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Informing future investment decisions for water and sanitation projects in the Asia Pacific by integrating statistical and qualitative information

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Abstract: International governments continue to mobilize their resources to assist in attaining the United Nations Millennium Development Goals targets. The Australian government is contributing to the goals of improving access to good quality water and sanitation for the world's poorest people through strategic planning for the allocation of financial and technical resources. Evidence-based information will assist in developing investment strategies where local needs for water supplies and sanitation in diverse, often remote locations are difficult to ascertain and deliver. Water management is a contextual and multi-faceted issue and there is a need to simplify complex aspects of water management into a smaller number of dimensions of meaningful information. This research investigates methodologies that support the integration of statistical and qualitative data to inform decisions on targeted aid interventions.

Indicator methodology inspired by the Water Poverty Index (WPI) has been used to assess water issues and rank water 'needs' of locations as a means of decision support. The choice of appropriate scale and inclusion of temporal and spatial variability of water supplies and demand is absolutely critical when understanding the usefulness of indicator methodology. There are, and will always be, many spatial information and thematic information gaps often relating to particular issues that need to be addressed. In reality, assessments are often deduced from a situational snapshot using available data and information. As such, it is important that limitations of an assessment are made apparent to stakeholders and potential users in order to address concerns, inform opinions and enable decisions to be based within the context of pertinent issues, rather than based solely on a modelled representation of reality.

A number of lessons have emerged when using indicators to formulate 'water needs' including the; (i) importance of considering data reliability issues, (ii) inclusion of qualitative information, (iii) need for a formal process for undertaking collective assessments, (iv) need for more coordinate data, information management and collection, and (v) choice of inclusive process to weight indicators and sub-indicators.

Indicator methodology can be supported by a broader deliberative process of engagement involving in-depth explorations of data and collective learnings. Based on the lessons from development of water needs for several locations and in reference to the current literature, a deliberative process for integration and selection of indicators and weights has been designed, to be applied at a workshop in the Philippines, to be further informed by a Delphi survey. Collective information will be used to inform the selection of data sources and assessment of the validity and reliability of the data sources.

The benefit of using a deliberative process is the improved ability to make strategic decisions at temporal and spatial scales where commonly, global data sets are unable to supply adequate and appropriate details. An engagement process with stakeholders allows for flexibility and greater adaptive capacity in decision making. The authors suggest the incorporation of the deliberative process provides a greater degree of analysis and an ability to better inform the index construct by providing a mechanism for the inclusion of qualitative information.

***Keywords**: Indicator methodology, weighting, assessments of water needs, collective learning*

1. INTRODUCTION

In response to climate change and predicted changes to rainfall, the Australian Government requires evidence-based research information to assist in prioritizing development investments for water and sanitation in the Asia Pacific region. Although there is a vast amount of information on the current status, future demand and impact of climate change on water supply and services, these data are not widely accessible or used by decision makers. In addition, there are many difficulties in deciding on factors that should be considered when determining the current water situation in these regions and the varying needs of different locations. Estimating future water needs is becoming increasingly difficult due to uncertain effects of projected climate change. *This paper explores the design of a valid and transparent process for high level assessments of water needs that can be applied at several scales and provides interactive knowledge management and which supports collective learning processes.* Methodologies have been selected that use statistical data from readily available international data sets with inclusive deliberative approaches.

1.1. The Decision Situation and Data Concerns

Water management is exceedingly complex, contextualized and has multi-faceted issues intersecting in the decision space. Consequently, there is a need to simplify complex aspects of water management into smaller dimensions of meaningful information. Satterthwaite (2000) argues that core problems in water management for an adequate supply of water are usually economical, political and administrative rather than as a result of environmental factors. Post-normal approaches to science are required to better understand and allow for socio-economic issues in highly politicized environments and to address the inherent complexity and uncertainty of water management. Post-normal methodologies are useful when all factors are not necessarily knowable and where accessing all relevant information is too time consuming or unclear due to high levels of uncertainty (Ravetz, 1986). Where stakeholders hold disputable values, stakes are high and urgent decisions are required, post-normal methodologies can supplant conventional methods of inquiry. Funtowicz and Ravetz (1993) claim dialogue with the peer community, particularly those affected by the issue, will allow the inclusion of local knowledge and information sources not accessible to conventional scientific processes.

