Institutions, Environment and Water Use:
the River Njoro Watershed and Lake Nakuru

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Abstract

Institutional, environmental, and economic factors are affecting water quality and quantity within the River Njoro, a major tributary to Lake Nakuru. Between 1979 and 1999, the population within the Njoro watershed greatly increased, from 270,912 people to 413,698 spurring large-scale land use change and increased pressure on watershed resources. In 2003, the USAID funded, Sustainable Management of Rural Watersheds Project (SUMAWA) implemented participatory rural appraisals in the Njoro watershed to identify water use and other resource concerns within the area. Local residents identified two main concerns: 1) lower water quality and associated increases in water borne diseases and 2) reduced access to water and lack of improved water supplies related in par to reduced water quantity. Preliminary results suggest that the hydrologic response within the watershed has been altered to favor increased annual runoff with higher intensity and longer dry spells (Baldyga, 2005). Forest conversion to small-scale agriculture reduces canopy cover, thus exposing soils. If rainfall rates exceed infiltration rates, water once intercepted by the forest canopy contributes to flow flashiness and altered flow regimes. In turn, this may affect the recharge timing of Lake Nakuru.

Key Words: GIS, Integrated Assessment, Water Quality

Introduction

This paper presents a case study currently underway within the River Njoro watershed under the USAID Global Livestock CRSP, Sustainable Management of Rural Watersheds (SUMAWA) project. A conceptual framework linking institutional, environmental, and economic factors that affect both the quality and quantity of water resources, water supply, and aquatic habitat is introduced. This framework facilitates the examination of resource use impacts through future scenarios, building a method to identify policies that could improve resource use within the watershed. In addition, early results from the SUMAWA project are detailed, future research directions are identified, and initial ideas are presented on alternative ways to address water related problems within the River Njoro watershed.

Poor water quality and decreased water quantity can be a result of increasing demand and competing multiple water uses, lack of infrastructure, and lax enforcement of water laws among many other factors. Poor water quality or lack of adequate quantity can negatively affect human health (in particular child mortality), economic production, and severely impact the sustainability of ecosystems systems supported by water resources. In some cases, feedbacks between human activities, water use, and ecosystem health lead to degradation of water resources for human and other uses.

The inter-linkages among institutional constraints, land use, water quality, human health, and ecosystem function are complex and not well understood and currently in flux. The new provisions in the Government of Kenya water act add additional uncertainty. A greater understanding of inter-linkages and feedbacks between these systems can provide scientists and policymakers with more information about factors influencing water quality and quantity.

The River Njoro watershed is located Kenya's southwestern Rift Valley at 0°30' South, 35°, 20' East (Figure 1). The river itself is approximately 50 km in length with an estimated 270-km^2 contributing source area. Originating in the Eastern Mau Escarpment at approximately 3,000m, the River Njoro winds through forested and agricultural lands before serving several urban settlements and finally terminating at 1,759 m in Lake Nakuru, a shallow soda lake typical of the Rift Valley.

