# Editorial

# Integrating scales of analysis and scales of action in water resources management

**Why do scales matter in water resources management?**

Research and development of natural resources face enormous challenges related to poverty alleviation, food security and environmental integrity. Around the world, competition across sectors for scarce water resources is intensifying. Agriculture is the principle user of water globally, and gains in water productivity in agriculture will be necessary to meet future global demands for food and environmental services (Molden et al., 2003). Some of these gains will come from improved technologies, however better management will also be necessary to ensure that water is allocated efficiently and equitably. It is widely recognized that to achieving this goal will require analysis and interventions at multiple scales integrating biophysical and socioeconomic factors.

When talking about scales different perspectives emerge. Each discipline, either social or biophysical, deals with scales in a different way. In a general way, Gibson, Ostrom, and Ahn (2000) define scale as the spatial, temporal, quantitative or analytical dimensions used to measure and study any phenomenon. The same authors distinguish four issues related to scale that are important for social and biophysical sciences: (1) how scale affect the identification of patterns and problems; (2) how diverse levels on a scale affect the explanation (causality) of observed patterns; (3) how propositions at one level of a scale may be generalized at another level; and (4) how processes can be optimized at particular points. While developed for the scientific context, these four issues encompass key aspects of scale-- identification, explanation, extrapolation and optimization-- that are relevant for both research and development in resources management.

*1. Identification of patterns and problems in water resources management*

Whether or not you see a problem or pattern is determined by the scale with which you are looking. For example, using a small geographical scale to analyze a water quality problem will tell you something about the problem locally but might hide cumulative processes that are expressed or evident at larger scales. At the same time, results can largely vary depending on the temporal scale used. Hierarchical systems in biophysical analysis are clearly defined, for example ecological hierarchies for analyzing species assemblages, trophic chains or stream orders. However many researchers and all development practitioners working the in area of water resources management are interested in human systems, and the scales used to analyze such systems are not always clear.

Within most agricultural landscapes the point of departure is often the farm scale. This scale may consist of plots, farmers or groups of farms (or farmer groups, if socially united). At higher levels of aggregation, this may go to catchments or to administrative scales like municipalities or provinces. This scale, at least in the lower levels, focuses on areas where farmers decide over the local land use and make their own management decisions. This may make sense for some agricultural technologies, but for soil and water management, not only "managed" areas are important but other land uses like roads, footpaths, windbreaks, wetlands (Swallow et al., 2001).

A farm-based scale would make it difficult to see these elements of the landscape and take them into consideration in analysis. At a higher level, whether a landscape is analyzed at a municipal or sub catchment scale may affect what you see. For example, if a sub-catchment is divided among several municipalities, and they have vastly different policies regarding, for example, water pricing, then whether you look at household water use at the catchment or the municipal scale will likely give very different results about what is happening in "the region."

In part to deal with these kinds of problems, the concept of watershed is usually the basis to understand landscape processes and determine hydrologic designs or water works. Large watersheds are made up of many smaller watersheds, and the selection of its size depends upon several factors and context of the problem addressed. Watershed management is a term that is globally used since many countries and regions have adopted the watershed as land unit for management. Conflicts and power disparities may arise with traditional national management based on administrative boundaries.

*2. Explanations and causality across levels within a scale*

A problem or phenomena is observed within a level of a scale but either the causes or its consequences might happen in other levels and/or scales. Acknowledgement that actions manifest at different scales or levels is a premise for water resources management. For example, sediment loading affects farmers, dams or wetlands locally but its root causes occur upstream. Some of these multi-level processes naturally occur or are the result of other people decisions over the management of the resources, known as an externality. At the same time, these decisions are influenced by multi-scale factors that affect their livelihoods like markets or culture, and biophysical processes that constraint freedom to decide such as climate and water availability.

Although some patterns are known to happen in large geographical scales or long periods of time, they can only be understood in a level that allows things to be measured or managed. For example, before the current use of remote sensing, processes occurring at the global scale lacked comprehensive data. Given the implicit relation of water with land resources that are characterized by high heterogeneity, multi-scale data for their analysis is usually not available. There is a prevalence of point measurements technologies, and data for regional analysis as can be obtained from remote sensing is still limited to surface properties (Mulligan, 2003). Despite the multiple research cases on hydrological modeling, analysis and prediction of multi-scale phenomena is poorly developed (Duffy, 2002). Current challenges focus on the best ways to integrate appropriate small-scale information into large-scale concerns.