Concerns of a pending 'global water crisis' are reflected in global and national development agendas and have prompted interest in the usefulness of indices as a means of conveying valuable and pertinent information to assess water issues and to relatively rank country or regional *'needs'*. Indices are based on a series of assumptions and consideration of proxy measurements and are used to provide a ranked indication of countries according to the intention of the measurement of the index. Indices can also provide an indication of the need for intervention and effectiveness of international aid for countries in need.

Global and regional data sets are important conventional information sources to be used in conjunction with local knowledge. However, several difficulties arise when dealing with data, increasing the uncertainty of what is measured and what the measurement represents. Data sources are contested on the grounds of (i) suitability, (ii) representativeness, (iii) method of collection, frequency and date of data collection, (iv) origin of source, (v) implications of the value, (vi) reliability, (vii) scale of reference, (viii) temporal reference, (ix) geographical limitations, (x) level of subjectivity, and (xi) misuse of average values (Alexander et al., 2008). Authors cite many examples of problems that reduce the usefulness of index methodology using global and regional data sets (FAO, 2003a, 2003b; Sullivan et al., 2006).

For example, the Total Actual Renewable Water Resources provides an estimate of the maximum theoretical amount of water resources in a country, and indicates the average annual per capita volume available to individuals within the country (FAO, 2003a). UNESCO (2006) uses water resource statistics collected by FAO (2003a) from national sources that have been reviewed to ensure consistency. They found dubious or undocumented methodologies and assumptions and/or extrapolations were used to compute estimations of the individual components of the water balance in many instances. There were multiple sources of information and different periods of reference that varied from country to country. Despite these difficulties Molle and Mollinga (2003) suggest that indicators are a quintessential attempt at legibility and simplification by centralized bureaucracies. Nevertheless, international statistical data can be used to develop indices and are valuable in providing a means of evaluating and ranking country performance.

2. THEORETICAL FRAMEWORK

Water availability and accessibility indicators have been used to represent the physical availability of water at national levels (Alexander et al.; 2008; Moglia et al., 2009; Molle and Mollinga, 2003; Sullivan and Meigh, 2005). Water indicators can be calculated by integrating diverse information types such as hydrological and social data into a single number for a particular location. Qualitative information can be translated into

quantitative form via categorization and ranking. Such information can be useful for informing policy makers, donor agencies as well as local water managers about water related needs in different locations, which can in turn inform investment, development and intervention decisions.

Lindholm et al. (2007) suggest that honest and objective appraisals of critical parameters are essential to inform selection and interpretation of analysis when using indices for any purpose. A major concern over the use of an index method is the potential for overlay and interactions between key variables. In addition, variability may not have been truly represented, as average values are often used in calculations for countries or regions. Average values do not always reflect the diversity of situations, or spatial and temporal variability. Issues of scale are important in understanding the costs of appropriate interventions. For example, technology and infrastructure costs cannot be considered at the larger scale as this will be largely dependent on the selected intervention.

Moglia and colleagues (2009) developed and applied the Water Needs Index (WNI) based on Climate Vulnerability Index (CVI) by Sullivan and Meigh (2005), at several scales. The WNI methodology provides specific insight into regional and local water needs, by including a variety of information types suitable for the geographical and thematic focus in countries of South East Asia and the Pacific Islands.

A number of lessons have emerged from this research among which the most important are the: (i) importance of considering data reliability issues (ii) inclusion of qualitative information, (iii) need for a formal process for undertaking collective assessments, (iv) need for more coordinate data, information management and collection, and (v) choice of inclusive process to weight indicators and sub-indicators. Additionally, based on literature, the choice of appropriate scale and inclusion of temporal and spatial variability of water supplies and demand is absolutely critical when understanding the usefulness of indicator methodology. There will always be many spatial and thematic information gaps relating to particular issues. In fact, assessments are often deduced from a situational snapshot using available data and information. As such, it is important that limitations of an assessment are made apparent to stakeholders and potential users in order to address concerns, inform opinions and enable decisions to be based within the context of pertinent issues, rather than based solely on a modeled representation of reality.

Moglia et al. (2008) has mooted the following practical considerations when applying index methodology:

- Indicators are simplifying reality and should be seen as just that, i.e. attempts to reduce complexity to something that can be more easily understood. As such they provide a bridge to the world of accountants and policy makers that want “simple answers”;
- There is a great deal of arbitrariness in terms of the choice of data sources and to reduce this level of arbitrariness it is be important to:
    - Recognise the subjective nature by providing more transparency in how decisions are made, and who have made them; and the assumptions underlying the index;
    - Decisions and assumptions should be part of a social learning process, where the group takes ownership of the final decisions and the index output;
- Data sources are as different as are their levels of reliability; this should be adequately acknowledged in indicator assessments. In particular the following issues should be taken into account:
    - Some information sources are qualitative in nature and should effectively be translated into a quantitative format, to be effective; regardless, such a translation may remain contentious ;
    - Data sources are prone to errors, uncertainty and questionable causality;
    - The value of historic data diminishes with time as water systems and societies are highly dynamic and changeable;
    - Decisions on data to be included are dependant on the knowledge of the person / organisation involved;
- The selection of unnecessarily complex indicators may confuse analysis of results.