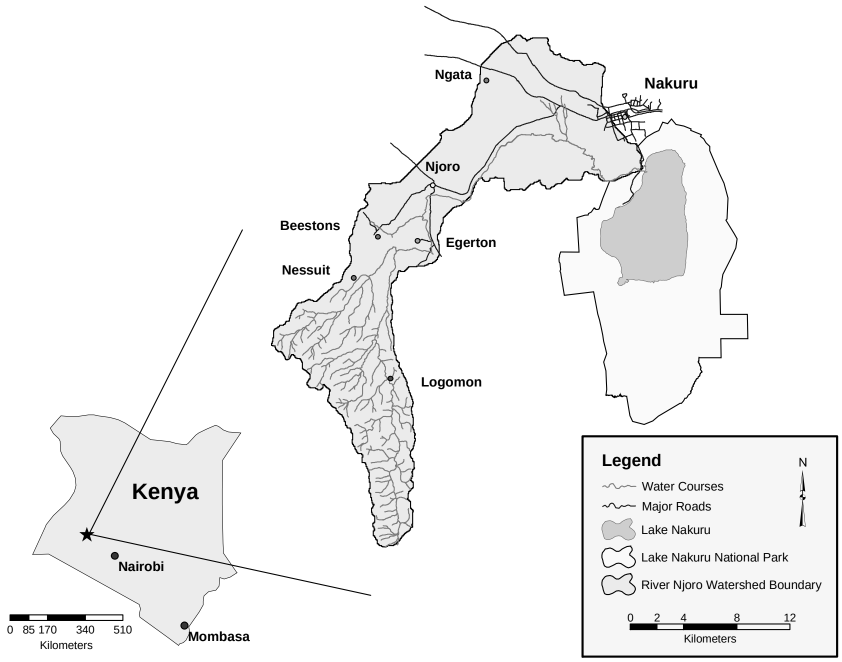

Figure 1: River Njoro watershed location.

The watershed contributing to the River Njoro serves as a living laboratory where the SUMAWA team can examine the interplay between institutional constraints (external drivers), such as ineffective land tenure and water rights policies and economic decisions and ecosystem productivity and function. Spatial patterns of human settlements and land use change may be causes of deteriorating River Njoro watershed health. However, little is known about the quantitative influence of specific human settlement patterns on the health of the ecosystems in the watershed.

Literature Review

Before delving into issues concerning water resources, it is crucial to define relevant concepts often used interchangeably despite their marked differences. In particular, 'water resources' and 'water supplies' must be distinguished. In the context of this paper, a water resource refers to naturally available water and the ecosystems supported by water. In contrast, water supplies refers to water that is managed or developed and available for human use. The World Health Organization (WHO, 2000) indicates that more than 50 percent of rural households and at least 25 percent of urban households do not have access to water in Kenya (WHO, 2000). Of the households having access to piped water supplies, 57 percent have only intermittent service and it is not uncommon to find leaking sewage systems running parallel to leaking water systems, thereby causing contamination (Njuguna-Githinji, 2004; WHO, 2000). While this analysis was conducted at the national scale, there are no publications for water policies and institutional governance at the regional and local level.

Njuguna-Githinji (2004) identifies several factors that are preventable but currently contribute to water shortages throughout Kenya, including water systems clogged by factory pollutants, water-pumping stations being disconnected due to non-payment of electric bills, infrequent repairs to damaged water systems, indiscriminant stream diversions, and vandalism by those in the water selling business. For those affected, there is little legal redress available. This begs the question as to whether Kenya's situation is one of water scarcity or inadequate infrastructure.

Water scarcity does not necessarily entail water absence, rather water supply absence for an intended use. Kenya has national drinking water quality standards in place based on WHO guidelines, but little enforcement of these standards. Kenya is predicted to be one of five countries that will run short of water by 2025 given current population growth (Hinrichsen et al., 1998). However, Njuguna-Githinji (2004), asserts that the reason for shortage is under-exploitation, estimating that 20.29 billion m^3 of water resources (surface water and ground water resources combined) are available to meet Kenya's 2.3 billion m^3 water resources demand in 2000. As such, Kenya is only using 28 percent of its total water potential.

Just as water scarcity does not equate to water absence, water presence does not equate to adequate water availability. Kenyan water law focuses on water itself and its use for reasonable and beneficial purposes, which by way of the water use permitting process are defined in economic terms. Kenyan water law essentially ignores water as an ecosystem dependent resource (Mumma, 2005), which by previous definition inhibits sustainability.

There are many examples in the literature of models used to examine a single dimension of a natural resource or economic problem. For example, the Automated Geospatial Assessment Tool (AGWA), which is a geographic information systems (GIS) based suite of two common hydrologic models the Soil and Water Assessment Tool (SWAT) and Kineros (Miller et al., 2002). This suite of tools examines the hydrologic response to land cover change. In addition, economists commonly construct models that examine only the economic dimension of problems.

