

SUSTAINABLE MANAGEMENT OF RURAL WATERSHEDS: BIOPHYSICAL, LIVESTOCK AND HUMAN INTERACTIONS IN THE RIVER NJORO WATERSHED

NARRATIVE SUMMARY

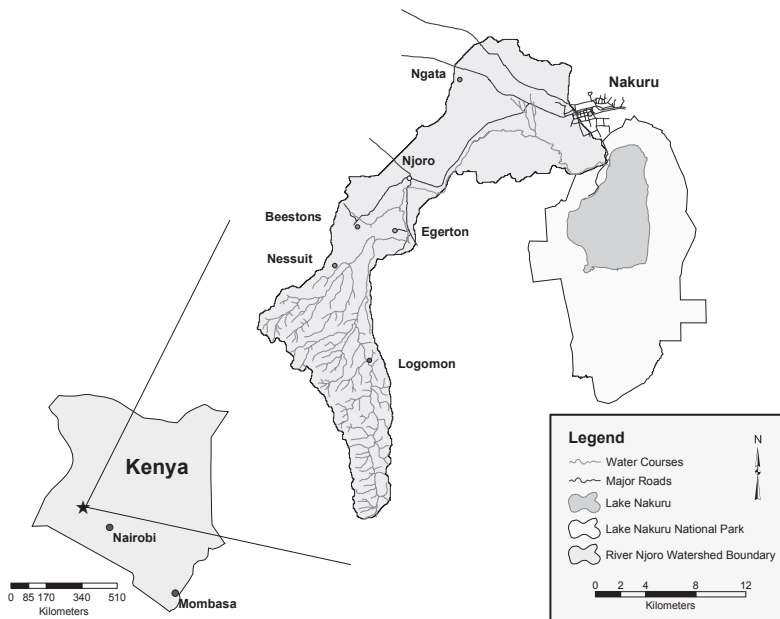
Results are presented from a cooperative research endeavor wherein faculty and scientists from three US academic institutions (University of Wyoming, University of California-Davis, Utah State University), two Kenya academic institutions (Moi University and Egerton University), and two Kenya governmental organizations (Kenya Fisheries Department and Kenya Wildlife Service) collaborated on interdisciplinary research for sustainable watershed-based management. This multidisciplinary team is subdivided into four components: watershed hydrology, ecology, stakeholder involvement, and socio-economics. The Njoro watershed (Figure 1) serves as the research test bed for a variety of research and developmental outcomes, and is being developed as an experimental

watershed where interactions among ecological and hydrological dynamics may be quantified. Analyses in the past year focused on defining human and watershed-based metrics resulting from policy decisions and resulting land cover change. Numerous field studies have provided basic information to a range of simulation and conceptual models to build a strong scientific understanding of the watershed system, as well as provide key information to decision makers for policy guidance and effective land management.

This year's effort was geared towards assembling representative conceptual and mathematical models of the biophysical and human dimensions of the watershed, as they relate to watershed and human health and sustainability. Watershed health is defined

as having the capability of supporting short- and long-term hydrologic and ecologic function. The human aspects of the project are aligned with minimizing risk to economic instability, and health hazards associated with water-borne diseases. Livestock are a central component to both the biophysical and human models with which SUMAWA is working, and will be embedded in the modeling tools for inclusion in decision support and outreach products generated in the coming year. SUMAWA researchers are developing a full suite of biophysical and

Figure 1. Map of the Njoro Watershed



human-related research for the purpose of creating a comprehensive watershed model that may be translated and transferred to stakeholders and policy makers who are the primary determinants of watershed and human health in the Njoro watershed.

RESEARCH

Research and outreach efforts in the 2005-2006 year were targeted to provide a basis for improved decision making for sustainable watershed management in terms of both human and ecological health. Several important topics that were identified in the early years of the project were addressed directly, including a detailed analysis of human health risks. The SUMAWA project was instrumental in the formation of the River Njoro Water User Association, which will serve as the primary point of contact for linking watershed stakeholders with scientists and policy makers. In addition, formal linkages have been made between the project and key policy makers and management agencies operating in the watershed, including the Ministry of Health and the Rift Valley Water Management Authority. These linkages will enable us to more directly link scientific outcomes with policy makers in order to stimulate positive changes.

