.5	0.432	-82	900	-43
62	Latvia	72.5	0.855	24	6,879	20
63	El Salvador	72.1	0.735	-22	2,467	-15
64	Philippines	72.0	0.771	-9	1,192	-34
65	Brazil	71.7	0.800	8	4,271	7
66	Peru	71.7	0.773	-3	2,838	-4
67	Indonesia	71.4	0.728	-21	1,302	-26
68	Barbados	71.3	0.892	43	11,465	37
69	Gabon	71.1	0.677	-31	5,821	23
70	Ghana	71.0	0.553	-43	485	-56
71	Uganda	71.0	0.505	-60	303	-69
72	Iran	70.8	0.759	-4	2,781	1
73	Honduras	70.7	0.700	-22	1,151	-26
74	South Africa	70.4	0.674	-27	5,109	24
75	Venezuela	70.3	0.792	16	5,275	27
76	Guyana	70.2	0.750	-3	1,048	-24
77	Republic of Moldova	70.0	0.708	-15	694	-38
78	Comoros	69.9	0.561	-34	645	-38
79	Bolivia	69.8	0.695	-19	1,017	-23
80	Algeria	69.8	0.733	-6	3,112	15
81	Tunisia	69.6	0.766	7	2,860	12
82	Jordan	69.6	0.773	13	2,323	1
83	Bulgaria	69.4	0.824	39	3,443	21
84	Senegal	69.0	0.499	-49	707	-30
85	Gambia	69.0	0.502	-47	304	-54
86	Syria	68.7	0.724	-3	1,382	-5
87	Sri Lanka	68.6	0.743	6	1,196	-10
88	India	68.0	0.619	-18	736	-22

RWLI 2008			HDI		GDP	
Rank	Country	2008 value	2005 value	Difference in rank (1)	2005 value	Difference in rank (1)
89	Viet Nam	67.8	0.733	3	631	-28
90	Nigeria	67.8	0.470	-45	752	-19
91	Belize	67.5	0.778	27	3,786	32
92	Namibia	67.4	0.650	-12	3,016	25
93	Trinidad and Tobago	67.4	0.814	47	11,000	61
94	Malawi	67.4	0.437	-46	161	-55
95	Armenia	67.4	0.775	29	1,625	7
96	Libya	67.3	0.818	51	6,621	53
97	Benin	67.3	0.437	-43	508	-27
98	Cameroon	67.2	0.532	-24	1,034	-3
99	Nicaragua	66.9	0.710	8	954	-4
100	Romania	66.4	0.813	52	4,556	43
101	United Arab Emirates	65.7	0.868	68	28,612	81
102	Lesotho	65.5	0.549	-14	808	-5
103	Bangladesh	65.4	0.547	-15	423	-27
104	Burkina Faso	65.4	0.370	-49	391	-28
105	Botswana	65.2	0.654	2	5,846	60
106	China	65.1	0.777	41	1,713	21
107	Djibouti	65.0	0.516	-20	894	2
108	Kyrgyzstan	64.9	0.696	11	475	-20
109	Saudi Arabia	64.1	0.812	60	13,399	80
110	United of Republic of Tanzania	64.0	0.467	-26	316	-28
111	Kenya	63.8	0.521	-15	547	-11
112	Rwanda	63.1	0.452	-26	238	-33
113	Morocco	63.1	0.646	8	1,711	27
114	Mali	63.1	0.380	-36	392	-17
115	Papua New Guinea	63.0	0.530	-8	840	9
116	Guinea-Bissau	63.0	0.374	-35	190	-32
117	Swaziland	62.7	0.547	-1	2,414	38
118	Qatar	62.4	0.875	89	52,240	115
119	Guinea	62.2	0.456	-18	350	-16
120	Pakistan	62.0	0.551	6	711	7
121	Cape Verde	62.0	0.736	38	1,940	38
122	Republic of Korea	61.9	0.921	100	16,309	95
123	Togo	61.4	0.512	-6	358	-10
124	Lao PDR	61.3	0.601	16	485	-3
125	Madagascar	61.1	0.533	4	271	-17
126	Central African Republic	60.6	0.384	-22	339	-10
127	Azerbaijan	60.4	0.746	47	1,498	38
128	Burundi	60.1	0.413	-16	106	-24
129	Kazakhstan	60.1	0.794	71	3,772	69
130	Solomon Islands	59.8	0.602	23	624	12
131	Mauritania	59.4	0.550	16	603	11
132	Cambodia	59.3	0.598	23	440	3
133	Niger	58.9	0.374	-18	244	-11
134	Angola	58.7	0.446	-5	2,058	52
135	Mozambique	58.3	0.384	-13	335	-2
136	Zimbabwe	58.1	0.513	8	259	-7

