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Land Cover and Land Use Change in the Njoro Watershed, Kenya: A Threat to Human and Ecosystem Health

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The River Njoro watershed and surrounding areas have undergone rapid changes in land cover and land use during the past two decades. In an effort to quantify these changes, and as part of the SUMAWA project, satellite images were acquired from January 28, 1986, February 6, 1995, and February 4, 2003. These satellite images were used to determine both the amount of overall land cover change as well as provide insight regarding the types of land use changes, representing the first quantitative assessment of land cover and land use change in the region. Results showed that significant changes in land cover and land use have occurred within the region as a whole and, more specifically, at an alarming rate in the uplands where the River Njoro headwaters are located on the escarpment. Results generated from this research have proven invaluable for all components of the SUMAWA project. Land cover and land use maps are primary inputs for the Soil and Water Assessment Tool (SWAT), the hydrological model currently employed in the SUMAWA project. Furthermore, as the project has developed and undertaken the task of building a spatial decision support system (SDSS) for rural watershed assessment and planning, the land cover and land use maps provided a basis for developing alternative land use scenarios. Finally, as part of the land cover and land use change mapping, a large-scale map was generated from these data and now sits in Lake Nakuru National Park where the River Njoro enters the park and helps tell the story of this rapidly changing landscape.

Background

In 2001, the Kenya Forest Working Group released a report indicating that deforestation was an ongoing critical threat to Kenya's five water towers: the Aberdare Range, Mt. Kenya, Mt. Elgon, the Mau Forest Complex, and the Cherangani Hills. These assessments, while an important step in identifying the problem of deforestation, fail to offer a rigorous quantitative assessment of temporal land cover and land use changes. The study detailed in this brief focuses on the River Njoro watershed, which finds its headwaters in the Mau Forest Complex on top of the rift escarpment.

From the available Landsat TM and ETM+ satellite images, it was clear that significant changes occurred in the Mau Forest after 1995. Local community members reported that significant changes in water availability had also occurred since that time. In 2003 and 2004, Participatory Rural Appraisal meetings were held as part of the SUMAWA project, and community members were able to express how changes in water resources within the watershed were affecting their lives. Within the community, people believe that the rapid and significant changes that have occurred in the uplands are the root cause of the water resources scarcity in the watershed. This coincides with the commonly accepted principal in hydrological science that when vegetation is removed from a landscape, the flow of water over the surface is modified and, in general, increases.

To this end, SUMAWA team members decided to examine in more detail the land cover and land use changes occurring within the Nakuru District, which would then allow for further examination of the linkages between land cover and flows in the River Njoro. For classifying the satellite images, two field campaigns were conducted in Nakuru District. During these field campaigns, data were collected on vegetation and land use. The areas were photographed, and GPS coordinates were used to combine these data with the satellite imagery, which resulted in the first quantitative land cover maps of the area. Using knowledge of the landscape at the time (2003 – 2004), team members were then able to use the older satellite images to make historical maps of the region.

Major Findings

Nine vegetation classes were identified as discernible for the land cover mapping: small-scale agriculture and pasture, basalt vegetation, dense vegetation, plantation forests, exposed non-vegetated areas, urban, large-scale agriculture, water, and algae blooms in Lake Nakuru. Results showed significant changes in land cover after 1995 (Table 1). Land cover changes were particularly notable in the upland regions (Table 1; Figures 1a and 1b). Throughout the region, the land cover change that generates the most concern is the decrease in dense

Table 1. Land cover as a percentage of total area for three years at multiple scales: Nakuru District, Njoro Watershed, and the Njoro Uplands

	Nakuru District			Njoro Watershed			Njoro Uplands		
Land Cover Class	**1986**	**1995**	**2003**	**1986**	**1995**	**2003**	**1986**	**1995**	**2003**
Mixed small agriculture/ pasture	34.4	36.7	50.6	32.1	32.5	51.2	14.8	14.4	33.4
Dense vegetation	32.5	31.8	25.5	30.9	27.8	23.6	67.1	60.0	49.8
Plantation forests	4.6	6.1	4.7	7.8	10.8	6.1	16.6	23.3	13.6
Large-scale agriculture	18.8	15.8	7.2	18.7	17.4	9.3	1.2	2.2	1.5
Exposed	7.1	7.1	9.5	8.0	8.4	6.1	0.2	0.1	1.6
Urban	0.3	0.4	0.5	2.5	3.1	3.7	0	0	0.01
Water	0.7	0.6	0.7	0	0	0	0	0	0
Algae bloom	0	0	trace	0	0	0	0	0	0

vegetation (e.g., indigenous forest and riparian vegetation) and plantation forests along with the concurrent increase in mixed small-scale agriculture and pasture. Additionally, the study found that the changes occurred predominantly after 1995 and over a short period.