*3. Generalization and extrapolation*

Theories and models are developed based on what researchers observe in specific scales. Usually theories or prepositions are more frequently developed at small scales and over short periods of time given the lower complexity implied. For example, theories regarding water-soil-plant relationships at local scale or rainfall-runoff models at large scales. Generalizations and theories are linked to specific domains, and limiting factors are specified for attempting to apply or extrapolate such theories at other levels.

In research for development, extrapolation or scaling is a notion frequently used when talking about implementation of a research finding at other levels or scales and knowledge generation that could be applicable across scales. Scaling out refers for example to processes of disseminating a new technology in the same level of a scale and scaling up to expanding an innovation beyond the original domain (Menter et al., 2004). Water rights policies for example will work successfully only under specific cultural conditions. Scaling out of such policies to other sites or higher aggregation levels might be constrained due to a different local vision of this resource regarding individual ownership or pricing.

*4. Optimization and improvement*

The purpose of research in water resources management is to identify technologies and management practices that improve management efficiency and equity. However the options for improved management that derive from research depend on the scale used, and what is optimal may vary depending on the scale used or the level at which a problem or process is analyzed within a scale. For example, a pump may solve the water problem for a given farmer on his/her farm, however widespread use of pumps may deplete groundwater sources and may not be optimal for society at higher levels of aggregation.

Policy makers address optimization issues regarding how to improve livelihoods conditions, societal economic and environmental benefits within a scale of action. These options or management schemes will try to maximize benefit to the different users and sectors while causing the least negative impact. Several trade offs arise while sharing common resources because normally stakeholders disagree with the objective function. Individual interests and power disparities will enhance or constraint particular actions.

Problems often arise because the scales of research do not often correspond to scales of action. Gibson et al. (2000) states that there is a mismatch between scales of scientific research and scales for policy support and action. Saunders and Briggs (2002) points out the difficulties of linking regional-scale catchment modeling and planning with local implementation and Ravnborg (2004), identifies difficulties on linking local land users to broader institutional arrangements.

The papers in this volume address these issues of scale from a research for development perspective. Most of these papers were presented at a workshop of Scales and Integration held during the baseline Conference of the Challenge Program on Water and Food (CPWF) of the Consultative Group on International Research (CGIAR) in Nairobi, Kenya, November 2003. The main objective of the workshop was to raise the awareness of the different aspects related to scales while conducting research related to water and agriculture in pilot sites. More than fifty researchers involved with CPWF projects located in nine basins[1] in the tropics attended the conference. This special issue includes revised papers presented during the workshop and other additional papers addressing key topics.

## Overview of papers in this issue

The first paper by Swallow, Johnson, Meinzen-Dick and Knox presents a conceptual framework for analyzing inclusive multi-level collective action in watersheds. The authors first describe how collective action at different levels of social aggregation is a key element for achieving integration for water resources management. The authors present a general model that describes the types of biophysical and social interactions that occur at different levels and across scales within a watershed. The paper presents different perspectives regarding the linkages between poverty and water, particularly addressed the issue of scales in poverty traps and their manifestations. The integration of natural resources interactions with action arenas in this model

[1] Andean System of basins, Nile, Volta, Limpopo, Karkheh, Indo-Gangetic, Mekong and Yellow River basins.

constitutes a useful tool for researchers and development organizations to think about what to look for when defining a problem for analysis or action.

The second paper by Sullivan, Meigh and Lawerence examines applications of a water poverty index (WPI) developed by Sullivan at different scales, going from local to national. Although developed primarily for application at local level, this type of integrated indicators prove to be a useful tool at higher levels for first assessment in a more holistic way. Caution is needed regarding the quality and scales of the data collected since although data can be scaled up or down, this may generate inaccuracies and decrease the reliability of the approach. The authors argue that the local scale is the most important because this is where action on the ground must be taken but assessments are needed in different scales to achieve integrated management.

