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Integrated modelling approaches to support water resource decision making: Crossing the chasm

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Abstract: Climate change is real and poses a grimmer risk to livelihoods and the environment. Strategic capacity building and knowledge sharing structures are essential for generating positive sum solutions from these generally negative forces. Adoption and adaptation are main responses to climate change and environmental care but transaction costs are substantial. What knowledge is protected and at what cost will guide the balancing of costs and benefits across actors sharing at the river basin level. Knowledge and capacity building using integrated modelling approaches has the potential to become the inputs and outputs of environment care processes–scientific, political and socioeconomic. Agents with better knowledge will be better able to cope with the climate change risks and to protect the environment through integrated water resources management. This paper presents findings of a recent UNESCO workshop on integrated modelling aimed at informing and support water managers and planners in making integrated water resource management (IWRM) decisions in the context of System Harmonisation approach. The workshop participants concluded that despite the substantial improvements in model development tools and large investment in the development of computer models by scientists and academics, their use as decision support tools by water management practitioners remains low. The suboptimal use of models and modelling in supporting water management decisions can be attributed to failures in two main areas – integration across modelling disciplines and inadequate integration between researchers and practitioners in all phases of the modelling cycle. Model development is still predominantly focused within narrow disciplinary boundaries such as climate, hydrology, water systems, economics, social science, etc; with little integration across discipline boundaries. This approach ignores the broader economic, social and environmental interactions of water management interventions that change the existing stocks and flows in the catchment or river basins and yields inappropriate responses to water planners and managers. This silo approach to modelling the behaviour of water resource systems in response to water management interventions is usually ineffective in achieving their intended purpose which is to inform water management and policy decisions made by practitioners. This is especially evident in the use of modelling to inform water sharing policies under severe competition between consumptive and environmental uses where despite of extensive modelling carried out by scientists and academics in major river basins that are currently under severe stress, these tools remain under-utilised by planners and policy makers. The main message is that we need to think differently about the role of integrated modelling in the wake of climate change and environmental care by modelling stakeholder responses with stakeholder. We must consider climate and environment as legitimate clients for maintaining and enhancing the multifunctional productivity of water and ecosystem resources so as to optimise physical, economic, social, and environmental benefits without compromising the quality of these resources–truly positive sum solutions for mankind.

Keywords: *Integration, climate, water, environmental care, system harmonisation*

1. INTRODUCTION

Climate change is impacting the livelihoods of millions around the globe. Prolonged and severe drought, extreme rainfall, flooding, hurricanes and storm surges from rapid changes and unseen variability in century scale climatic patterns are posing a grimmer risk to livelihoods and the environment. Strategic capacity building and knowledge sharing structures are essential for generating positive sum solutions from these generally negative forces. Adoption and adaptation are main responses to climate change and environmental care but transaction costs are substantial both due to the common good nature of climate change and the environmental care as well as due to the geopolitical economy and inequitable distribution of costs and benefits among various social groups, locally, nationally and globally. Integrated Water Resources Management (IWRM) emerged around the 1980s in response to similar pressures on water resources from competition amongst various users for a limited resource, the recognition of ecosystem requirements, pollution and the risk of declining water availability due to climate change. A central goal of IWRM at the river basin level is to achieve water security for all purposes, as well as manage risks while responding to and mitigating disasters. The path towards water security requires resolving trade-offs to maintain a proper balance between meeting sector's needs, and establishing adaptable governance mechanisms to cope with evolving environmental, economical and social circumstances. IWRM strives for effective and reliable delivery of water services by coordinating and balancing the various water-using sectors – this is an important part of sustainable water management. As water is mainly managed locally, the river basin approach is recognized as a comprehensive process for managing water resources in a more sustainable manner. However, well-tested, scientifically robust, socially acceptable and economically viable integrated approaches to implement IWRM at the river basin level are still not widely available.

To address integrated modelling issues UNESCO organised a workshop titled "Integrated Modelling Approaches to Support Water Resource Decision Making: Crossing the Chasm", UNESCO-Paris, 20-21 April 2009. This workshop used "System Harmonisation" framework to address integration issues in the context of developing water sharing strategies aimed to harmonise economic uses of water (irrigation, urban, industrial) and environmental demand. It envisaged seamless integration of the water cycle analysis and impacts from alternative water management policies, economic and eco-hydrological analysis and modelling and socio-cultural and institutional elements that may impinge or constraint the application of alternative policies.