Field- and lab-based approaches were pursued in the past year. A comprehensive watershed-monitoring program was maintained, including data collection for climate, runoff, water quality, human health, conservation practices, livestock utilization and impacts, and ecological integrity. Results from both field data analysis and modeling exercises indicate that there is a high degree of variability in indicators of health throughout the watershed.

Activity 1. Conceptual and mathematical model development of the dynamics governing watershed health, economic stability, ecological systems, and stakeholder perceptions and management strategies.

1.1 Effects of livestock grazing on the hydrological characteristics within the River Njoro Watershed: Problem Statement and Approach. The activity was

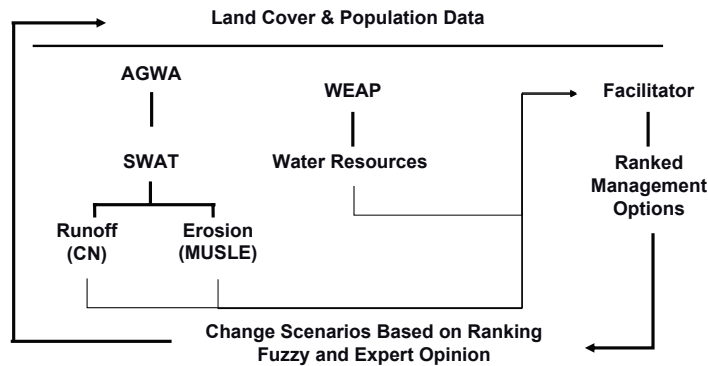
to assess the capacity of the riparian vegetation to reduce nutrient and sediment input into the river at livestock watering/grazed and non-grazed sites, as well as the capacity of in-stream vegetation to take up nutrients.

Accomplishments:

- Riparian strip vegetation species composition 30m from the centre of the stream, on either side of the stream at watering/grazed and non-grazed sites identified and documented.
- Percent vegetation cover at livestock watering/grazed and non-grazed sites quantified.
- Generation of 30 m stream cross-section profiles.
- Infiltration measurements at disturbed and non-disturbed sites.
- 589 topsoil, subsoil and sediment samples were taken for laboratory analyses to assess the capacity of the riparian vegetation to reduce nutrient input into the river at disturbed and non-disturbed sites. A soil condition index that identifies soils as fertile or not fertile has been generated. Wet chemistry on 30 of the soil samples has been done and results received. Prediction of the same variables (pH, nitrogen, phosphorus, particle size, exchangeable Mg²⁺ and Ca²⁺ ions and organic carbon) on the rest of the soil samples is yet to be done (results on prediction of the wet chemistry variables on the rest of the samples still held at ICRAF laboratories in Nairobi pending payment of wet chemistry analyses costs).
- Width of stream at disturbed and non-disturbed sites measured.
- Width of the riparian vegetation on either side of the stream measured.
- Land use activities within 30m from centre of the stream and beyond recorded
- Sediment samples of three tributaries (at Logoman, Ruguma and Little Shuru) on River Njoro collected and sent for laboratory analyses to determine which sub watershed/ tributary contributes much sediment to the main stem.

Progress. The activity was successfully accomplished and data are being analyzed to assess

Figure 2: Land Cover & Population Data



the capacity of the riparian vegetation to reduce nutrient and sediment input into the river at livestock watering/grazed and non-grazed sites. A first draft of a MSc. thesis for Eric Enanga is being written.

1.2 Water Evaluations and Planning Model. Efforts towards developing decision-support system modeling (Figure 2) this year were focused on technical capacity building among Egerton University and Ministry of Water personnel in integrated water resources and demand evaluation and planning analyses, using the WEAP21 modeling system. A series of general model development and hands-on input data collection, analysis, and data preparation training workshops, using the preliminary Njoro WEAP21 model application, was conducted over 11 weeks from late March to late June 2006 at Egerton University for SUMAWA students, researchers, a consultant, and Ministry of Water engineers and staff from the Rift Valley Water Resources Management Authority (WRMA) in Nakuru. The training was prepared by Dr. Jenkins and carried out by Niels Riegels, an experienced water resources systems engineer with extensive GIS and water resources modeling experience in California. Mr. Riegels was recruited as a research assistant to the team on leveraged funding at no cost to the project, to go to Egerton for 3 months to work collaboratively under the WRMA MOU to help improve technical modeling skills.