More recently there has been explicit recognition that complex, integrated systems might be better studied using interlinked models from several disciplines (Antle et al., 2001). There are many examples of models that have tried to incorporate both economic and ecological dimensions of a system together, particularly in the areas of fisheries, forestry, and other renewable resources (*e.g.* Wilen, 1985; Milliman et al., 1992; Sylvia and Enriquez, 1994; Bach, 1999; Sohngen et al., 1999). Barbier (2000) reviews alternative approaches modeling economic and ecosystem inter-linkages using a production function approach whereby the environment is an input to production that contributes to the economic value of a marketed output.

Methods

The relative economic profitability of alternative land uses influences the decisions that landholders make regarding land use and land cover and thus can have profound impacts on ecosystem function. Figure 2 presents a conceptual framework illustrating how institutional, economic, and environmental factors can be linked together within a decision support system. Solid arrows represent process relationships, while dashed arrows represent feedbacks between process within ecological, health, and economic models as well as system states from one model that act as drivers within other models.

The SUMAWA project will develop an empirical integrated watershed model that links ecosystem, water management and development, and human health with the livelihood security of stakeholders. We anticipate that when appropriate scales and land use types are considered, landscape pattern metrics can be used to indicate habitat conditions for a variety of species. Using relationships established in the literature and process and empirical models, the effects of fragmentation on a range of ecosystem processes from nutrient transport to terrestrial and aquatic species will be inferred. Spatial pattern influences on hydrologic response and nutrient processes will be tested through land cover change scenarios. A model that allows the effects of both direct land use change through human actions and indirect effects through ecological change to be evaluated will be developed (Miller et al., 2001; Miller et al., 2002).

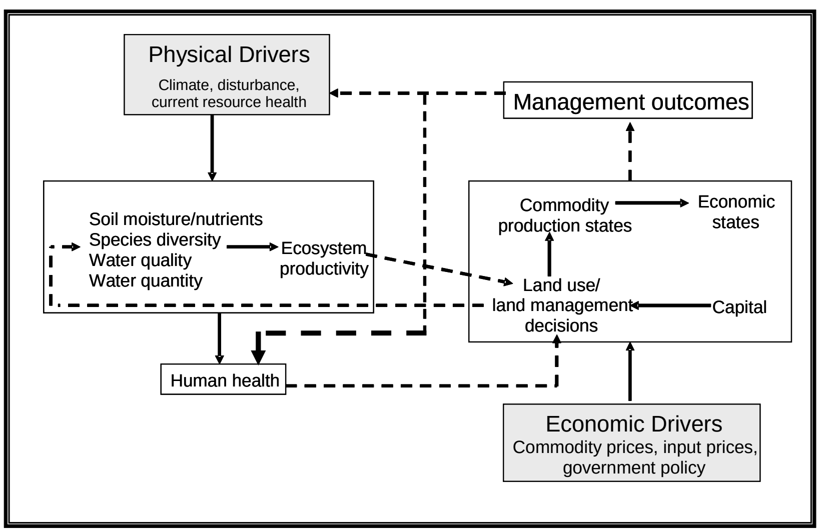

Figure 2: Watershed decision support system conceptual framework.

Results

SUMAWA is an ongoing project, but preliminary data have been collected through participatory rural appraisal (PRA) techniques at several stakeholder workshops within the watershed and initial modeling efforts. Preliminary results are presented in the sections below.

Participatory Rural Appraisals

Thus far, the PRA process has identified several broad water uses within the watershed: domestic, livestock watering, water collection for sales, irrigation, commercial and domestic laundry washing in the main river and its tributaries, and baptism by various Christian churches for their practitioners (Jenkins et al., 2005). Community members were given the opportunity to voice their concerns over water resources at PRA meetings held during 2003 and 2004. Two principal concerns were raised in this forum: 1) increased population has led to water quality deterioration and an increase in the incidence of water borne diseases (typhoid, other diarrheal diseases and malaria), and 2) many community members are left without access to sufficient water supplies because the river goes dry more often and they lack alternative water sources.