The aim of this workshop was to discuss strategic approaches that ensure the:

- Convergence of different disciplines in the development of integrated modelling frameworks to assist decision making by water management practitioners, and;
- Convergence of modellers and practitioners in the development and application of modelling frameworks to support water management decision making.

2. SYSTEM HARMONISATION APPROACH

System Harmonisation is an approach that has been developed to overcome this lack of integration problem (Khan et al, 2008). The 'System Harmonisation' approach seeks to identify business opportunities for irrigators to become an integral part of an expanding environmental services industry and in so doing support a truly sustainable and diversified irrigation business environment. The system harmonisation framework involves an all encompassing approach that combines research and business principles to achieve productive and environmental improvements at the catchment level. The framework involves five feasibility steps including three research components and a business analysis component leading to the formation of Regional Irrigation Business Partnerships (Khan and Mushtaq, 2009). The system harmonisation process establishes the base physical, economic and social position of the region, identifies the key biophysical, economic, social, environmental or institutional pressure points in the system and the system constraints. Changes in these key pressure points need to be assessed and acted upon, in a comprehensive and systematic way, to enhance the multifunctional productivity of irrigation systems.

The phases involved in developing and implementing system harmonisation processes are shown using a conceptual-operational framework (Figure 1). New science and knowledge needed for harmonising irrigation system within their operating environments are developed in the first three phases of the process. This knowledge feeds into subsequent phases, which are designed to operationalise the process. The terms 'feasibility stage' is used to refer to the steps involved in designing and delivering the system harmonisation framework. This approach is used to clarify the conceptual understanding of this process. However, these boxes constitute permeable boundaries that allow information, concepts and data to flow across them in a seamless fashion to ensure shared learning. Another important element of this framework is the iterative rather than linear nature of the process. The first three steps of the process are designed to inform the business development phase, which in turn relies on the analytical and modelling framework to evaluate and explore alternative business options in an iterative fashion.

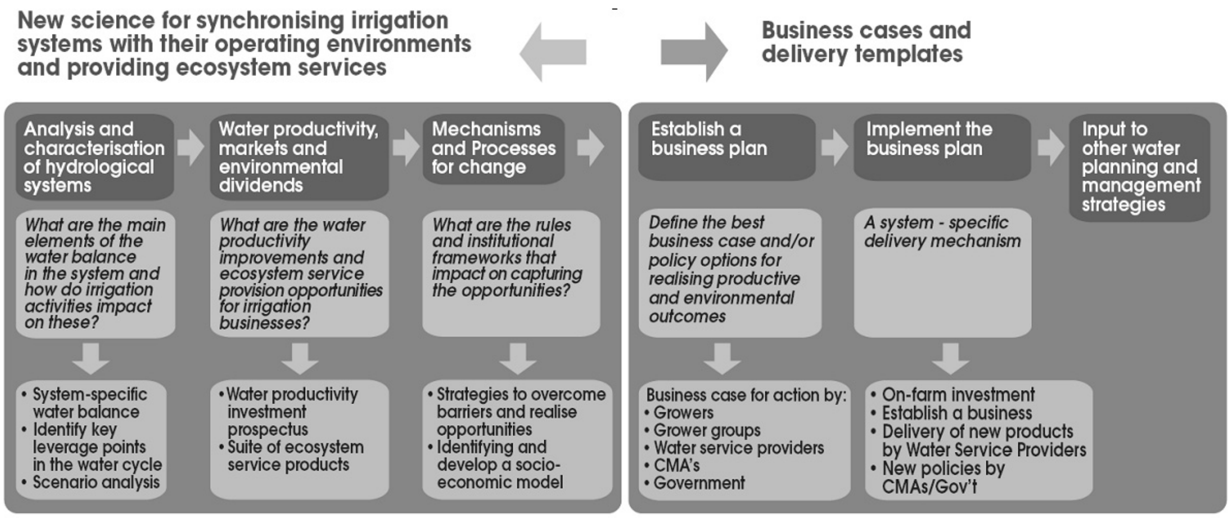

Figure 1. The System Harmonisation Approach

In the first phase the hydrologic system is analysed and characterised. This entails the quantification of stocks and flows of water, pollutants and other constituents within the entire catchment water cycle. The understanding of the system dynamics achieved in this process is crucial in analysing the existing hydrologic situation of the system and in formulating, calibrating and modelling predictive tools to assess system responses to alternative operational policies designed to achieve productive and environmental improvements.

