Ecohydrology and climate change science: A challenge and opportunity in understanding the Nile Basin System

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Abstract

The Nile River system is regarded as one of the most important ecohydrological systems of the world. Although the freshwater carried by Nile accounts a very small fraction of the volume of water compared to Amazon (2%), Mississippi (15%) and Mekong (20%) Rivers, its diverse ecological richness, history, mosaiced landscape and land-cover makes it unique and a valuable resource to the basin countries. The basin is the home of over 160 million people in 10 countries providing basic livelihoods for the agriculture, fishing, tourism, recreation, power generation and domestic water supply. Despite the rich resources, the basin is also characterized by limited knowledge on the ecohydrology of the basin. Studies have shown that, the river system has shown a fluctuation of seasonal and annual flows and in some watersheds a decline in dry season flows across the basin. This is mainly driven by impacts of the erratic and unpredicted changes in climate variables, undesirable changes in land-use on hydrologically and hydraulically sensitive segments of the river system. Ecological stress on the natural resources such as vegetation, soil and water is significant from the ever increasing demand for tillable land by the increasing population and also from lack of watershed management. Given the trend in demand for resources (water, land and soil), extreme climatic events and climate change will make sustenance challenging. Some predict the worst is yet to come, unless we take active measures and adapt to the changes.

Taking active measures to understand the ecohydrological system of the Nile Basin and the impacts of natural climate variations and climate change land-water system of the Nile will require a sustained study. The land-use and climate changes are the major drivers that lead to the decline and variability of river flows. Although these changes alter the hydrology in many ways, they are also interrelated and influence one anther in a fashion poorly understood. Partitioning the changes in water fluxes attributed to changes in land-use and climate shift is not yet fully explored.

The interactions of the hydrology, ecology and the dynamic climate are one important aspect of the bigger picture worth researching. Eco-hydro-climatology is an approach to understand the interaction of the three fields of science for better mapping of fluxes, response of vegetation to fluxes, impacts of climatic variables on the hydrology and vegetation patterning and vice versa. This approach will be unique in that it addresses the underlying problems surrounding the interaction and causation. This effort will require systematically gathered scientific data on the landscape cover, biotic resources and also well monitored hydrometrological data of the basin.

Despite its contribution to the Nile flow system, the Blue Nile River basin suffers from little or incomplete data covering the hydrologic and hydraulic aspects of the river and streams. Studies are either limited to large scale flow analysis or incomplete. Scattered information on hydrology of tributaries and other water bodies, which are equally important for flow sustenance, is also limited. The resilience of the systems to shocks of land use alterations, precipitation variability in timing and volume, changes in air temperature, sediment fluxes to Lake Tana are not understood. Programs that promote sustainable water and land use practices are not perceivable. Watershed management and water use policies that encourage community participation, promote environmental education, empower regional offices to monitor, protect and manage water resources and support scientific studies are vital. On the science front, understanding of the upper portion of the basin is an effort long overdue.

Another challenge is the scale mismatch among the ecology, hydrology and climate science. The close interaction and relationship of the three fields in shaping the hydrological and ecological landscapes of the basin will necessitate exploring the possible interactions and correlation at different spatial and temporal scales. Understanding the water flux of the basin at a river basin scale will require upscaling field/ecological scale processes and downscaling climatic process which are at regional scale or higher. Aggregation and disaggregation of parameters on the other hand suffer from uncertainty and can also result in error propagation.

The opportunities in the eco-hydro-climatological approach are the ability of remote sensing tools in providing various information at different spatial and temporal scales. Although the role of current remote sensing techniques decrease as we go from regional to field or from climatological to ecological scales, various techniques of down and upscaling techniques have proven to provide reliable information. In the Nile basin this approach will suffer from the absence of field scale experiments and research undertakings that help understand the fundamental processes which govern the movement of water and nutrients in the atmosphere-soil-water interface.

Scientific and Technological Interventions to Alleviate Transboundary Water Concerns in the Nile River Basin

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Protracted environmental and climatic stresses exacerbated by persistent cycles of severe droughts, flooding, excessive deforestation, erosion, unproductive agricultural practices, desertification, population growth, etc., have been greatly impacting the Nile River basin. However, potentially serious water supply concerns in transboundary drainage basins are not unique to the Nile River Basin. In fact, there are approximately 261 international drainage systems and a larger number of transboundary aquifers, covering about half of the global land surface that is home to 40% of the world population (Wolf, 1999). Nevertheless, the Nile River Basin transboundary water resources issues demand immediate attention given the persistent drought history of the region. The rain-fed Nile River waters mostly come from the Ethiopian Highlands with additional input from the Lakes Region of east-central equatorial Africa. The Nile River crosses several unique hydroclimatic zones that range from equatorial rainforests to hot and dry desert environments before it trickles into the Mediterranean Sea.

