100 East Francis
Aspen, Colorado 81611
Phone: 303/925-7376
Fax: 303/925-7097
E-Mail: AGCI/EcoNet

# Aspen Global Change Institute

## 1992 Summer Science Session I: "Freshwater, Land and Biologic Interactions: Changes and Impacts" August 16 - August 29

**Dr. Mark Meier and Dr. Malin Falkenmark, Co-Chairs**

## Workshop Report
## Submitted to *Eos, Transactions*, American Geophysical Union

# FRESHWATER, LAND, AND BIOLOGIC INTERACTIONS: CHANGES AND IMPACTS

Water is essential to human life and the functioning of all terrestrial ecosystems. As human population expands and anthropogenic effects induce climate change, many water availability systems are or will be modified and stressed. The stress will be felt very differently in different regions, depending on the complex relationships of water, vegetation, land, and human activity. Yet, many aspects of the interactive biogeochemical cycles are poorly understood, making it difficult to predict the effect of changes in climate or land use on water as an integral element affecting ecosystem processes and sustainability.

An international group of 19 scientists and 2 educators addressed these issues at the Aspen Global Change Institute from July 19 to August 1, 1992 as part of its six-week annual series on global change topics. The state of knowledge of climate change and coupled climate-hydrologic models, people/water/ecosystem interactions and the distinctive processes and problems in different eco-hydrological regions were discussed. Risk, uncertainty and social conflict in water management schemes were addressed; followed by an instructive examination of the impacts of climate and other changes on several large international basins. Finally, issues of sustainability as well as social and policy response to change were considered.

In an introductory statement, Mark Meier (University of Colorado) noted that climate and atmosphere trace gases change on many spatial and temporal scales, sometimes abruptly, and that models to predict these changes and their effect on hydrologic systems are still in their infancy. In another overview, Malin Falkenmark (Swedish National Research Council) emphasized environmental vulnerability (water partitioning as affected by land use), landscape sustainability (the balance between manipulation and adverse side effects), water availability constraints

(especially in regard to food production), and the confusion between drought and desertification (water scarcity being due to either hydroclimatic effects or induced by human action).

Malcolm Hughes (University of Arizona), in discussing paleoclimatic evidence for climate variability, noted that the rapid changes of the Younger Dryas, presumably due to changes in the thermohaline circulation of the ocean, may not be a problem in the future because they happened during the waning phase of an ice age, but that other surprises may be in store. He also noted that the spatial extent of the medieval warming and the Little Ice Age is still poorly known. Roger Pielke (Colorado State University), discussed the problem of downscaling GCM's to simulate effects at the meso-scale of hydrologic basins, and emphasized that changes in the landscape due to human action, such as extensive crop irrigation, have and will continue to have major effects on global and regional climate, and that this needs to be addressed in modeling efforts. Steve Hostetler (U.S. Geological Survey) also pointed out problems in developing mesoscale models, including simulating terrain effects and improving treatment of soils, slope, vegetation, and biosphere-atmosphere transfer schemes.

Paul Quinn (Lancaster University) addressed the balance between point measurements (too much noise) and mesoscale hydrologic models (may not incorporate relief correctly), and suggested the summing of representative elementary areas (REA's) to simulate watershed response. Geochemical and water quality problems were addressed by George Hornberger (University of Virginia) and Jake Peters (U.S. Geological Survey); they noted problems of simulation, scaling and regionalization, and the fact that no "pristine" water exists today although the prognosis for improvement in water quality is good.

Whether important and desirable ecosystems can be sustained locally, regionally, or globally, was addressed by Bob Woodmansee (Colorado State University); he laid out the conjunction of science, management, and policy issues needed to move toward ecosystems

sustainability. Emmett O'Laughlin (CSIRO, Australia) pointed out how human- or fire-induced changes in ecosystems have had major, and sometimes non-intuitive, effects on the water yield from drainage basins. Vit Klemes (Environment Canada-retired) took up the difficult notion of certainty and uncertainty in water and climate change issues. He argued that uncertainties in large climate and hydrological simulation models means that they will not offer reliable predictions in a useful timeframe; sometimes too much energy was put into modelling potential climate change impacts that could be assessed more informally and dealt with along with other uncertainties routinely considered in water resources planning.

The idea that much of the problem of dealing with global change, and maintaining healthy ecosystems and their hydrological sub-systems, is in the social rather that physical science realm was offered by Jody Emel (Clark University). She sketched out the long history of social conflict over water and the enduring effects of development on water quality in New England and elsewhere. She especially pointed to weaknesses in social institutions faced with new problems, such as when surface water management traditions are applied to groundwater. Emel also argued that it is more socially useful to solve current water problems than to expend effort trying to anticipate global change.