In the second phase the economic, social and environmental outcomes from the hydrological systems are assessed. At this feasibility stage the markets for ecosystem services and economic trade-offs and synergies between productive and environmental outcomes are evaluated. It is assumed in this phase that the purpose of an irrigation scheme is to satisfy society's demands. The desire for environmental outcomes is no different to economic outcomes. These outcomes need to be measured in physical terms prior to being valued.

In the third phase the institutional aspects and mechanisms for change are investigated. This analysis is intended to understand the existing institutional framework and identify potential barriers to the implementation of change and capture of productive and environmental opportunities. In the following two boxes business plans are developed to capitalise on the findings from the research (Khan and Mushtaq, 2009).

Elements of an integrated modelling approach to support the system harmonisation philosophy are illustrated in Figure-2. A key feature of this approach is modelling with stakeholders from defining water management issues to finding solutions with stakeholder acceptance.

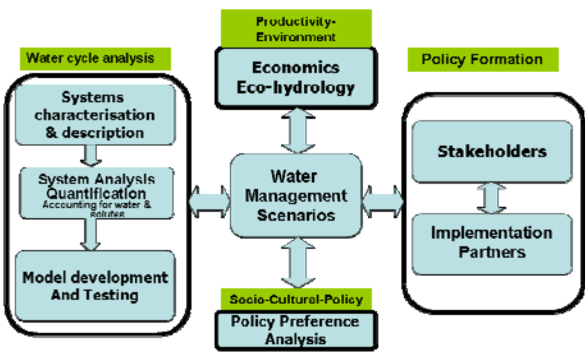

Figure-2 Modelling tools to support System Harmonisation Approach

3. KEY FINDINGS OF UNESCO WORKSHOP

The participants of the UNESCO Workshop on Integrated Modelling Approaches to Support Water Resource Decision Making: Crossing the Chasm, UNESCO-Paris, 20-21 April 2009 used system harmonisation as a framework to discuss integrated modelling approaches. Key observations made by the participants are noted below.

Conventional Disciplinary Modelling

The participants noted that a number of water management modeling activities are going on within the individual disciplines. A synthesis of such activities will be of great use to the water community. Given the uncertainty in data and climate process, models looking into thresholds may be of great value. There is a need to continue discussion on whether to integrate everything or keep some tools separate. It is important to distinguish between modelling people's behaviour or model with people? There can be benefits either way. Concentrate on how to use the models rather than which models to use. Need to start thinking about models in a different way for example new machine learning modelling approach.

Purpose Driven Modelling and Local Capacity Building

Modellers need to ask themselves what these models are going to provide and to whom?

The key questions to ask include:

- How to use the model?
- What should be the integrating factor?
- Relative role of economics and social issues?
- How to balance different considerations?

Which Disciplines to Integrate

Several disciplines are needed to provide decision support for different issues. There is a need to integrate modelling capabilities from different disciplines. Local capacity building is required to make sure modelling efforts are utilised by the water managers and decision makers. There are missing links between different components (e.g. between physical and human systems – stakeholders, users and the institutions and policies). Conflict of interest between stakeholders may not be captured by optimisation tools. Can we use optimisation as a negotiation tool with stakeholders?

Coupled Modelling

It was positive surprise to see similar approaches for coupled modelling. Linking biophysical and economics is clear. Link between ecology and water dynamics are not very clear. Still only water flow based modeling is common in water allocation decision making. Scale is a big issue in linking ecology with hydrology. Water and people possibilities are eye opener – modelling with people can be very useful – bring modelling processes closer to understanding is the way forward.

Complex versus Simple Modelling Approaches

Model together with stakeholders can help with deciding right level of complexity. Modelling is a very time consuming process. There is a need to have quick rough models followed by detailed efforts. Cultural component is an important consideration. Water quality so far has been concentrated on rural aspects what about industrial and urban (point sources). Modellers put a lot effort on model development rather than developing credible water management scenarios (we do a cheap job on scenarios). We need smarter scenarios.

Water Quantity vs Quality Issues

Quantity modelling should go along with quality and environmental considerations. Starting with stakeholders is very important. This can help develop simple tools and indicators. This can also help with ownership and protection of water quality. Landuse is an important parameter for understanding water quality dynamics. A single water quality indicator is often not adequate.

