Challenges of Data and Innovations in Modeling across Multiple Sectors in Mozambique, Mekong, and Bhutan

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The Challenges

River basins world-wide are facing a series of challenges critical to their future, centered on the availability and distribution of water. Floods and droughts will impact biodiversity, freshwater resources, agriculture and livelihoods. Increasing development of hydropower provides much-needed energy, but alter the flow regime and sediment transport of rivers. Climate change is then superimposed on all aspects of the system, bringing changes in temperature and rainfall regimes, and reduction of snow cover. Global economic impacts and food shortages are a growing concern, and international effort must be made to predict and mitigate potential changes. Planners must increasingly account for how the intersection of these issues will affect overall water, food, and energy resources. Our international work from the River System Research Group in the University of Washington in this challenging area includes smallholder agriculture in Mozambique, hydrology/land interface management in Bhutan, and basin simulation in the Mekong. These cover major transboundary rivers: Mekong involves six countries, the Zambezi involves eight counties, and Bhutan is the upstream country for rivers that run through India and Bangladesh.

As such, these targets represent a very complex set of intersecting issues of scale, cross-sector science and technology, education, politics, and economics. In some regions of the world, sophisticated tools and rich data sets exist to deal with these problems. But in many regions, they do not. However, techniques are emerging within the so-called "Global Change/Earth System Science" community that may help, complementing existing or traditional approaches to resource evaluation and management.

For example, on-going programs are incorporating distributed modeling and multi-sources of information, in support of their objectives. The Ministry for the Coordination of Environment Affairs (MICOA) of Mozambique is developing a GEF project for the lower Zambezi River basin, including developing baseline and scenario datasets on landcover, biodiversity and hydrology, in support of improving smallholder agriculture. The Ministry of Agriculture (MoA) of the Royal Government of Bhutan is developing the capability to use landuse and climate change scenarios to proactively address land and natural resource management to minimize and reverse land degradation, and impact on floods and hydropower. The Mekong River Commission is building on the outcomes of several projects, to produce a "Virtual Mekong Basin," to synthesize and communicate potential outcomes of climate and landuse change and hydropower development on water, agriculture, and fisheries.

A Common Approach: a “Dynamic Information Framework”

To address these questions, information from multiple sources are brought together, organized and evaluated (preferably according to organizing principles), and disseminated. A template is developed where decision-makers can consider rigorous scenarios of alternative futures plays for complex environmental and economic decisions. This requires an accurate understanding of linkages between water and multiple allocations, with the ability to quantitatively forecast individual and combined impacts of demand. With such information, specialists, planners and ultimately decision-makers evaluate the trade-offs between sectors, forming the basis for policy interventions and financial investments.

We have found that establishing such a process is not a trivial task, for several reasons.

- The information required comes from multiple sources, from individual rain gauges to statistics on rice yield and fisheries. The information required comes from multiple disciplines, which presents problems with even communication between specialists. Existing data holdings are not always readily obtainable, sometimes for institutional reasons. New field measurements, especially holistic and cross-boundaries, are challenging.
- Handling such diverse data and executing models is not straight-forward. There are very real problems in converting data streams into useful information that go beyond a database.
- Perhaps most challenging is how to not only create such information, but how to get it into the hands of users of different levels, from the specialist to the local and regional decision makers to the local farmer or fisherman.

In this spirit, we have employed a *Dynamic Information Framework (DIF).* A *DIF* is an instrument for a (quantitative) analysis of complex interdependent problems, based on the integration of data and information tools from multiple sources, of interest to multiple parties. This involves use of satellites, new generations of dynamic "models," field measurements, and, especially, a thinking and practice of "integrated systems." Fundamental to these is a new class of hydrology models, which can be regarded not only as hydrology models, but as overall landscape models, because of the processes (and data layers) they represent. These models are geospatially-explicit, fully-distributed, recognize the spatial heterogeneity of the watershed, and are process-based. Because these models can, and must, "meld" information from multiple sources, we have found that they can be functional in specific regions where local data are relatively sparse. We have also used visualization techniques to convey results to a broader audience than the specialist.

Using available data and filling gaps with satellite data

Applying the DIF construct requires starting with a "complete" description of the topography, soils, and vegetation of a landscape - ground data which are typically sparse to non-existent in specific regions. But progressively, new products from "global" databases are being made available which can be used to complement local knowledge. For the Zambezi, satellite data sources were used, to develop a digital elevation model (from SRTM), landcover classifications at moderate resolution (from MODIS) and high resolution (LANDSAT), and soils (FAO). In the absence of local data, outputs from a European weather model were used to describe surface climatology. While relatively coarse, these data sets allowed the initial setup of a spatial hydrology model (VIC). Similar strategies are being taken for Bhutan and the Mekong. Surprisingly-good descriptions of the distributions of water (in the soils, in the channels) can be produced. Because the models are process-based, they can be used to produce scenarios of the consequences of climate and/or landuse changes in a basin, including consequences of and for hydropower.

Modeling changes in climate

Substantial progress is being made in developing global models to consider the impact of CO_2 and changing atmospheric conditions. Applying such techniques to a particular region is more problematic. For the Mekong, the project used the output from 14 IPCC 2007 AR4 GCMs for the

21st century, downscaled and bias corrected to the spatial scale of the VIC hydrology model. For closer to real-time conditions, a regional scale climate model (WRF) is being used to drive VIC. Results help evaluate basin dynamics, with implications of, and for, hydropower.

Simulating hydropower

Reservoir operation is an important element in water resources planning and management, consisting of several control variables that define the operating strategies for guiding a sequence of releases to meet a large number of demands from stakeholders with different objectives, such as flood control, hydropower generation and allocation of water to different users such as irrigation water demand. The Mekong currently has the "Chinese Cascade of dams" built or under construction. A series of dams are being discussed for the lower Mekong, including the mainstem, with utterly unresolved consequences. To examine the impacts of these dams, within the context of the basin, the VIC model is being modified to a reservoir model, based on an optimization scheme. Initial results show that the primary effects of the reservoirs are an increase in dry- season flow and decreases in wet-season flow, or effectively a reduction in streamflow seasonality. To be resolved is the cumulative magnitude impact of all current and planned dams, on downstream resources, and, ultimately to the Mekong delta.