The training was well attended and well received, especially by WRMA staff and SUMAWA

students. Understaffing at WRMA, combined with a major re-hiring of staff in July, and limited prior computer modeling experience has meant that additional technical support will still be needed before WRMA-Nakuru are in a technical and staffing position to take on WEAP21 modeling on their own. Discussions regarding the WRMA contracting out the work to complete an updated Njoro WEAP model to technical consultants were initiated. This may be the most appropriate way for the WRMA to apply this tool to the

Njoro and other watersheds where they are keen to enhance quantitative analyses to support water resource decisions, which they are responsible for, such as basin water allocation planning, and water withdrawal and use permitting.

Of note, two workshops and resultant technical memos on population trends for demand estimation and methods for using and manipulating historical hydrologic stream flow records for WEAP model inputs for the Njoro watershed were conducted, prepared, and shared with the training participants and WRMA. An inventory of water service providers operating in the watershed identified over 30. A tool and approach was developed and tested to characterize water and wastewater system infrastructure, resources, operations, and demand components of each water service provider. So far, data for characterizing the demands, sources, and infrastructure for 9 service provider systems in the watershed have been collected and reported. This work was expected to be completed this past year, however, the loss of one of the students and the unavailability of WRMA staff during the summer caused significant delays. Once the remainder of the systems are characterized, necessary data for configuring an updated and complete Njoro watershed WEAP model application will be available.

1.3 Evaluation of Soil Erosion Risk using the RUSLE Model: Problem Statement and Approach. Many of the land management actions in the Njoro have the potential to lead to enhanced soil erosion and downstream sedimentation. For example,

grazing impacts on upland watersheds and trampling of near-channel areas is a significant contributor to both surface erosion and rilling, as is bed and bank failure leading to poor riparian condition. In the Njoro there has also been a widespread transition of forest to agriculture, which has the potential to increase soil erosion dramatically. The adequate mapping and modeling of erosion risk zones will be of benefit to local managers and stakeholders, and will provide a metric to track for the short- and long-term tracking of watershed health.

Progress. A GIS modeling framework has been implemented in the Njoro that uses the MSLE modeling framework, a variant of the RUSLE model. The two models share the core mathematical representations of erosion, the main difference being that RUSLE is a stand-alone system, while the MSLE implementation is embedded in the Soil and Water Assessment Tool (SWAT), which has been calibrated for hydrological response on the watershed (see 2004-2005 Annual Report). A spatially distributed map of soil erodibility following the MSLE modeling system has been adequately completed. Inputs to the RUSLE (RUSLE 2.0) model have been fully captured in GIS, and the models themselves installed on computers in Kenya and the US.

We are currently re-evaluating the need to fully implement the stand-alone version of RUSLE given that the SWAT model provides an effective and stable platform for modeling erosion, and one that is fully linked to ongoing hydrological modeling efforts. The goal of this research activity was to identify erosion-prone areas by modeling the combined effects of rainfall intensity, soil erodibility, landscape structure, and agricultural management based on the principles of the Universal Soil Loss Equation. The remaining research question in this area is whether continuing to build erosion models on two platforms (RUSLE and SWAT-MSLE) is appropriate, or if the SWAT-MSLE approach provides a robust and defensible scientific platform.

1.4 Development of Biological Monitoring and Assessment Tool (BIOMAT) for River Njoro Watershed.: Problem Statement and Approach. This activity was part of the assessment of the trends in watershed health and is part of the ongoing lake and river monitoring. It focused on the development of a water

quality map that will be used as a visual presentation to the stakeholders. Maps of water quality provide more than just a picture of the present state of the environment and can be used to identify stream reaches that are potentially environmentally sensitive or the best sites to concentrate restoration efforts.