In the application of the WNI, the data has been scrutinised for data reliability, documented methodologies, assumptions and extrapolations. Suitable data have been selected to inform indices that are pertinent for the study of water issues in South East Asia and the Pacific Islands. Tailored selection of data has then been subjected to analysis. The theoretical application of the CVI developed by Sullivan et al. (2006) has been used to construct a more tailored version, suitable to the regional analysis where data are difficult to obtain. To improve the analysis, qualitative methodologies have been considered to better inform the selection of data and to add insight into the derivation of the index construction by integrating participatory research.

2.1. Addressing theoretical concerns

Indicator methodology used in this research has been socially constructed and remains subjective, and therefore the need to clarify transparency of assessment decisions persists. Assessments are agreed upon by stakeholders with vested interests in an inclusive transparent and equitable process where decision outcomes are owned by the group. Assessments then become a learning process.

Indicator methodology also reduces a complex and adaptive reality to a handful of numbers. If the most pertinent aspects and meaningful information are chosen to be included in the index, then as claimed by Gladwell (2005), the individual decision making capability will increase considerably via the sharpening of intuition in a rapidly changing environment. To support this sharpening of intuition, radar diagrams are used to represent the output of water needs assessments, and hence visualizing in a manner which (i) shows multiple dimensions in a single graph, (ii) allows for easy comparison between different radar diagrams, (iii) allows for comparisons with other locations using a single diagram, and (iv) indicates dimensional strengths and weaknesses of a particular location (Campbell, 2001). Comparisons are important, not only when comparing two different spatial units (such as two countries), but also when monitoring progress over time, a critical factor in adaptive management. This capability enhances the value of the WNI, where decision makers can understand the significance of the differences in components of the index construct under scrutiny.

In addition, the application of the WNI needs to be done in a manner which acknowledges the complex process in which the index informs decision making. Therefore, formulation of the index needs to be incorporated into an adaptive learning framework where there are constant iterations between assessments, decisions and monitoring of results and a constant re-evaluation of the assessment process resulting in informed decision making. While the CVI relies on quantitative analysis, the WNI incorporates iterative participatory methodologies complicating the process, but better able to inform the selection and computation of the final index.

A variety of techniques can be used to gain opinions from field 'experts' and other stakeholders. The International Association for Public Participation's (IAP2) Spectrum of Public Participation (IAP2, 2005) provides a framework for determining the required level of participation, the main objectives and the appropriate engagement technique (IAP2 2005). A participatory process with local water managers and stakeholders can be used to (i) provide information where data are insufficient, (ii) explore local issues and (iii) assess the potential success of proposed interventions. A deliberative process has been chosen as the most appropriate method to inform the index methodology.

3. OUR VISION OF AN INDICATOR APPLICATION

Data, information and knowledge can be shared with donor agencies, experts and local water managers in a deliberative process using the indicator methodology to provide a structured and transparent process for carrying out water needs assessments, following a number of steps as shown in Figure 1 involving:

1. Identification of relevant stakeholders; i.e. who has a significant enough stake so that it warrants involvement in the process?
2. Identification of data sources; i.e. what data do we have in order to make any statements of the states of affairs in the particular locations;
3. Decision on problem focus and dimensions; i.e. what do we want to achieve with the assessment (i.e. addressing food security, water health, or water service issues, etc) and deciding on the key dimensions that are important for understanding the particular goal;
4. Choice of assumptions and representative data; i.e. how can we best represent the chosen dimensions with the limited and uncertain data that we have and how to best acknowledge this uncertainty?
5. Application within the WNI framework; which creates an output in terms of overall rankings of needs and radar diagrams for each location.

