



Global Water: The Emerging Crisis of the 21st Century

The distribution and availability of water are defining features of life. As populations increase and global temperatures rise due to human-induced climate change, we will see more frequent droughts and floods and an increasing scarcity of fresh water. These changes will have tremendous implications for human health, global food security, and the peace and well-being of society in general.

Our sense of urgency has never been greater. At the Earth Institute, we are studying the world's significant weather patterns and their effects on the world's population. From the cities and villages of Africa to the river basins of the United States and Asia, we are working to better understand the global water crisis and find effective strategies to minimize human hardship.

SHIFTING PATTERNS OF WATER AVAILABILITY



Photo: Tobias Slegfried

Earth Institute researchers are working to obtain a better understanding of the way human-induced climate change is shifting patterns of drought and water availability and the effects these shifts will have on human health and vulnerable populations.

Mapping the Asian Monsoon

The Asian monsoon system plays a significant role in large-scale climate variability over much of the globe and has a direct connection to the amount of water available for drinking and agriculture in India and many other parts of Asia. Scientists at the Tree-Ring Lab at the Lamont-Doherty Earth Observatory have entered the last year of a five-year effort to reconstruct the past behavior of the monsoon through the use of tree-ring analysis.

In areas where there are distinct seasons, like the monsoon-affected regions of Asia, the severity and cadence of these seasons is recorded in the width and other characteristics of tree rings. "Tree-ring records provide absolutely dated, quantitative estimates of past climate on a year-by-year timescale," says Ed Cook, director of the Tree-Ring Lab.

Understanding how the monsoon has behaved over the last many hundred years will help scientists address the urgent need to predict its future behavior—and impacts felt by almost half of the world's population—on annual, decadal and longer timescales.



Photo: Nicole Drai

Left: By reading the characteristics of tree-ring cores in Asia, scientists can reconstruct the history of the region's monsoons and better understand a climate system that affects nearly half the world's population.

Threats to the World's Drylands

Research into the history of drought in the southwestern United States has led Lamont-Doherty scientists to the conclusion that, just as humans are able to drive large-scale climate change through the production of greenhouse gases, they may also be able to increase the severity and occurrence of natural events such as drought.

Using computer models to simulate the 1930s Dust Bowl on the Great Plains of the United States, climate modelers Richard Seager and Benjamin Cook have found that dust raised by intensive agriculture amplified a natural decline in rainfall, turning an ordinary drying cycle into an agricultural collapse.

Hard-pressed farmers and herders in places like China and Africa's Sahel region may be repeating the experience, degrading marginal lands in order to feed themselves in the short term. "If subtropical regions become drier in the coming years as a result of climate change, this, in combination with the pressure from rising population and demand for food, could lead to a similar cycle of drought, dust storms and more drought. The lesson of the Dust Bowl is there to be learned," says Seager.

Water, Climate and Human Health

Among the world's most vulnerable populations, fluctuating cycles of water abundance and scarcity can have direct impacts on human health. Heavy rains and flooding can lead to the spread of illnesses such as diarrhea and malaria. Droughts can result in health issues due in part to the lack of clean water.

Research at the International Research Institute for Climate and Society (IRI) is leading to a greater understanding of the connection between climate and infectious diseases like malaria and meningitis. In the summer of 2008, IRI teamed up with the Center for International Earth Science Information Network (CIESIN) and the Mailman School of Public Health at Columbia University to hold an intensive two-week workshop on "Climate Information for Public Health" that was attended by 13 professionals from nine countries.

The Millennium Cities Initiative is carrying out water and sanitation needs assessments in seven cities in Africa, with generous support from a \$1.9 million challenge grant from the Tides Foundation. The research, conducted primarily by Columbia graduate students, will help municipal, regional and national governments, development partners, and urban stakeholders work toward the Millennium Development Goals—eight globally endorsed targets that seek to help the world's poor.

Right: Professionals from nine countries attended a summer workshop on using climate information for public health.

Facilitating Action, Convening the World's Great Minds

Every year, the Earth Institute holds hundreds of seminars, conferences and events at Columbia University and around the world to facilitate dialogue between the world's most influential and innovative thinkers and practitioners in academic, nonprofit, corporate and government spheres.

From the biannual State of the Planet conference to the select events listed below, the Earth Institute hosts and co-hosts events that lead to the tackling of many of the world's problems.

The Growing Climate Crisis in the Drylands

November 2007, Dubai

To address the dramatic effects climate change will have on the world's drylands—specifically the Sahel, the Middle East and Central Asia—and the lack of a sufficient global response, HRH Princess Haya of Dubai and the Earth Institute co-hosted this conference under the auspices of the Global Humanitarian Forum.

Climate Knowledge for Global Health

March 2008, New York City

Co-organized by two Earth Institute centers, the Center for Global Health and Economic Development (CGHED) and the International Research Institute for Climate and Society (IRI), this conference convened more than 70 high-level experts from public health agencies, private institutions and corporations to brainstorm about ways to overcome the challenges that climate change poses to global health.