Progress. This activity focused on the development of a Biological Monitoring and Assessment Tool (BioMAT) for the Njoro watershed of the Lake Nakuru Basin based on the Biological Monitoring and Assessment Program (BioMAP) developed in Canada by Griffiths (1996), and the Rapid Bioassessment Protocols (RBPs) developed by the Assessment and Watershed Protection Division of the Environmental Protection Agency (EPA) in the USA (Plafkin et al., 1989). Macroinvertebrate distributions and proportion (%) of natural riparian vegetation determined by GIS analysis will be used for mapping River Njoro water quality. Classifying and mapping stream water quality is a prerequisite for water quality management. It is difficult to manage that which cannot be identified and visualized.

Accomplishments:

- A total of 93 month of May samples for refined benthic macroinvertebrate taxonomic work collected.
- 67 samples processed, sorted and benthic macroinvertebrates positively identified to family level.
- A criterion for assigning sensitivity values to the benthic macroinvertebrates in the river Njoro watershed and lake Nakuru basin was developed.
- Initial map analysis used to estimate the density of riparian vegetation (within 50 meters of the stream) along the complete length of the river course of the stream by GIS analysis in University of Wyoming.

The following activities are yet to be accomplished but are being carried out, and are slated for continuation in future project years: relate water quality to riparian vegetation density; classify and validate water quality along the river based on the regression relationship between water quality and the proportion (%) of natural riparian vegetation.

A draft MSc proposal for Charles Kigen to finalize the remaining parts of “Development of Biological Monitoring and Assessment Tool (BIOMAT) for River Njoro Watershed” has been written and is scheduled to be submitted to the Faculty of Egerton University in the coming year.

Activity 2. Ongoing data collection and interpretation to better understand watershed systems dynamics and establish a true experimental watershed.

2.1 Assessment of Groundwater Potential and Monitoring of Groundwater Levels Fluctuations within River Njoro Watershed: Problem Statement and Approach. This activity focused on the assessment of the overall potential of groundwater resources within the watershed, its availability and accessibility for use by the stakeholders, and its linkages to and control of river flow (water yield). One of the basic objectives of this project is to quantify the amount of water that would be available for the stakeholders, with a major source of such water being groundwater. Stakeholder engagement activities have clearly demonstrated that this is a critical and high priority for all members of the watershed. The biophysical components of the watershed are equally reliant on water resources, and preliminary modeling and data analysis have shown that groundwater and near-surface control are the driving factors for river flow and annual discharge. These findings underscore the importance of groundwater to the Lake Nakuru National Park and to riparian communities.

The objective of this activity was to assess the overall potential of groundwater, thereby enhancing the hydrologic database for effective planning and management of the watershed. It would also result in the enhanced collaboration with the personnel in the water office in Nakuru, thus assisting in the development of the groundwater model, especially water balance, infiltration, river base flow, recharge by precipitation, and also the surface water-groundwater interactions.

Progress. To satisfy this objective, a range of field and lab activities have been completed. A borehole census has been ongoing, which to date has resulted in the spatial identification of over 150 boreholes

(wells) in the watershed alone. Detailed hydro-geological characteristics (such as aquifer levels and extent, natural discharge and recharge zones, surface water divide, groundwater divide, and hydrologic interconnectivity for the watershed) have been developed based on field records of depth to water table and the estimation of the piezometric surface. A water quality assessment of groundwater collected from various boreholes in the watershed is ongoing with expected results forthcoming. Preliminary maps in GIS format of the distribution of the boreholes in the watershed have been created and are being modified as field efforts continue. Two pump tests have also been carried out in collaboration with the Water Office in Nakuru, with the data analysis forthcoming.

2.2 Assessment of riverbank stability at disturbed and non-disturbed sites in the upper and middle reaches of River Njoro watershed: Problem Statement and Approach. The activity was to assess riverbank stability and assist in initiating ecological rehabilitation process in the watershed. The activity assisted in the identification of riverbank sites for rehabilitation. The activity also assessed the effect of livestock on the stability of riverbanks.