RWLI 2008			HDI		GDP	
Rank	Country	2008 value	2005 value	Difference in rank (1)	2005 value	Difference in rank (1)
137	Zambia	57.9	0.434	-5	623	18
138	Haiti	57.4	0.529	14	500	13
139	Sudan	57.3	0.526	14	760	31
140	Uzbekistan	57.0	0.702	46	533	17
141	Egypt	56.9	0.708	49	1,207	45
142	Chad	56.8	0.388	-5	561	21
143	Mongolia	56.1	0.700	48	736	32
144	Sierra Leone	56.1	0.336	-10	216	-3
145	Congo (Republic of the)	55.5	0.548	28	1,273	51
146	Kuwait	55.1	0.891	120	31,861	128
147	Liberia	54.4		n.a.		n.a.
148	Oman	54.0	0.814	102	9,584	113
149	Yemen	53.8	0.508	19	718	37
150	Turkmenistan	53.7	0.713	60	1,669	63
151	Iraq	53.7		n.a.		n.a.
152	Maldives	53.6	0.741	70	2,326	72
153	Ethiopia	53.1	0.406	7	157	3
154	Congo D.R.	51.1	0.411	9	123	3
155	Tajikistan	46.6	0.673	53	355	21
156	Eritrea	44.8	0.483	22	220	10
157	Afghanistan	44.0		n.a.		n.a.
158	Somalia	43.4		n.a.		n.a.

(1) A negative value in the “difference in rank” indicate that the RWLI performs better than the HDI or the GDP for a given country, a positive value indicates a RWLI score lower compared with those of HDI or GDP

Appendix V: UN Countries excluded from the calculation of the RWLI due to lack of data

List of countries which were deleted from the initial RWLI due to too much missing data	
Andorra	Palau
Antigua and Barbuda	Saint Kitts and Nevis
Bahamas	Saint Lucia
Bahrain	Saint Vincent and the Grenadines
Belgium	Samoa
Brunei Darussalam	San Marino
Democratic People's Republic of Korea	Sao Tome and Principe
Dominica	Serbia and Montenegro
Equatorial Guinea	Seychelles
Grenada	Singapore
Kiribati	Slovenia
Liechtenstein	The former Yugoslav Republic of Macedonia
Luxembourg	Timor Leste
Marshall Islands	Tonga
Micronesia (Federated States of)	Tuvalu
Monaco	Vanuatu
Nauru	

Appendix VI: Comments from reviewers

A draft of this report was submitted to a group of experts for their review. To the extent possible, their comments and suggestions have been used in the finalisation of the report. As the subject of water index remains highly controversial, the need was felt to include these comments as an annex to this report as a contribution to the debate on water indexes.

Reviewer 1

...I have found it difficult to respond in any positive fashion because the framework for and approach of the paper is so weak that it is hard to know where to begin. I am currently grappling with policy issues around water and rural livelihoods in a South African situation of very unequal rural communities where livelihoods are a critical issue and have to say that this approach would not contribute at all to addressing these challenges.

As an initial comment, I find that the attempt to place all water issues into a single "box" is generally unhelpful whether at national level or at a sectoral level (if rural can be considered a sector). It is generally more useful to consider the resource and then the specific services derived from this; such as irrigation, potable supplies, livestock water; they are not generally particularly interdependent.

Further, the determinants of access to water for agricultural crop production and for animal husbandry depend fundamentally on physical, institutional and economic factors. Access to clean water and sanitation are dependent on what is usually a different set of physical, institutional and economic circumstances. The two are often completely unrelated.

In environments where access is institutionally mediated (as for instance, requiring dams and distribution systems for irrigation, boreholes for livestock water or small pumping and treatment facilities for potable water) the determinant of access will be the effectiveness of the particular institutions.

In this regard, the use of a "corruption" index is really not very helpful to determine whether there are institutions, whether they are effective, and whether this ineffectiveness is due to corruption or any of a multiplicity of other factors. Even if it was a useful indicator, the CPI used is based primarily on the perceptions of business rather than of individual rural citizens for whom experiences are likely to be very different.

The use of livestock variability as an index of security is also problematic. Good practice in a variable climate is to ensure that herds are adjusted as a function of conditions – thus low variability could be an indicator of poor adaptation not the converse! High variability could be an indicator of excellent management.

Equally, in respect to pressure on water resources, simply using nitrogen application is too blunt a tool. What about dilution capacity? What about the nature of the crops?

In general therefore, if it is hard to understand what this index seeks to achieve, it is even harder to understand why it is composed in the way it is and what possible application it could have. It mixes inputs, outputs, outcomes and perceptions in a methodologically confused way. Perhaps in the end, its most useful function will be to demonstrate the limits of indicators as policy tools.