The third paper by Otero, Rubiano, Lema and Soto presents a methodology to identify similar sites to nine basins across the Andean region for scaling out solutions based on variables that biophysically and socially characterize the area. When scaling out research findings several socio-economic, institutional, biophysical and technical aspects should be reviewed previous implementation. Two methods that combines biophysical and socioeconomic data were used: (a) a combination of Weight of Evidence (WofE) and Logistic Regression (LR) methods and (b) Fast Cluster analysis. This methodology could be applied to obtain first guidelines for site selection while scaling out research findings or could support decisions on interventions and technology applications. Although it is applied to a regional scale, could also be applied to different scales and different sets of variables. For example, application at a lower scale could be based on variables that have specific influence on desired research outcomes.

Rubiano, Quintero, Estrada and Moreno provide a case study in a Colombian watershed with high eutrophication problems. Biophysical and socioeconomic data at multiple scales is integrated to understand the various dynamic relations between upstream and downstream areas. The impacts of different land uses on water quality were analyzed in order to identify prioritization areas. Hydrological understanding of the current situation is the basis to determine sound strategies such as compensation mechanisms to promote changes that reduce the negative impacts of such land uses and management practices. This paper is an example of the challenges that represent the integration of different physical and social dimensions when finding appropriate development strategies.

Ravnborg's paper addresses the relation of water access and management with poverty from a local perspective through two cases in the northwestern mountainous region in Nicaragua. In contrast with the WPI developed by Sullivan in which the components are all water related, Ravnborg develop a poverty profile based on people's own perceptions of poverty. This index is then compared to the stakeholders' conditions regarding access to water and management strategies. She founds for example, that the poorest are the least likely to be members of village water committees and have less power to enforce locally negotiated norms. One of the contrasting arguments presented by the author is concerned with recent tendency of establishing hydrologically defined water-management institutions. Ravnborg argues that there is a high risk of loosing democratic mechanism, which have been gradually and sometimes difficult to gain, through transferring the water authority from national governments to hydrologically based institutions. No matter the type of organization, water management happens to be in multiple and overlapping scales depending on different biophysical and social relations.

The article by Campbell, Hagmman, Sayer, Stroud, Thomas and Wollenberg is concerned with the need of new approaches for development and research for integrated natural research management (INRM). It describes three basic research principles that are relevant to issues of water and scale: (a) commitment to action research, learning and experimenting among stakeholders, (b) project flexibility and adaptation to the types of actions required and (c) new forms of organization to implement effective development research. Given the complexity that implies the implementation of these principles, eleven operation cornerstones focusing in aspects like governance, organizational capacity, incentives, information and scaling up are described. Two case studies in Zimbabwe and Indonesia, of contrasting contexts, are incorporated as examples to expose complexities faced by researchers in INRM.

## Conclusions

Several trade offs arise when dealing with water resources management. There are multiple dimensions and interactions that emerged between water resources users and uses. While one sector could benefit from its use, other sectors either downstream or upstream will be negatively affected. Thus it is not possible to define a unique optimal water management strategy holds at all scales or levels. Modeling and analysis can help to understand particular process, however they must be incorporated into a social process in which decisions about priorities and interventions are negotiated among stakeholders.

Given the context specificity mentioned above, generalization and extrapolation of technologies or processes is not always possible. It is important first to understand the processes and their interactions across scales in a particular site in order to determine actions that will be successful. Some actions could be innovations based on the context analyzed, which can be generalized afterwards and used to predict success in other areas, or could be actions already developed somewhere else. In both cases, success of these actions is related to variables that are scale dependent. Unfortunately, there is not a common recognition and awareness of the need to be more precise regarding scales issues and domains when conducting and implementing research for development.

One generalizable principle around which there is consensus is that given that stakeholders will have to in some form negotiate solutions to problems, local capacity to do this, especially among poor and marginalized groups, needs to be strengthen, especially in areas of legal and regulatory aspects process (Ravnborg, this volume, Swallow at al., this volumen). Such capacity should enhance the mobilization of effective local collective action and the linkage with higher order level institutions that might facilitate their participation in decision-making processes, allocation of resources and technical support. Feedback between action in the ground, researchers and policy makers is needed in order to adapt and improve future management mechanisms.

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