The highlight of this workshop, for many participants, was discussion of case studies of the potential impact of global climate change and human actions on water resources in different parts of the world. Luis Martinelli (University of Sao Paulo) discussed the history of failed (or marginal) economic activities in the Amazon rainforest (cattle raising, farming, gold dredging) and noted that our poor understanding of the region's complex biogeochemical processes makes impacts prediction difficult; he stressed the need for scientists and planners to work with the local population in a hitherto unprecedented arrangement. Ken Strzepek (University of Colorado) elaborated the complexities of the present and future water resources of the Nile River basin, with

its large latitudinal and climatic extent, the extensive wetlands of the Sudd, and the political and cultural constraints on water development. Chris Magadza (University Lake Kariba Research Station) brought up the problem of tensions between traditional and modern land uses in Zimbabwe, and how these play out in terms of environment and society relationships, access to resources, and resource degradation. Using the current drought as an example, Magadza showed how stresses brought on by development (e.g., ecosystem fragmentation) or climate change (e.g., reduced water availability) can be magnified through biological systems to bring about disruptions and extinctions. Stewart Cohen (Canadian Climate Center) reported on an integrated assessment of the effects of climate change on the Mackenzie River Basin; he stressed the importance of climate model results to "demystify" the potential changes for the regional stakeholders.

Le Huu Ti (Mekong Secretariat, Bangkok) stressed the difficulty of managing water, especially in a changing climate, given political and institutional constraints and conflicts such as those found in Southeast Asia. In this way he struck a theme common to all of the basin case studies: hydrological and ecological systems often straddle political and social boundaries in ways that make integrated management nearly impossible. James Wescoat (University of Colorado) further supported this idea with lessons from the complex irrigation system of the Indus Basin. He showed, for example, how upper and lower basin conflict reduced water management efficiency. He concluded that physical and engineering uncertainties often pale by comparison to the political, historical, religious, and cultural forces affecting river basin development.

Finally, the Institute turned its attention to the local scene, exploring water development, law, and conflict in the Roaring Fork Valley with guests Joe Bergquist and Alan Martellano (Colorado Department of Natural Resources). The complex, and sometimes counter-productive, structure of water allocation in the western U.S. was made more concrete by visits to ranches, farms, and sub-urban developments that were competing for water. Local uses and impacts were

then placed in the broader context of the heavily managed Colorado River system, bringing home another common issue in discussions on both physical and social science modelling: the need to pay more attention to time and space scales in analysis of water/land/people interactions.

Two weeks of discussions on interactions of land, water, ecosystems and people led to a set of general conclusions:

1. Climate change is not smooth at any time scale; decadal to century variability may as large as interannual variability. Abrupt climatic jumps should be anticipated, but cannot be readily predicted. Thus, adaptive management and education are important to cope with climate variability.

2. Regional and mesoscale models of climate change need to be coupled to GCMs, with the GCM output serving as boundary conditions for the higher-resolution models. Data collection must be guided by model needs, and data collection and analysis programs need to be united with local programs in the source countries.

3. Global change has multiple causes. Land-use changes may be as important as the greenhouse effect in changing meso-scale climates; the history of regional land use must be known in order to understand critical land-biota-atmosphere feedbacks. Global change involving land/water/vegetation interactions also may be related to causes or effects not involved with climate, such as water scarcity due to human use or the discharge of waste into large water systems.

4. Ecosystems must be carefully defined in time and space in order to access and predict effects of physical, biological, and socio-economic changes. The values of species vs ecosystems approaches to system definition and management need to re-considered in light of the growing pressure to define and achieve ecosystem sustainability.

5. Fundamental differences exist in eco-hydrologic processes in different regions, especially in regard to the effects of climate change on water quality, land use, land degradation, water demand, and biomass production. The problem of regionalization, how to generalize in a credible way within and across boundaries, remains a critical area for conceptual development.

6. Related to regional issues is the problem of scaling, including especially how to avoid the pitfalls of simple averaging of point data in non-linear systems. The use of distribution functions or representative areas may be useful; simple ways need to be found to parameterize the complexity of natural processes as input for mesoscale models and for GCM's.

7. The causes and rates of land-use changes and their effects on water and atmospheric quality, and on climate, needs to be further investigated. What social forces bring about land changes and how do they affect aquatic biology, groundwater, soil moisture, and the flux of greenhouse gases? The rates of climate change due to changes in regional land use may greatly exceed the rates of climate change due to other anthropogenic effects such as greenhouse gas production.

8. The release of nutrients and wastes by humans affects water quality, but the effect of these releases on land and air quality, and on greenhouse gas emissions is not well understood, especially on a global basis. Perhaps some of these inadvertent releases can act as tracers to improve our knowledge of how the hydrologic system operates.

9. The inseparable nature of ecological and social issues embedded in various economic, cultural, social, and religious settings must be recognized in any response to global change. The experience of complex river basin development indicates that integrated solutions are needed. In particular, questions of conflict, cultural differences, and who benefits and who

pays, must be addressed. Means must to be found to manage global change in a meaningful way especially in a relatively short-term (10-30 year) perspective, with special regard to protecting water and land quality, and coping with water scarcity.

10. Every plan to cope with global change must be considered in the context of continuing population and consumption growth. The growth and redistribution of population and consumption must be considered in efforts to protect the integrity and function of interacting natural and social systems. And this must begin now!

This two-week session at the Aspen Institute on Global Change demonstrated the value of bringing natural scientists, modelers, social scientists, engineers, and managers together to establish closer communication and understanding. The complexity of water-biosphere interactions is not fully incorporated in models of climate change, nor is it adequately considered in analyses of the human dimension of global change as in predictions of sustainability and food production. And it is apparent that a better understanding of the hydrologic cycle and its interplay with the biosphere and human action needs to be a stronger component of school curricula, especially at the primary and secondary levels.

*Submitted by Mark F. Meier, Malin Falkenmark, and William E. Riebsame, co-chairs.*