Modelling People's Behaviour

Modelling of water resources and integration with economics has reached a fairly mature state. This does not apply to ecosystem response and people's behaviour. People's behaviour is a weak link in modelling water allocation. Integration with water resources systems and economics with people considerations is very important.

Appropriate Models for Stakeholder Engagement

Examples from HELP Basins focusing on stakeholder driven approaches are complimentary to the system harmonization concept. This can lead to better integration of models and integration of stakeholders and links between the two. Approach to integrating people with the modelling framework is different to modelling people behaviour and the two things compliment each other.

Stakeholders (policymakers, water users and community) need to have access to spatial and temporal based outcomes. Feedback at all stages of modelling is important.

There is a need for water quality indicators which can be used by hydrologists, economists and others involved in the process. Everyone thinks economics can be dealt with quite easily. Coupled models are the way to go but not the only way to go. Bayesian and other approaches need to be explored further. Landuse and water are closely linked together. There is also a need find a better way of explaining economics (e.g. value, gross margins etc). Modellers need to find ways to explain succinctly, quickly and accurately. Policy links with models are still very grey. Timing of modeling outputs and policy needs is a big issue. Integration of models is still not very clear in some cases particularly across disciplines.

Comparative Modelling for Tackling Global Issues

Comparative analysis of impacts of big projects on water quantity, quality, environment and links with climate change are important for tackling global issues. Real time data collection capturing dynamics of environmental changes using a common database structure is important. This can help to develop bench mark solutions and to share data across different regions. Incorporation of observed complexity vs adoption of reductionism is important consideration – complex and accurate models need to be coupled with rules for simplifying information.

How to Tackle Uncertainties

Modellers need to deal with uncertainty by explaining it to people while satisfying local vs global interests. Learning machines can help simplifying data collection and modelling of floods, droughts and climate change leading to strategy development and mitigation measures. Using models which can show the consequences of action/inaction can be a proper way of putting issues such as global change on the agenda.

Use of Models as Training Tools in Schools

It is not clear how to link water models with community schools? Primary and secondary education in the context of community education in water management is the key to sustainable development.

Use of Optimisation vs the Simulation Mode of Models

Modellers need to focus on appropriate role of optimisation and simulation models. Optimal scenarios as compared with optimisation techniques are different concepts.

4. RECOMMENDATIONS

The workshop participants made the following recommendations to progress integrated water resources management modelling:

- Setup e-group, facebook, Wiki on modelling in the short term to share these ideas with a wider group
- Standardisation of database platforms (and modelling suites environment) to aid data and model plug-ins. UNESCO IHP's HELP and FRIEND initiatives to facilitate this process (IHP 2007).
- Need to develop capacity in use of models and engagement with stakeholders. Modellers need to learn appropriate communication skills. (start with training the modellers) – this will need regionally customised training workshops

- Publications to create wider awareness of modelling efforts (e.g. a policy brief, special journal volume/book on frontiers in integrated water systems modelling and good practice in modelling guidelines
- Capture state of art on linking hydrology and ecology in a dynamic framework.
- Integrate modelling with planning, decision making and policy implementation using dynamic feedback from field to modify models and decision making process.
- Need guidelines for stakeholder engagement, scenario development, and integration of disciplines, modelling, and decision making activities.
- Take into account policy development and implementation time frameworks by defining appropriate inputs and outputs.
- Synthesis of best practices in the use of models to develop, adapt and modify policy
- Economics modelling need to focus in four areas:
    - Financial assessment, values and costs – neo classical – done
    - Institutional/Ecological economics – minimise transaction costs – need to explore
    - Possible future investments in General Equilibrium models
    - Regional economics assessment – input-output analysis
- Need to closely interact with emerging modelling techniques such as the motivated machines (may require integration of existing models with new machine learning methods). This will also integrate with modelling people behaviour with biophysical models. A study of state of art and possible seminar e.g. agent based approaches.

5. CONCLUSION

While significant progress has been in understanding the hydrological cycle and coupled modelling there is still need to better integrate social and ecological aspects. The UNESCO workshop addressed these integration issues in the context of developing water sharing strategies aimed to harmonise economic uses of water (irrigation, urban, industrial) and environmental demand. Future efforts need to focus on seamless integration of the water cycle analysis and impacts from alternative water management policies, economic and eco-hydrological analysis and modelling and socio-cultural and institutional elements that may impinge or constraint the application of alternative policies. Modellers will be increasingly challenged to model stakeholder behaviours for climate, water and environmental care while working closely with them.

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