In this example, the deliberative mode reflects the "thinking processes" for decision making. Within the deliberative mode, information from a wide variety of sources is gathered through consultation with stakeholders within and outside relevant agencies. The information and facts are considered and weighted with a view to making a decision or reflecting upon the reasons for or against a particular choice. The process applies selected indices to identify the symptomatic water issues and identify hotspots requiring attention. Importantly, indicator methodology is used to identify suitable intervention strategies for different local

contexts and circumstances, given adequate information. An aspect of this methodology is the ability to allow collaborative learning to take place through interactive planning and knowledge management in the deliberative mode of the process (Figure 1), involving a wider range of stakeholders. International aid organizations, Non-governmental Organizations, community leaders, government departments, water utilities and river commissions could use the process to inform water management in their areas of interest. Additionally, where reliable data are not available approaches will be developed to involve stakeholders as advisors.

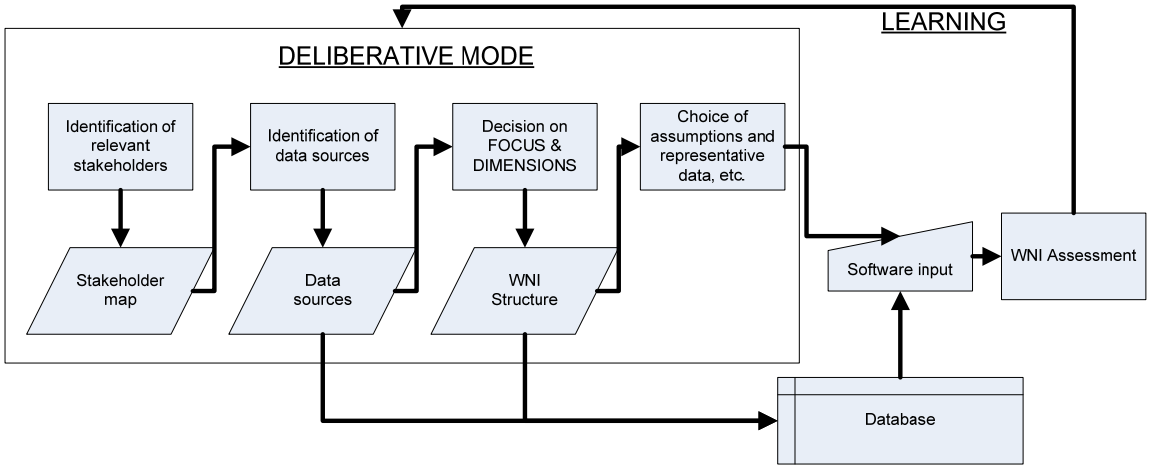

Figure 1: WNI Assessment process (Adapted from Alexander et al. 2008)

The benefit of using a deliberative process is the improved ability to make strategic decisions at temporal and spatial scales where commonly, global data sets are unable to supply adequate and appropriate details. An engagement process with stakeholders allows for flexibility and greater adaptive capacity in decision making. The authors suggest the incorporation of the deliberative process provides a greater degree of analysis and an ability to better inform the index construct by providing a mechanism for the inclusion of qualitative information.

3.1. Deliberative processes

As shown in Figure 1, the deliberative mode is a critical component in the application of the WNI methodology. In order to formally incorporate multiple and conflicting perspectives and allow consensus to emerge for contentious issues, a Delphi process will form the basis of the deliberative mode. This requires stakeholders to be selected and opinions reflecting their interests and knowledge of water needs devolved into a stakeholder map (Fig 1). There are several formats a Delphi process can take, i.e. via conference telephone call, committee meeting, formal conference or seminar, workshop, email or internet (Linstone and Turoff, 2002; Rixon et al., 2007).

The Delphi process has been described by Linstone and Turoff (2002) as a method for structuring group communication processes such that a group of individuals, as a whole, are able to deal with a complex problem. This is achieved through a series of questionnaires that are iteratively developed using responses from participants. Consequently, the outcome of the survey reflects the knowledge and opinions of participants. A Delphi process may involve between 10 and 50 participants, selected on the basis that they are experts, practitioners and stakeholders with a considerable experience on the topic in question and able to reflect a wide range of views and perspectives in a meaningful exchange of ideas.