Ongoing efforts since the last decade have created conducive opportunities for dialogue and cooperation among the Nile River Basin riparian nations to collectively prepare policy guidelines for strategic action plan on the sustainability of the finite water resources and environmental conditions of the basin (Nile-COM, 1999). The Nile Basin Initiative (NBI) strategic action program covers general principles, rights and obligations, institutional structure, subsidiary institutions, and other provisions. Scientific and technological investigations outlined in the cooperative framework are crucial because without such interventions, the major factors that have drastically impacted the quality and quantity of the Nile River will not be properly addressed.

Lack of current and accurate integrated and transparent local and regional climatic, hydrological, hydrometeorological, and hydrological data and models in most of the basin countries has greatly contributed to the transboundary water resources concerns. However, systematic and timely scientific investigations could facilitate historical data processing and new data acquisition and integration for climatic, basin hydrology, rainfall, stream flow and flooding, reservoir operations, irrigation, erosion, sedimentation, etc., evaluations and modeling. Such information could be ultimately fed to decision support systems to develop multiple solutions to address ongoing concerns related to the Nile River water problems and the unpredictable climatic conditions. Most Nile Basin countries lack the resources and expertise to tackle the major factors that threaten the region on their own. There is a need for genuine material support and expert participations from the developed countries in order to apply scientific and technological advances for evaluating and reversing the ongoing hydrological, environmental, and ecological problems in the basin. For example, the following fundamental items could be addressed through such collaborative efforts.

1. Develop regional climatic models to determine major source of moisture flux for rains that feed the major tributaries of the Nile River.
2. Adopt new technologies (remote sensing and Geographic Information Systems) for water resources applications, climatic monitoring, and drainage management
3. Encourage and establish regional climatic and meteorological data collection, repository, processing, and sharing opportunities.
4. Establish modern short- and long-term basin-wide hydrometeorological forecasting capabilities.
5. Develop modeling capabilities for critical infrastructure, environmental/ecological conditions, and the social basis for instabilities as part of the Nile River Basin Initiative.

Such collaborative scientific engagements among scientists from the Nile basin countries and their peers from the developed countries could lead to long-term productive interactions to address pressing issues of the day such as those listed below.

1. Develop and test complex decision support systems that deal with the assessment of potential transboundary water conflicts and social unrests as climatic conditions fluctuate, water supplies tighten, food security threatened, and environmental and ecosystems degrade.
2. Transboundary freshwater disputes are critical global issues; the Nile River basin template could be applied to international watersheds and countless aquifers covering about half of the land surface of the globe that is inhabited by 40% of world population.
3. Because of its unique geographic location, the Nile River basin provides an important test bed for new science and technological applications in the areas of remote sensing, GIS applications, ground truthing, and complex and multidisciplinary regional modeling for drainage basins, climate, and ecology.

In conclusion, genuine and balanced long-term engagements of the U.S. and its allies with the Nile Basin riparian countries could greatly contribute to lasting and effective regional sociopolitical and economic stabilities and growth.

References

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Water resources of the Nile Basin - extreme events, climate change, and regional security

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EXTENDED ABSTRACT:

Many river basins world-wide are experiencing increasing pressures on water resources, due in most part to ambitious economic goals, population growth and climate change. To assist in measuring societal stress caused (in part) by water, indicators such as "carrying capacity" have been introduced; sustainability has been used in a generic sense; and diversification of the economic base has been pursued. When the carrying capacity is exceeded by some degree, one of the possible societal responses is to migrate; and in some cases migrations are less than welcome. The Nile Basin is a classic example of a Basin undergoing increasing societal stress, due to increased pressure on water supplies.

The Nile River basin drains about 3.3 million km^2 of terrain that includes 81,500 km^2 lakes and 70,000 km^2 swamps in the 10 riparian nations of Burundi, DR Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, and Uganda. The mean annual rainfall is estimated at 2,000 billion m^3, resulting in an annual flow of about 84 billion m^3 at Aswan Dam in southern Egypt. Very little Nile River water ever reaches the Mediterranean Sea; and there is tremendous interannual variability in rainfall amounts. In each of the riparian states, there are ambitious economic growth targets, populations are rapidly growing, and agricultural production is accelerating to feed the increasing populations. The Nile Basin, like many other river basins, is being strained economically and politically, due to increasing pressure on resources that do not adequately support the growing population.

A unique and complicated feature of the Nile Basin is that water is managed by decades-old treaties, and each of the dominant countries has uniquely different economic and political goals. For example, Egypt's livelihood relies upon water flowing down the Nile; Sudan relies on Nile River water both for its agricultural and energy production needs; and Ethiopia has a rapidly growing population in need of agricultural production and economic growth. The NBI has explored basin-wide initiatives to create common goals and agendas, so that each of the nations can coordinate and manage water, particularly during lean precipitation years.

A unique feature of the Nile Basin during recent decades is the prevalence of extended droughts, interrupted by occasional floods. Management of water during extreme events has become challenging, insofar that today's reserves often don't support even the average year. However, little is known of the overall water budget of the Basin, thus the reason for this workshop. Our goal is to build a better understanding of Nile Basin water budgets and sectoral needs: overall input of rain water to the basin, subsurface water and recharge rates within the basin, utilization by society (agriculture, urban, energy, etc), new technologies to consider to advance efficiency, and emerging challenges.