Reviewer 2

General

The basic notion of constructing an index of the role of water in determining rural livelihoods is a useful one and the paper makes a serious attempt at deriving such an index. The four components of access to basic services, crop and livestock water security clean and health water environment and secure and equitable water entitlement make sense and I imagine emerged from the discussions that have been carried out in the process of developing the index. I offer some comments on the way in which the components are measured and possible applications of the index. I also have a few specific comments you may find helpful.

Components of the Index

One general point about the way you measure the components is that while some indicators are closely related to water availability, others are quite far removed.

Access to water: these indicators are clearly a measure of the link between water and livelihoods.

Crop and livelihood security: here the link to water is close but not perfect; the coefficient of variation of crops and livestock (especially the latter) can also be affected by other factors such as diseases. Can this be allowed for in measuring the variation?

Clean and health water environment: the pressure on water resources has a complex relationship with livelihoods and these is a strong element of non-linearity as well as dynamic considerations. Withdrawals may be close to available water resources without compromising livelihoods but persistent withdrawal in excess of available resources are likely to impact on livelihoods. These components are not well captured in the indicator. As far as nitrogen use is concerned, it certainly influences water quality but the impacts on drinking water depend on water treatment, which varies a lot across countries. I am not convinced that nitrogen use is a good indicator of a healthy water environment without taking account of responses.

Secure and equitable water entitlement: the indicators proposed are only indirectly a measure of water security and I feel some measures more directly relevant should be identified. Perhaps a water rights indicator can be constructed?

Other Comments

The exercise comparing the RWLI with other indicators such as HDI is useful, but what about comparing it to the water poverty index? Indeed the relationship between the RWLI and the WPI should be made clear.

In the presentation of different forms of capital, I would not include financial capital. It does not have the same role as other forms of capital and is not a factor of production as such. Also be aware that water-related impacts on rural livelihoods will come through not only natural capital but also physical and social capital. That point is worth making.

You should test the sensitivity of the index to other weighting methods. Of course, to do that you need to have some application in mind, such as the effect of a program that allocates water rights in a given area. Such an application would strengthen your paper.

Table 5 is rather weak and could be strengthened for parts 3 and 4.

Reviewer 3

I read with interest the RWLI paper you sent me. I tried to provide all my impressions and suggestions in what follows. This could give you the idea that my overall evaluation of the paper is negative, but this is not the case. In brief I found it a very interesting and operational proposal, with some weaker parts which should be possibly developed further, in particular sections 4.1, some parts of 4.4, 4.5 and section 6.3.

I think it is a relevant attempt to contribute to provide policy makers at the international level with a quantitative assessment of the state of water resources and their relationships with society.

It has, I think, all the pros and cons of similar indices developed for application at the national level, even if the paper clearly states the intention to make it applicable also at more local level. I am referring in particular to the risks of compensatory effects from averaging varieties of different local situations, and in this case, specifically (i) the effects of the hierarchical combination of multiple sub-indices, and (ii) the effects of using some indicators that seem to be not fully specific of rural areas. But I must admit that I'm not a specialist of national assessments and I don't have a clearest picture of data availability.

Those problems are touched for instance in paragraph 4.1, but this should be possibly further developed, with more support from the international literature. Similarly the problem of weighting touched by paragraph 4.5, seems a bit to simplistic and some sentences could be debatable: e.g. the fact that multiplicative or additive combinations require "a system of weights anyway". Also, There are many other weighting approaches besides, the five presented.

One important aspect I think is the clarification of how this new index can complement and integrated those that are already available, in order to provide comprehensive pictures at the national level.

The normalization procedure proposed in section 4.4, is not the only practical solution to the problem of making different indexes/indicators to be compared. Very importantly, this specific approach (please note that the normalization formula reported at p.20 is not consistent with the description, which is given in percent), is note suitable for comparison outside the original set of values used. Meaning that if this formula is used, the intertemporal comparison mentioned later in the paper may not be possible. In that case absolute and stable max and min values should be identified.

I appreciated for instance the efforts to exploit all the information used for the calculation of the index, by means of polar graphs, standardised reporting forms, maps, etc. I found some minor requirements for editing.

There are many indications that water is becoming an increasingly scarce resource, a point often made over the last 10 years (Falkenmark, 1997, SEI, 1997, Molden, 2007. Access to water is now recognised as a prerequisite for poverty reduction (Sullivan and Meigh, 2003), but in today's complex and changing world, competition for water from many different sectors can divert attention from its role in the improvement of human livelihoods (Llamas and Rogers, 2005). To better manage this vital resource, we need to develop ways of quantifying it which reflect this complexity, while providing robust representations of reality. Some 75% of the world's poorest people live in rural areas across the world, and for them, water access can literally mean the difference between life and death. The Rural Water Livelihood Index (RWLI) attempts to assess some of the more fundamental, water-related components which influence rural livelihoods, and which can support rural poverty reduction. In this way it can help decision makers target investments more effectively, ensuring funds get allocated to where there is most need.

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