Progress. Variables required to generate stability index i.e. bank height, bank angle, bank percent vegetation cover and bank substrate in the upper and middle reaches of River Njoro have been identified through literature and field experience from the past several years of data collection efforts. A field program for measurement and monitoring was established and carried out with a repeated measures survey strategy in the past year. Stability indices of disturbed and non-disturbed sites in the upper and middle reaches of the River Njoro are being generated based on field metrics.

The activity was successfully accomplished and data are being analyzed to assess riverbank stability at sampled sites and identification of riverbank sites for rehabilitation. A first draft of an MSc thesis for Eric Enanga is being written and should be submitted to the Faculty of Egerton University in the coming year.

2.3 Evaluation of the impact of livestock grazing and trampling on structure and function of the riparian vegetation in the upper and mid-portions of the

River Njoro. This activity was combined with the activity reported above under the heading “Effects of livestock grazing...” Please refer to that section for the report.

2.4 Determination of temporal and spatial dynamics of waterfowl as a measure of proper functioning of riparian habitats: Problem Statement and Approach. Biological species are indicators of ecosystem health, and their spatial and temporal distribution and species dynamics are influenced by habitat quality. River Njoro watershed is a critically important biodiversity conservation area, whose fragmentation is leading to biodiversity loss and poverty prevalence. Monitoring avifauna temporal and spatial distribution will be used to document watershed health. Results from this activity will be used in the development and refinement of the BIOMAT tool, as described earlier in this report.

Progress. Fieldwork related to the collection of and ringing of birds in Eastern Mau using mist nets was carried out from the 4th to 26th of August 2006. 240 birds in various fragments in Nessuit, Sigotik, Sigaon, and Logoman Riparian zones of River Njoro watershed were ringed and identified, with the data entry and cleaning completed, and preliminary analyses begun.

Ms. Milkah Faith Ngugi has completed the portion of her MSc thesis entitled “Effects of Eastern Mau Forest Fragmentation on Avifauna in River Njoro Watershed, Kenya,” with an anticipated submittal date of the thesis for review by her supervisors by the end of 2006.

2.5 Maintenance of long-term data collection and equipment. This activity was successfully carried out. All hydrological and climatic data was collected as per the already established protocol, and database records updated accordingly. The data has been used for studying the climatic trends in the watershed and as input to hydrologic model development and calibration.

Data loggers and automated tipping bucket rain gauges were installed to capture the spatial and temporal variability of climate data in three segments of the watershed: 1) at Sigaon Primary School (Upper watershed); 2) at Egerton University (Middle reaches); and 3) at KWS mini weather station for the lower reaches.

Activity 3. Integrating research findings with stakeholders to enhance long-term sustainability and re-align research priorities.

Problem Statement and Approach. The SUMAWA project is an action-research project whose aim is to have all stakeholders within the watershed participate in addressing the challenges they are facing as consumers and guardians of resources within the watershed. Thus, the project has been designed to embed stakeholder concerns into the biophysical research, and for the research findings to be availed to all interested stakeholders. To achieve this interaction six Participatory Rural Appraisals have been conducted throughout the watershed, as well as a stakeholders meeting, women leaders’ forum, and in-house scientific sharing and training workshops for all the leaders from the initially identified six zones and all the interested stakeholders of the watershed. The formation of a genderized River Njoro Riparian Management committee known as the River Njoro Water Users Association (RN-WUA) was the climax of the process with representation from all the zones within the watershed.

Progress.

3.1 Information dissemination and linkages to other groups. Initial outreach efforts put forth by project members were through personal communication and professional contacts. Although this has achieved its own successes, for sustainable and long-term objectives we have undertaken a more institutionalized approach. Towards this effect, the Project has signed two memorandums of understanding (MOUs) with the Water Resources Management Authority (WRMA) and the Nakuru District Health Management Team (DHMT). Although these MOUs are tailored to meet certain objectives, their presence is a clear indication of Project influence over regional policies.