Okoli and Pawlovski (2004) describe several steps in the process of interactions with participants as (i) selection of participants and assignment to panels, (ii) brainstorming sessions, (iii) response classification, (iv) selection of factors, and (v) ranking factors. Under these circumstances, the personal bias of the researcher facilitating the process is unavoidable. To minimize this bias, the process involves iterative participant validation of the categorizations and rankings and invitations to provide feedback on the process (with adjustment of the process when considered appropriate). For learning and validation purposes, there is also a focus on identifying and discussing inconsistencies and disagreements between participants. The researchers envisage enacting a formal workshop based on the Delphi process with selected stakeholders to pilot the application of the deliberative mode (Fig 1). The information gained would be used to inform the

development of a more rigorous survey, used in an iterative fashion, as an additional feature of the deliberative mode. During the process a nominated 'champion' would direct selected workshop participants to agree on and clarify the purpose of the metrics by deliberating on the focus of the output, prior to discussions of appropriate data sources for inclusion. In doing so, the data concerns would be highlighted and assumptions clarified, finding ways to minimize data gaps and the use data of low certainty. The process entails eliciting diverging opinions (i.e. brainstorming) followed by conversations that allow for convergence to occur with an iterative feedback capacity to further inform the discussions. Through this process the selection of indicators and sub-indicators is established.

In-depth discussions to determine the relative importance of factors within sub-indices, and the consequent weightings of relative importance, are critical to leveraging the iterative capacity of the process. Initially, weighting will be unitary, the appropriate setting of weights then contested and determined through decisions of mutual agreement reached using the Delphi process. Once established the weightings inform assessments and provide a more reliable representation of the water needs of the region under discussion.

When making decisions about data sources and weightings, it is essential that there is a structure for tracing and mapping how decisions have been made in order to increase the validity of the methodology. Qualitative recording and the use of decision mapping software would be an advantage. In addition, the implications of choices of data sources need to be considered, i.e. data reliability, accessibility of updates, methodological rigor etc. After such deliberations, the outputs are subject to scrutiny and mutual agreement as an iterative process of learning, with assumptions, weighting and decisions reported in the findings. Repeated attempts at ranking with other stakeholder groups allows for reconsideration based on a variety of opinions and attempts at developing rankings. The rankings can be further influenced using measures such as mean rank, median ranks, standard deviations and correlation factors. Finalized assessments have embedded opinions, knowledge, and consensual agreements that are useful in validating results and gaining a more informed ranking of indices and outputs.

The pilot workshop data selection, rankings, and weightings of indices will be validated using a Delphi survey eliciting responses from experts, practitioners and other stakeholders. The advantages of using the Delphi survey approach is an (i) ability to respond to surveys at will, (ii) express opinions and critique opinions in anonymity,(iii) inability to dominate by personality or authority, and (iv) often an iteratively developed questionnaire generates a wider set of ideas (People and Participation, 2009). The disadvantage of using the approach is the difficulty in coordinating and motivating the group, the bias of participants and that the results rely on qualitative reflections rather than statistical rigor.

3.2. Next steps

Water resources management will be examined using the deliberative approach with local stakeholders, in the Tigum-Aganan Watershed, Iloilo, Philippines during May 2009. The Tigum-Aganan Watershed Management Board (TAWMB) has identified the lack of shared understanding regarding the ecology, hydrology, and institutional agendas of various government agencies and non government agencies as key stalling points in developing their environmental strategies. Resolving the water resource problems in terms of vulnerability of the catchment, ecosystem services maintenance and the impacts on the ecological systems and human population of extreme weather events, requires evidence based information and dialogue between decision makers and other stakeholders. Consequently, the TAWMB has sought assistance in helping to resolve these water catchment issues. The aim of the exercise is to promote common understanding for cooperative stakeholder management between the 8 municipalities and one city department in the Tigum-Aganan Watershed and provide scientific and technical methods to assist stakeholders in making good water planning decisions. Findings will be reported at the MODSIM conference, July 2009.

4. DISCUSSION AND CONCLUSIONS

Index methodology provides a valuable way to inform international investment decisions for aid agencies. Review of literature and data sources suggest the need for careful consideration of data selection and the use of deliberative processes and methodologies that can improve the capability and accuracy of the index. Accessing relevant and reliable data, development of indexes, indices and components is complex and fraught with uncertainty. Incorporation of qualitative approaches will better inform and bridge the limitations of indicator methodology where there is scant reliable data available. Qualitative methodologies will enable the use of deliberative and participatory processes, and will be more inclusive and iterative in nature. Participatory enquiry is essential to the research process when information is required for assessments in smaller countries and when conducted at community level.

The benefits of using deliberative processes are the provision of a means to condense and collate stakeholder opinions where a series of iterative steps, and provides a pathway for consensus. Many water issues are bound by local knowledge and access to all relevant information is too time consuming or unclear due to high levels of uncertainty. Consequently, the use of post-normal methodology through a deliberative process increases the scientific rigor and allows for an adaptive capacity in the development of the index methodology. As a result the deliberative process allows those involved to better understand and allow for socio-economic issues in highly politicized environments of water management.