There are a number of scientific challenges to pursue:

- identify the water budget components of the Nile Basin for both average precipitation years and during extreme drought years, where one combines rainfall potential, surface water reserves, aquifer reserves and recharge rates, etc.;
- Determine where the water losses are in the urban and rural collection, storage, and delivery systems, in order to assess which technologies are needed to improve efficiencies;
- Identify the agricultural needs for water and how water is managed during extreme events (droughts and flood); and
- Document the more confident predictions of climate change and how such changes will alter future precipitation and evapotranspiration patterns of the Nile Basin, including the looming issue of how climate change will affect the frequency of occurrence and severity of droughts and flood.

Each of these challenges requires that one taps into a world-wide brain trust, since the challenges are beyond the capacity of any one university, agency, nation, or continent. All river basins share these challenges, where lessons learned from one river basin experience can be considered when addressing another river basin.

Securing Water for the Environment in the Mara River of Lake Victoria Catchment, Kenya and Tanzania

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Abstract

The Mara River basin encompasses some of the world's most unique ecosystems and human communities, tightly linked by their dependence on water from the Mara River. From its headwaters in Kenya, the Mara River flows through a mosaic of forests, tea fields, and croplands before entering Maasai pastoral lands. In this semi-arid landscape, human demands for water – especially for livestock and agriculture – run high and surface flows of the Mara River system are essential to meeting demands.

Downstream of these burgeoning human communities lay two of the world's most important wildlife refuges, the Masai Mara National Reserve and the Serengeti National Park. Together these protected areas host nature's largest annual migration of land animals, when more than two million wildebeest, zebra, gazelle, and other animals migrate to the Mara River each dry season. The Mara River is the only perennial source of water for these animals. Both they and the river's aquatic organisms are dependent on the quantity and quality of its flows.

Water demands further downstream continue to be high where the river feeds into the Mosirori wetlands and Lake Victoria. The lake and its adjoining wetlands have long been recognized among the world's most bio-diverse freshwater systems. Hundreds of fish species inhabit the lake and wetlands at the mouth of the Mara River, and fisheries provide a primary source of income for the thousands of people living along the wetlands and Lake Victoria coast.

Meeting human water needs while minimizing adverse effects on ecosystems and wildlife is a fundamental tenet of Integrated Water Resources Management (IWRM), and the specification of environmental flow allocations (EFAs) is a widely recognized mechanism to ensure minimal ecosystem water needs are met. Protection of EFAs is mandated in the Kenyan Water Act of 2002 and the Tanzanian National Water Policy of 2002, and more detailed rules and strategies for implementation have since been drafted in each country. Responsibility for determining and enforcing EFAs is assigned to the Kenyan and Tanzanian ministries of water.

With these political and institutional enabling conditions in place, the Global Water for Sustainability (GLOWS) Program, with financial assistance from USAID East Africa, is supporting the efforts of the Ministry of Water and Irrigation (Kenya) and the Ministry of Water

(Tanzania) to implement the new rules and strategies for water resources management, including the specification of EFAs for the Mara River.

GLOWS is facilitating and coordinating a full-scale environmental flow assessment in the Mara River Basin in close collaboration with the local water offices. Presently there are more than 200 methodologies used worldwide for estimating environmental flow needs. The GLOWS Project has elected to apply the Building Block Methodology (BBM), which was developed in South Africa during the 1990s and has been widely utilized.

The BBM is carried out over a period of eight to twelve months by a team of experts representing the disciplines of hydraulic engineering, geomorphology, hydrology, aquatic ecology, riparian ecology, water quality, and social science. The assessment was launched with a five-day training course in May, 2006. Three sites were selected for detailed studies and filed visits were made during March and July of 2007. The experts reconvened in October of 2007 to discuss the findings of each specialist and to reach consensus among the experts on the required environmental flows. A coordinator oversaw the entire assessment and facilitated the individual actions of the experts. Representatives from the water offices and other local authorities are also participated in the effort.

The assessment is emphasized the environmental flow needs of the Masai Mara National Reserve and the Serengeti National Park during the dry season. This includes meeting the drinking water needs of the millions of migrating ungulates and other animals as well as providing for the critical aquatic habitat needs of hippos, crocodiles, fish, and for riparian vegetation. These efforts were made more urgent by the intense drought the Mara River basin experienced during late 2005 and early 2006, when the river fell to its lowest levels in many years. The impacts on humans, livestock, and wildlife were severe, and as a consequence local stakeholders and institutions are acutely aware of the importance of quantifying and protecting the highest priority flows for basic human needs and the environment.

It is not enough to make recommendations of flows for the environment. Environmental flow allocations must become binding and be enforced. GLOWS is continuing to support the water offices in both Kenya and Tanzania to implement the EFA recommendations.