The strategy behind the MOU signed with the WRMA was to mobilize communities within the watershed to form a water users’ association. A series of preparatory meetings were organized, culminating with a 4-day workshop for watershed stakeholders (this workshop is reported later in the report). The

result of these efforts was the formation of the Njoro River- Water Resources Users Association (RN-WRUA). The RN-WRUA now serves as the entry point to the watershed communities, and has strong and formalized ties to the SUMAWA project and WRMA. Furthermore, this body enables other interested parties who have interest in the welfare of the watershed to use the association as an entry point to the communities. We have effectively used the association to arrange for visits of our visitors, identification of on-farm research sites, scouting and “cleaning” the river, and above all introduction of interventions, such as tree seedlings nurseries, planting trees, demarcation of riparian zones, livestock water troughs, bio-sand water filters, and advocacy for better watershed health.

Poor water quality has a high correlation with water borne diseases. For this reason among others we had to partner with the DHMT. As long term plans for improved water quality and quantity are underway by watershed parties, there remains a need for a stop-gap solution on water quality. To address this immediate need, the project has trials underway on bio-sand filters at University of California, Davis and Egerton University. These filters will be migrated from the bench-testing phase to the use in households with high risk for diarrhea diseases to test their efficacy. This activity relies heavily on the relationship and communication established through the MOU and good-faith efforts in data sharing and leveraged efforts.

Telltale billboards have been placed at watering sites warning people on the quality of water. These signs post clear health warnings in 3 languages related to the risks to human health (Figure

3). Other advisory boards are planned on the improvement of the watershed health. Boards are in English and Kiswahili, and in local languages where appropriate.

3.2 Research / Stakeholder conference. This activity was not undertaken as originally envisioned in the project work plan. Efforts related to the formation of the RN-WRUA and associated workshops and training efforts were more significant than

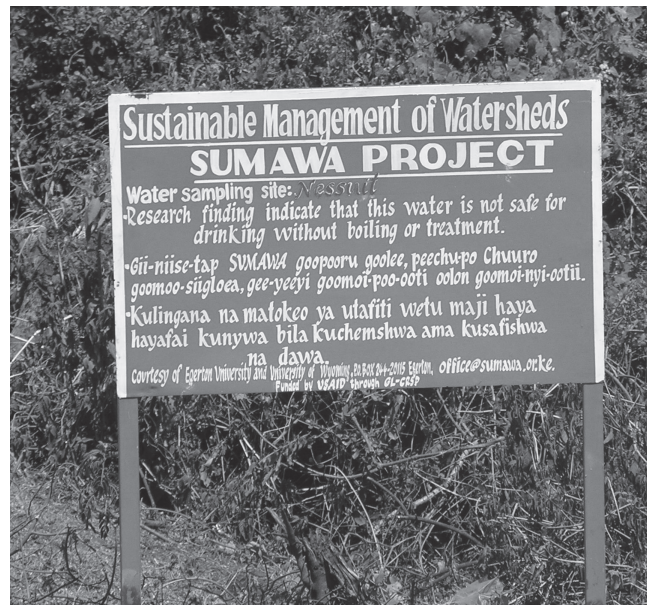
had been anticipated. Human resources and budgets were redirected to ensure that the watershed association linkages were sound at the expense of a formal conference. A 5-day Workshop was the primary substitute for this effort, entitled “Proceedings Towards Formation of Water Resources Users’ Association (WRUA), Sharing Workshop at Saint Mary’s Pastoral Centre Nakuru from 31st May to 4th June 2006”. At this

workshop SUMAWA scientists presented their research findings to community members, who in turn presented and discussed their primary concerns related to the watershed, and their expected goals for the RN-WRUA. A report on the workshop was generated, and serves as a template for the scientific and outreach exchange among project personnel and the community members of the RN-WRUA.

3.3 Perception measurements and longitudinal visits: Problem Statement and Approach. This activity was targeted to document the River Njoro Water Resource Users Association (WRUA) perceptions regarding the watershed both before and after the training. This was achieved by administration of a questionnaire to all the participants that was later analyzed using the Statistical Package for Social Sciences (SPSS).

Progress. Most respondents were able to recognize

Figure 3. SUMAWA sign describing risks to human health



the different sources of pollution in the river, compared to earlier perceptions where they pointed a finger at a particular polluter. Furthermore, the participants were quick to appreciate that the watershed's health can be restored by concerted efforts of all the stakeholders. They were able to identify the primary stakeholders (the community living along the River Njoro) as the main polluters of the river, and expected them to lead the action-oriented efforts to conserve the watershed. In particular, the participants identified the WRUA as a potential force to mobilize the whole community over the conservation issue. The participants identified the actions they anticipated to undertake in order to restore the watershed and have also listed the accrued benefits to these actions.