Photo: Daniel Yeow

DROUGHT, FLOODS AND AGRICULTURE



Although the long-term effects of increasing temperatures and extremes of floods and drought on agriculture may be widespread, the developing world will be particularly vulnerable. Researchers at the Earth Institute are finding ways to help people escape from the trap of poverty and prepare themselves for the uncertainties of weather that will result from climate change.

Protecting Small Farmers in Africa

In rain-fed regions where groundwater stores are not sufficient or accessible, drought can have devastating effects on crop production and other agricultural activities. Even in good years, the fear of drought can keep productivity low because farmers are conditioned to be wary of investing too much money in improved seeds, fertilizers or equipment.

The International Research Institute for Climate and Society (IRI) is working with partners in Africa to help protect farmers in the Millennium Villages and in Malawi against periodic, crop-destroying droughts through an innovative application of agricultural insurance. Traditional insurance arrangements pay farmers for lost crops. Index insurance compensates farmers when rainfall drops below a set of predetermined trigger points.

In June 2008, IRI and Swiss Re jointly hosted a high-level roundtable on the use of index insurance for poverty reduction at the annual meeting of the Global Humanitarian Forum in Geneva.

Improving Crop Yields in Poor Areas

Through the **Millennium Villages** project in Africa, researchers from the Earth Institute are considering the threat of climate change as part of a larger effort to help villagers lift themselves out of economic distress.

When it comes to agriculture, “one of the best ways to adapt to climate change is to have a situation in which crop yields are higher,” says Pedro Sanchez, head of the Millennium Villages project. Work in the Villages has shown that crop yields could be three times as high as standard predictions for the region. “So if droughts happen,” says Sanchez, and damage local crops, “they could reduce the amount of corn, but production would not drop as low if it was already higher” to begin with.

► The Bill & Melinda Gates Foundation has supported the Earth Institute’s scientific work in agriculture, nutrition, energy, water, health, environment and information technology in order to inform policy and practice for achieving the Millennium Development Goals.

Left: We are finding ways to help people lift themselves out of poverty and adapt to the effects of a changing climate through initiatives like the Millennium Villages project and others.

Photo: Pedro C. Sanchez

Building Future Thought Leaders

The **Earth Institute Fellows Program** gives highly qualified postdoctoral scholars the opportunity to research critical issues of sustainable development facing the world today, such as the effects of climate change on agriculture and the growing scarcity of fresh water. The program is an important component of the Earth Institute’s strategy to enrich the overall quality and depth of scholarship in the field of sustainable development.

Tobias Siegfried

Earth Institute fellow Tobias Siegfried has focused the last 10 years of his doctoral and postdoctoral research on the management of scarce water resources in the face of changing climate conditions and increasing population pressures.

“Focusing on water scarcity narrows down my work geographically to places where there’s not enough rainfall to sustain livelihoods—drylands in Africa, parts of India, the Middle East and Central Asia,” says Siegfried. “These are places where increasing demand, often for irrigated agriculture, makes it important to carefully manage what water there is to not deplete or degrade the resources.”

In India, for example, Siegfried is looking at situations where small farmers rely on groundwater as a backup for breaks in the monsoon rains, but can run into trouble when groundwater is depleted locally due to ongoing water mining.

With a Ph.D. in environmental science and master’s degrees in environmental physics and international relations, Siegfried is well-equipped for the interdisciplinary approach of the Earth Institute. “There are many people out there pursuing a narrow focus when it comes to allocating water to meet demand,” he says.

“We look at the big picture and draw on concepts from systems management, economics, game theory and political science to come up with tools to study allocation outcomes in imperfect political and economic environments.”

During his time at the Earth Institute, Siegfried has worked with researchers at the new Columbia Water Center, the International Research Institute for Climate and Society, and the School of International and Public Affairs, where he is an adjunct assistant professor.

“There are many people out there pursuing a narrow focus when it comes to allocating water to meet demand. We look at the big picture.”



Photo: Bruce Gilbert



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Above: Tobias Siegfried and Brenda Lin were two of 16 postdoctoral researchers in the Earth Institute Fellows Program in the 2007-2008 academic year.

Brenda Lin

An ecologist by training, Brenda Lin came to the Earth Institute Fellows Program with a Ph.D. in resource ecology and management from the University of Michigan. Lin was drawn to the Earth Institute’s multidisciplinary approach and the emphasis its researchers place on using science to address complex problems of climate change and sustainable development.

“I didn’t want my work to just be in a paper that would contribute to theory,” says Lin. “I wanted my work to be applicable to sustainable development and to contribute to real-world projects.”

During her time at the Earth Institute, Lin has worked on several interdisciplinary projects addressing the vulnerability of agriculture due to climate change. With Walter Baethgen at the International Research Institute for Climate and Society, she modeled cropping systems in water-stressed regions of Brazil to find ways farmers could improve their production. Now she is studying how farmers can protect their crops from extreme climate events like hurricanes.