REFERENCES

Alexander, K.S., Moglia, M., and Austin, J. (2008), Regional and Country Scale Water Resource Assessment; Informing Investments in Future Water Supply in the Asia Pacific Region – a Decision Support Tool CSIRO: Water for a Healthy Country National Research Flagship

Campbell, B., Sayer J.A., Frost, P., Vermeulen, S., Ruiz Pérez, M. Cunningham, A. and Prabhu, R. (2001), Assessing the performance of natural resource systems. Conservation Ecology 5(2): 22. Retrieved April 2009 from http://www.consecol.org/ vol5/iss2/art22/

FAO (Food and Agriculture Organization). (2003a), Review Of World Water Resources by Country. Retrieved May 2008, from www.fao.org/landandwater/aglw/aquastat/water_res/index.stm

FAO (Food and Agriculture Organization). (2003b), Choosing a method for Poverty Mapping. Agriculture and Economic Development Analysis Division. Rome: Retrieved April 2008 from http://www.fao.org/DOCREP/005/Y4597E/Y4597E00.HTM

Funtowicz, S.O. and Ravetz, J.R. (1993), Science for the Post-Normal Age, Futures, 25(7) 1993, 735-755.

Gladwell M. (2005), Blink: The Power of Thinking Without Thinking. Back Bay Books: US ISBN 0-316-17232-4 & ISBN 0-316-01066-9

IAP2. (2005), Public participation spectrum. International Association for Public Participation. Retrieved 3rd March 2008 from URL: http://iap2.org.

Lindholm, O., Greatorex, J. M., and Paruch, A. M. (2007), Comparison of methods for calculation of sustainability indices for alternative sewerage systems--Theoretical and practical considerations. Ecological Indicators, 7(1), 71-78.

Linstone, H., and Turoff, M. (2002), The Delphi Method: Techniques and Applications: Information Systems Department at the New Jersey Institute of Technology.

Moglia, M., Burn, S., and Tjandraatmadja, G, (2009), Vulnerability of Water Services in Pacific Island Countries: combining methodologies and judgment, Water Science and Technology (under review)

Moglia, M., Alexander, K.S., Cook, S., Sullivan, C., Lane, B., and Lipkin, F. (2008), Regional and Country Scale Water Resource Assessment; Informing Investments in Future Water Supply in the Asia Pacific Region – a Decision Support Tool CSIRO: Water for a Healthy Country National Research Flagship

Molle, F., and Mollinga, P. (2003), Water poverty indicators: conceptual problems and policy issues. Water Policy 5 529–544.

Okoli, C., and Pawlovski, S. D. (2004), The Delphi Method as a research tool: an example, design considerations and applications. Information and Management, 42, 15-29.

People and Participation, (2009), Retrieved 8th March 2008 from http://www.peopleandparticipation.net/display/Methods/Delphi+Survey

Ravetz, J. R. (1986), Usable knowledge, usable ignorance: incomplete science with policy implications. In Clark, W. C., and R. C. Munn, ed. Sustainable development of the biosphere. 415-432. New York: Cambridge University Press.

Rixon, A., Smith, T. F., McKenzie, B., Sample, R., Scott, P., & Burn, S. (2007), Perspectives on the art of facilitation: a Delphi study of natural resource management facilitators. Australian Journal of Environmental Management, 14, 179-191.

Satterthwaite, D. (2000), The links between poverty and the environment in urban areas of Africa, Asia and Latin America: International Institute for Environment and Development

Sullivan, C. A. and J. R. Meigh (2005), 'Targeting attention on local vulnerabilities using an integrated index approach: the example of the climate vulnerability index'. Wat. Sci. Tech. 51(5): 69-78.

Sullivan, C., Vorosmarty, C., Craswell, E., Bunn, S., Cline, S., and Heidecke, C., et al. (2006), Mapping the links between Water Poverty and Food Security. Report on the Water Indicators workshop held at the Centre for Ecology and Hydrology, Wallingford, UK, 16 to 19 May, 2005.GWSP Issues in GWS Research, No 1. GWSP IPO, Bonn. www.gwsp.org

UNESCO, (2006), United Nations World Water Development Report, (WWDR) Retrieved March 2009, from http://www.unesco.org/water/wwap/wwdr/wwdr2/indicators/pdf/CH04-IPSFinalEdits.pdf