Governmental and institutional arrangements regarding land tenure within Kenya after independence spurred large-scale land use and land cover changes. In particular, plantation forests in the once forested uplands region around the River Njoro watershed were removed and converted to small-scale agriculture. Census records indicate that population in the Nakuru district nearly doubled from 270,912 in 1979 to 413,698 in 1999. Population increases were greatest after 1989. Between 1979 and 1989, the recorded population only increased by approximately 15,000, with the additional population increases occurring between 1989 and 1999.

Practical Implications

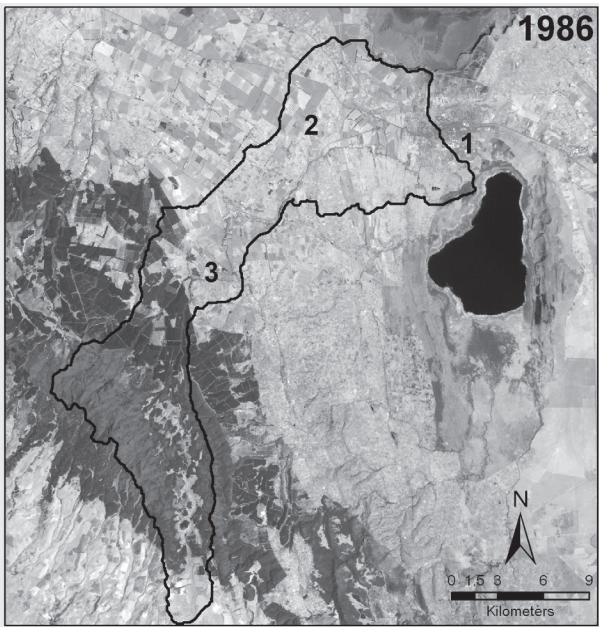
While changes in land cover and land use can have many and various deleterious effects, the changes in hydrological response and implications of land use change on soil erosion are critical to address. When vegetation on the landscape changes, there is the potential to change the way water flows across the landscape, as well as the amount retained in the soil. Under conditions such as dense forest, overland flow is slow, and water infiltrates the soil.

When vegetation is removed, water flows more freely across the landscape and does not have an opportunity to infiltrate the soil. The result is a change in the timing and amount of runoff to the river. "Flashier" flows are also increased, as water rushes from the landscape into the river channel.

Consistent with the hypothesis that changes in the watershed are associated with upland vegetation changes, floods and high flows have increased in recent years within the River Njoro watershed. The impact land cover changes are having on soil erosion is an additional concern. At Lake Nakuru National Park, reports indicate that sediment yields from the river to the lake are worsening.

There are two main contributing factors to the recent increase in sediment yields. First, with less dense vegetation to provide land cover, there are increased opportunities for rainfall to detach soil particles, which are then transported via overland flow processes to the river and, ultimately, the lake. In 2003, an algae bloom appeared marking a new event for the lake. It is likely that this bloom appeared as

Figure 1a. River Njoro Land Use and Land Cover, 1986. 1: The city of Nakuru, Kenya. 2: The Njoro watershed near Ngata. 3: The River Njoro headwaters in the uplands of Kenya. See Figure 1b (following page) for more detailed images.