Activity 4. Evaluation of alternatives to current watershed management, and potential benefits and costs.

Problem Statement and Approach. Decisions made at the household, community, watershed or regional scales are effectively determined on the basis of trade-offs. Choices are selected on the basis of both perceived and actual costs and benefits, and long-term beneficial or deleterious outcomes are determining factors. This activity was designed to gauge both the real outcomes of management strategies (in coordination with the field research activities; Activity 2) and to further develop reasonable scenarios for input to conceptual and mathematical models (Activity 1), so as to provide materials for stakeholders and policy makers interpreting and understanding outcomes of decisions (Activity 3).

Progress.

4.1 Understanding the role and impacts of land cover classification error on spatial modeling efforts in the watershed. This activity was aimed at improving the error understanding in classified remotely sensed imagery by using a modified Monte Carlo technique to propagate random classification errors through a hydrologic simulation model using a Geographic Information System (GIS). Land cover data derived from Landsat imagery is a critical

input to the hydrologic, ecologic, and economic tools used in this project. Errors in spatial data that serve as inputs coupled with uncertainty in landscape propagate through the modeling process. Such error and uncertainty potentially undermines the usefulness of model results. Confusion matrices are standard outputs generated during land cover classification accuracy assessment. These matrices indicate informational classes and likelihood of error for each informational class within a classified image. An analysis of error placement on simulated runoff and erosion will improve model architecture by accounting for error.

A Landsat scene (Path 169, Row 60) acquired on 04 February 2003 was selected for this study. This date corresponds to pre green-up periods and was chosen to capitalize on pronounced differences in reflectance between forested and non-forested areas, decreasing confusion at forest edges between dense forest vegetation and small-scale agricultural plots. Seven thematic classes, excluding shadow and cloud cover, were identified as relevant for quantifying the range of vegetation types and associated transitions across space and time. These thematic classes represent coarse data aggregates corresponding to basic land management practices occurring within the River Njoro watershed. A combination of unsupervised and supervised image classification methods were used to digitally classify the pixels in all three Landsat images (see 2004-2005 report for details on this procedure). The ArcGIS software package was used to generate 100 alternate land cover maps based on the probability distribution of error reported in the error matrix developed from the accuracy assessment. The hydrologic model SWAT was parameterized and run using these 100 alternate land cover maps with all other data elements remaining the same for subsequent model runs. SWAT outputs were compared in a GIS at the sub watershed level to discover how random error placed in the classified imagery would ultimately affect runoff entering the main channel.

SWAT visualizations indicated that in areas where forests were flipped to agriculture, the increase in runoff to the main channel was pronounced, and in many instances more than doubled (Figure 4). Of even greater interest, however, was that final

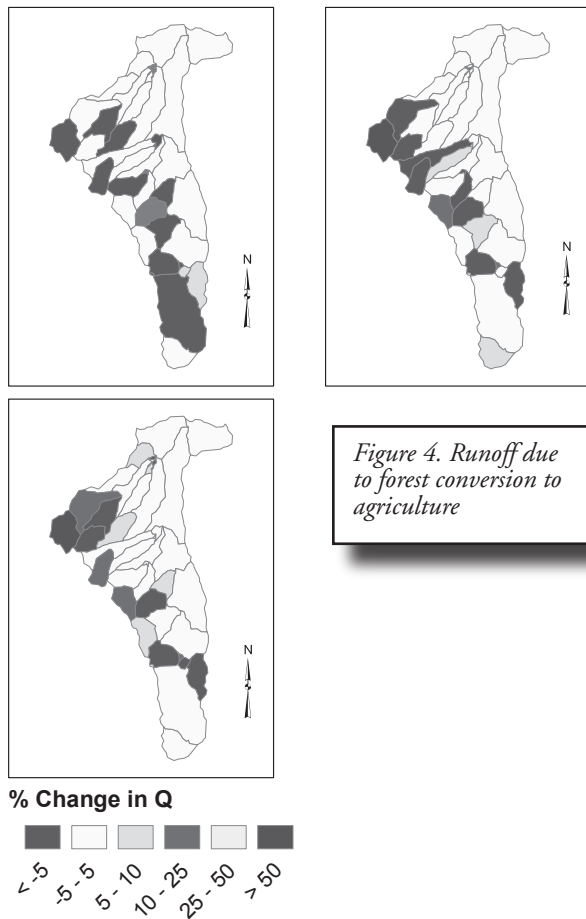
discharge measured at the watershed outlet remained similar among the different model runs. Results from the 100 SWAT realizations indicate that it will be most crucial to incorporate further rules to determine smart error placement as opposed to random error placement; in particular, areas that are most likely to be incorrectly classified (such as edges) versus areas that are unlikely to be misclassified (such as large blocks of contiguous forests). While this study indicated the overall effects of misclassification, it did not directly indicate areas in the watershed that are most vulnerable to degradation. Steps beyond identifying compensating errors are now necessary.