Deforestation and Land Cover Change

While deforestation estimates of the Mau Forest complex are varied, there is no dispute that deforestation has occurred in recent years and continues. Current research indicates that at least one-quarter of the forested areas within the Likia forest portion of the Mau, which is home to the River Njoro headwaters, have been converted to managed grasses (pasture) and small-scale agriculture (Table 1; Baldyga , 2005). This change has serious implications for water resources in the region because forested canopies no longer intercept rainfall. During rainfall events, exceeding infiltration rates water no longer intercepted by the forest canopy contributes to flow flashiness and altered flow regimes. It is apparent that deforestation has had a negative impact on the hydrologic processes in the watershed (Shivoga, 2001) but the relationships between land use and water quality in the area is not well known and are subject to further research by the SUMAWA team.

Table 1: Land cover type in hectares by year within the study area as estimated via remote sensing and land cover classification.

Land Cover Class	Land cover in ha		
	1986	**1995**	**2003**
Grass	4,415	3,341	4,750
Dense Veg.	7,935	7,010	5,949
Acacia	124	126	133
Plantation	2,128	2,934	1,664
Riparian	358	502	361
Urban	675	817	996
Degraded	2,187	2,282	1,661
Large-scale Ag	5,087	4,713	2,522
Small-scale Ag	4,324	5,503	9,141

Hydrologic Simulations of Runoff and Flow Regime

Baldyga (2005) modeled changes in hydrologic response using AGWA within the watershed over eight years using land cover maps from 1986, 1995, and 2003.

Results indicate that hydrologic response within the watershed has been altered to favor increased annual runoff, Figure 3. These results are based on model calibration to discharge data collected during the simulation period with model efficiencies approximately 0.90.

A geological survey (McCall, 1967) of the region described the area encompassing the watershed as volcanic and characterized by porous pumiceous formations. This survey further indicates that Lake Nakuru, which is the terminus for the Njoro, is not solely recharged by surface water runoff. Rather, the Lake is recharged through a combination of direct rainfall and groundwater accrued from stream losses through the highly porous landscape. As a result, water no longer intercepted by the forest is entering the porous material via cleared small-scale agriculture areas and recharge timing to the Lake may be altered. The effects, if any, of this change in timing are unknown presently. Modifications to the natural flow regime brought about by deforestation impact water resources availability and historical predictability, which is vitally important to an area dominated by small-scale subsistence agriculture.

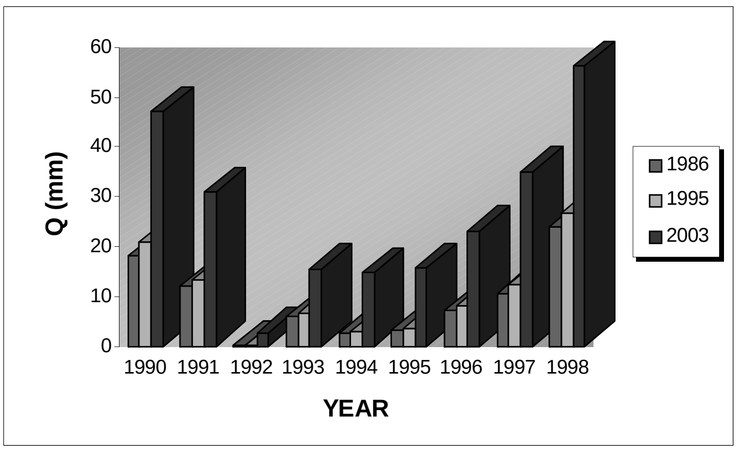

Figure 3: Direct surface runoff (Q, mm) simulated results for each of three land cover maps using standardized rainfall and climatic inputs. Results indicate the impacts of land cover alteration on watershed hydrologic response for each classified remote sensing scene (1986, 1995, 2003).