Reflecting on her time as an Earth Institute fellow, Lin says, “I’ve learned so much here—I’ve learned how people across disciplines think and how to work with them, how different institutions work, and gained a better understanding of how to make my work more applicable.

“But perhaps the biggest thing that I’ve gained from this program is colleagues for life. In a sector where cohesion can be difficult, the Earth Institute Fellows Program is building collaborations across disciplines and institutions for the next generation of sustainable development professionals.”

MANAGING A LIMITED RESOURCE



Identifying strategies to manage water resources in real-world settings and improve access to water is a crucial part of our response to an emerging global crisis. Many parts of the world are facing increasingly limited stores of fresh water due to shifting rainfall patterns, increasing population pressures and the degradation of existing water resources.

Water Politics

Where there is water scarcity, there is tension. In the western United States, a region currently facing its seventh consecutive year of severe drought, populations continue to grow, leaving watersheds under increasing strain. Tanya Heikkila, associate director of the **Columbia Water Center**, and several Columbia graduate students have spent countless hours over the last three years working on a database of western water conflicts in conjunction with their counterparts at the University of Arizona.

“Water is fundamental to life. We have to share it and provide universal access,” says Heikkila. She hopes to build a better understanding of how institutions can address inevitable conflicts over water, particularly in transboundary settings, and adapt to changes in water availability and competing water needs.

In the Middle East, water has long been a source of conflict. Although the last few years have not been as dry as the ones preceding them and times have been comparatively peaceful in the region, the work of doctoral student Rana Samuels suggests this could change. Her climate models show rainfall could drop to zero in some areas by the middle of this century. The Abraham’s Well project, initiated through the Columbia Water Center and the **Center for the Study of Science and Religion**, is building a forum for Palestinian and Israeli academics and water scientists to discuss water issues in a nonpartisan environment.



Improving Water Sustainability

A landmark project to address global water scarcity through local action in India, China, Brazil and Mali is underway at the Columbia Water Center. By using private and public strategies, the Water Center hopes to improve rural livelihoods and sustained access to water by promoting the efficient use of water in agriculture and helping communities deal with uncertainties such as climate change and market shifts.

In the Ceará region of northeastern Brazil, where drought is a recurring phenomenon, the focus of the project has been on using sophisticated climate-based forecasting systems to determine rainfall patterns. Like many parts of the world that feel the effects of El Niño/La Niña events, there is a direct correlation between ocean surface temperatures off the coast of northeastern Brazil, the amount of rain that falls on land, and the amount of water flowing in streams and rivers in a three- to six-month period.

Experts at the Columbia Water Center and the International Research Institute for Climate and Society (IRI) are exploring ways these streamflow predictions can be used to manage reservoirs and water use at a watershed scale to mitigate the devastating effects of drought.

Providing Access to Water

Periodic water stress threatens the health and stability of communities around the world. Through the Millennium Villages project in Africa, Earth Institute engineers are bringing improved water and sanitation infrastructure to impoverished populations living in arid regions, where access to water is unreliable and often requires a long, daily trek.

In Potou, Senegal, an existing water pipeline system was not adequately serving the community’s needs. Vijay Modi, a professor of mechanical engineering who works with the Columbia Water Center, has led the effort to significantly improve the distribution of water in the area.

With the generous help of JM Eagle, which donated and delivered 110 kilometers of PVC piping to Senegal, the work of the Earth Institute team will result in nearly 95 percent of Potou being covered by a piped water system, more than double the previous extent.

In Koraro, Ethiopia, sporadic rainfall and sparsely populated communities are just two of many serious challenges to finding safe and reliable sources of water for residents. Earth Institute experts are helping villagers devise sustainable, long-lasting solutions by “retraining” the landscape and recharging aquifers so that when it does rain, water can be more effectively gathered and stored.

Left: Access to fresh water for drinking and agriculture is an increasing challenge in many parts of the world and we are finding solutions.



“Water is fundamental to life. We have to share it and provide universal access.”
— Tanya Heikkila

Water Security in Asia

Water security is a dominant concern in Asia, especially in densely populated arid regions subject to highly variable rainfall. Continuing population growth and the prospect of an uncertain future climate are exacerbating this problem.

Through the support and guidance of the Asian Development Bank, Earth Institute researchers are finding that challenges such as drying rivers and groundwater depletion and the emerging food crisis can be addressed through strategic investments in initiatives to manage the risks associated with extremes in drought and rain.

The early stages of this research have begun in India, where overtaxed water resources have diminished buffering capacity for times of drought or low rainfall and where agricultural productivity is frequently connected to the quality of rains in a particular monsoon season. Researchers have collected data to assemble baseline scenarios of local economies, groundwater and surface water resources, and rainfall patterns.

The new Columbia Water Center is working to improve our understanding of the global water crisis and create innovative solutions to the water problems affecting many parts of the world. Read more in the Water Center profile on page 26.