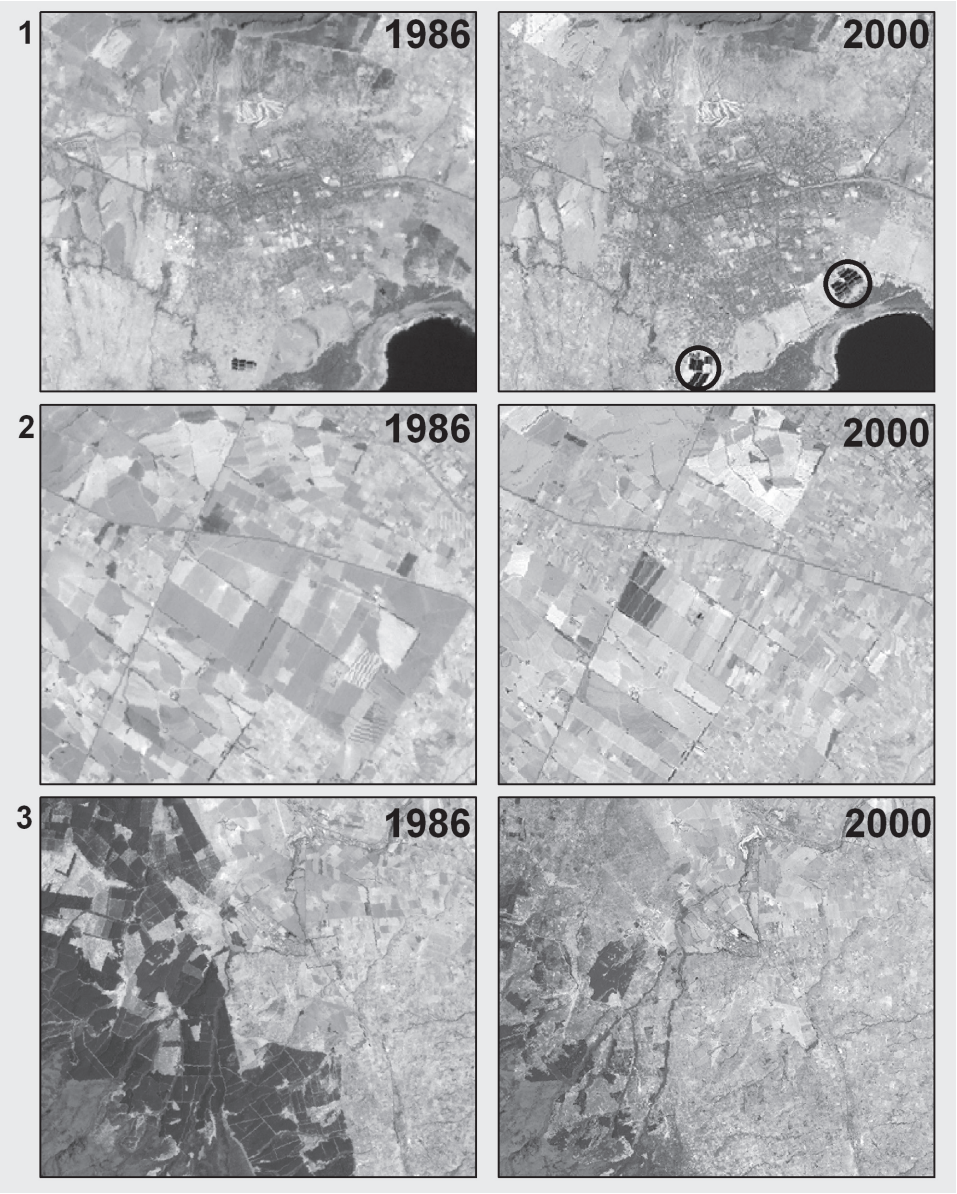


Figure 1b. Examples of River Njoro Land Use and Land Cover Change, 1986-2000. 1: Nakuru, Kenya's fourth largest city, grew substantially between 1986 and 2000. In this image, the city center pixels appear darker. Also note increased sewerage ponds (circled). 2: Subdivision of large-scale agricultural lands into small-scale agricultural plots is ongoing in this area of the watershed, near Ngata. 3: In the uplands, where the River Njoro headwaters are located, conversion of plantation and native forests to small-scale agriculture is ongoing. Such disturbances in the upper watershed are of particular concern, as they lead to changes in the river response such as flash floods followed by prolonged dry periods.

a result of agricultural run-off from an increased number of small-scale farms that replaced existing vegetation in the watershed uplands or increased effluent from the surrounding area. The appearance of the algae bloom is a sign of eutrophication, which indicates a lack of oxygen in the lake. In turn, this has severe implications for water quality in the lake and can negatively impact fish, bird and animal populations. Second, as soil transport (erosion) increases in the River Njoro watershed, large quantities of pesticides and fertilizers are potentially carried along with the soil thereby contaminating domestic and livestock water sources.

In short, the land cover and land use changes occurring in the watershed are not only alarming due to the impact on biodiversity and ecological services but also pose a significant challenge to improving both human and watershed health.

Further Reading

Baldyga, T. and F. Holley. 2008. "Introduction to SEADS: SUMAWA's Spatial Environment and Agricultural Decision Support Tool." *Research Brief 08-03-SUMAWA.* Global Livestock Collaborative Research Support Program (GL-CRSP), University of California, Davis.

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The GL-CRSP Sustainable Management of Rural Watersheds (SUMAWA) project was established in 2003 and is a multidisciplinary research effort focusing on biophysical and human-related factors governing health in the River Njoro watershed in Kenya.

The Global Livestock CRSP is comprised of multidisciplinary, collaborative projects focused on human nutrition, economic growth, environment and policy related to animal agriculture and linked by a global theme of risk in a changing environment. The program is active in East and West Africa, Central Asia and Latin America.

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