Discussion

While stakeholder responses at PRA meetings imply that the Njoro is now drying up when it has not done so historically, the 1967 Geological survey (McCall, 1967) indicates otherwise. A more likely scenario is that the river is drying up along reaches where it has not done so historically and for longer periods. Areas drying up now as compared to areas that flowed continuously in the past have yet to be determined, though indigenous knowledge indicates that the drying up is occurring further upstream and negatively affecting agricultural production and water security.

Without contest, water has no substitute and is a basic biological requirement. In a water-scarce region such as Kenya, what alternatives or remedies could be utilized for adequate water resources allocation? Water users are motivated by utility maximization, which can occur on many levels from domestic water use to agricultural usage to tourism. Ultimately, institutional arrangements at the national level are what must dictate the route to water sustainability in Kenya. Incentives and legislation that recognizes water as a resource whose quality and quantity are dependent upon healthy ecosystems and local economies are critical.

Kenya took steps towards addressing water scarcity issues by revising its water law and drafting The Water Act, 2002, which received presidential assent on October 17, 2002. However, Water Resources Minister Martha Karua acknowledged that the Act would not be fully effective until other laws are reviewed and updated to bring about the Act's enforcement (Kimani, 2004). A potentially high-impact step Kenya could take towards protecting its water resources is to ensure water is a protected right. To facilitate water appropriation and lessen conflict water rights must be legally specified, enforced, transferable, and depending upon the nature of its use it should be non-rival and exclusive. A property rights regime determines the rate of extraction and therefore provides water security insofar as what is available can be determined. Another consequence of the property rights regime is that liability can be assigned and compensation collected by affected parties. When an affected party does not have a way to obtain redress, damages remain a persistent negative externality. Because the consumer's nature is to maximize utility, in this case to maximize the benefit of adequate water quantity and quality, water rights support sustainability. Greater water right security and enforcement is one policy scenario that will be examined by the SUMAWA decision support tool.

While the Kenyan government views water supply infrastructure privatization as a means to solve water scarcity issues, steps have not been taken that provide social equity in water access. Government spending on water resources is Ksh200 (2.50 USD) per capita per year (Sammy, 2004), which is not enough to create an adequate water delivery system that could eventually be controlled by private enterprise subject to government regulation. Transitioning to demand-side water provision would foster an incentive for the community to maintain, protect and conserve water resources because there arises a sense of ownership and value. This arises as a direct result of the community making informed choices about their water and how it is managed (Nicol, 2000). A demand driven system allows the government to switch its focus to facilitating national policies that can ensure water resource sustainability and opens the door for privatization.

Some have criticized water supply privatization on the grounds that the poorest members of a community will be denied access. However, the poorest community members are already being denied under a supply-side structure that does not promote water resources sustainability. Allowing private sector involvement in water supply does not alleviate a government of its responsibility to provide all its citizens with an adequate clean water supply. Privatization has the potential to allow the Kenyan government to focus its efforts on the broad base of water resources sustainability.

Conclusions

Kenya's government, through its water laws, recognizes that access to water is a fundamental human right and essential to future development, but also recognizes that it is unable to provided needed water supplies to its people (Sammy, 2004). To this end, The Water Act, 2002 and associated efforts to adopt demand driven principles for water supply are crucial steps to bringing efficiency and the prospect of better water supplies to its people. Continued efforts are needed to turn the government's focus from water supply to water resources sustainability. This is an urgent need in light of possibly irreversible damage caused to the River Njoro watershed as a result of government-approved deforestation in the Mau Forest complex. The integrated decision support system being developed by the SUMAWA project is one tool that can be used to assess the impacts of these institutional changes and provide alternative management practices.

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References

Antle J., Capalbo S., Elliott E., Hunt W., Mooney S. & Paustian K. (2001) Research Needs for Understanding and Predicting the Behavior of Managed Ecosystems: Lessons from Agroecosystem Research. *Ecosystems* 4(8), 723-735.

Bach C.F. (1999) Economic incentives for sustainable management: a small optimal control model for tropical forestry. *Ecological Economics* 30, 251-265.

Baldyga T.J. (2005) Assessing land cover change impacts in Kenya's River Njoro watershed using remote sensing and hydrologic modeling. MS Thesis submitted to Department of Renewable Resources, University of Wyoming, USA.

Barbier E.B. (2000) Valuing the environment as input: review of applications to mangrove-fishery linkages. *Ecological Economics* 35, 47-61.

Hinrichsen D., Robey B., & Upadhyay U.D. (1997) Solutions for a Water-Short World. Population Reports, Series M, No. 14. Baltimore, Johns Hopkins School of Public Health, Population Information Program.

Jenkins M.W., Marques G.F., Lelo F.K. & Miller S.N. (2005) WEAP as a participatory tool for shared vision planning in the River Njoro Watershed in Kenya. *Proceedings of the World Water and Environmental Resources Congress 2005: Impacts of Global Climate Change, 15-19 May 2005, Anchorage, AK.*

Kimani W. (2004) Kenya's water getting scarce as forests are depleted. Published in *The Nation* newspaper, September 13, 2004.

McCall, G.J. (1967) Geology of the Nakuru Thomson's Falls – Lake Hannington Area. Publish by the Ministry of Natural Resources, Geological Survey of Kenya.

Miller, S.N., Semmens D.J., Miller R.C., Hernandez M., Miller P., & Goodrich D.C. (2001) Automated Geospatial Watershed Assessment Tool (AGWA) – A GIS-Based Hydrologic Modeling Tool: Documentation and User Manual. U.S. Department of Agriculture, Agricultural Research Service.

Miller, S.N., Kepner W.G., Mehaffey M.H., Hernandez M., Miller R.C., Goodrich D.C., Devonhold K.K., Heggem D. T., & Miller W. P. (2002) Integrating landscape assessment and hydrologic modeling for land cover change analysis. *Journal of the American Water Resources Association* 38(4), 915-929.

Milliman S.R., Johnson B.L., Bishop R.C., and Boyle K.J. (1992) The bioeconomics of resource rehabilitation: a commercial-sport analysis for a Great Lakes fishery. *Land Econ* 68, 191–210.

Mumma, A. Kenya's new water law: an analysis of the implications for the rural poor. *Proceedings of the International workshop on African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa, 26-28 January 2005, Johannesburg, South Africa*.

Nicol, A. (2000) Adopting a sustainable livelihoods approach to water projects: Implications for policy and practice. Overseas Development Inst., Working Paper 133.

Njuguna-Githinji W. (2004) Kenya. ITT Industries Guidebook to Global Water Issues. URL: http://www.ittind.com/waterbook/ Accessed December 10, 2004.

Sammy W. (2004) Water Privatization in Kenya. Global Issue Paper #. 8, March 2004.

Shivoga W.A. (2001) Influence of Hydrology on the Structure of Invertebrate Communities in Two Streams Flowing Into Lake Nakuru, Kenya. *Hydrobiologia* 458, 121-130.

Sohngen B., Mendelsohn R. & Sedjo R. (1999) Forest management, conservation and global timber markets. *American Journal of Agricultural Economics* 81:(1), 1-13.

Sylvia G & Enriquez RR. (1994) Multiobjective bio-economic analysis: an application to the Pacific whiting fishery. *Marine Resource Economics* 9, 311-328.

Wilen J.A. (1985) Bioeconomics of renewable resource use. In: *Handbook of natural resource and energy economics*, Volume 1 (eds A.V. Kneese, J.L. Sweeney) North-Holland Publishers, Amsterdam.

World Health Organization (2000) Water supply and sanitation sector assessment 2000, Part II, Chapter 23. Kenya.