4.2 Understand and interpret the factors leading to adoption of conservation or alternative management practices. The subject of this research is focused on understanding the relationship of determinant factors (social, economic, biophysical, and human perception), and the effect they have on individual farmers' decision-making processes. This research

is rooted in innovation-adoption theory and has ramifications for watershed planners, policy makers, and physical scientists alike. Because land use in the River Njoro watershed is primarily agriculturally based, improving our understanding of why farmers implement conservation practices to protect soil and water resources from erosion, livestock impacts, and degradation of riparian vegetation is of paramount importance for the improvement of water resources.

Extraction activities in previously natural areas have resulted in conversion of large tracts of native and plantation forest lands primarily into small-scale farming (shamba) tracts. This conversion has occurred throughout the middle and upper portion of the watershed from Mukungugu near Egerton University, upstream to Logomon on the main stem, and to Sigaon Primary on the Little Shuru tributary (i.e., to the upper extent of cultivated lands). These recently introduced agricultural activities likely contribute inordinately to a detrimental change in the retention and temporal release characteristics of water resources, and to increased sedimentation of the main stem River Njoro. Increased populations, soil tillage for growing agricultural crops, and year-round livestock keeping have increased pressure on soil resources via less than optimal farming practices, grazing pressure on increasingly limited pasture, increased pressure on riparian zone vegetation, and stream bank trampling and destabilization. Thus, our understanding of the connectivity and relationships between agricultural systems and SWCBs to riverine/riparian ecosystems is vital for developing a reliable and effective watershed management plan.

Over the past 10 months, a doctoral candidate at Utah State University has been responsible for focusing on "Riparian Farmers," classified as small-scale farms located within 500m of the River Njoro and its major tributaries. Background data collection, successful completion of a pilot study in the Barut community, and completion of a household survey throughout the upper and middle portions of the watershed were completed. Two hundred and twenty two households in total were surveyed during the months of August and September, 2006. Data entry and QA/QC of data was performed concurrently and completed 23 September. Data cleaning was



completed during the two-week period following conclusion of the household survey. Data analysis and synthesis of finding is currently underway, and it is anticipated that this phase of the research will be completed by April 2007.

4.3 Human Health Research – Drinking Water Quality Improvement through POU Treatment. Activities and achievements in this area during the past year have focused on understanding the extent and magnitude of fecal surface water pollution in the River Njoro and exploring potential sources, with attention to contributions from livestock and in particular cattle, and addressing stakeholder priorities for clean safe drinking water through identification, adaptation and testing of low cost alternative point-of-water treatment options for households at high risk for water-borne diseases in the Njoro watershed (see Table 1).

Twelve months of surface water fecal pollution monitoring at 15 sites along the River Njoro from the uppermost reaches above settlements to just before the boundary to Lake Nakuru National Park was completed this year. Table 1 reports the averaged results from an initial intensive sampling of 38 sites, but community and section. Where water borne diseases are most prevalent and the burden of disease highest, as indicated by childhood diarrhea prevalence, is among rural agricultural households and communities located above Egerton University

who lack access to improved water supply sources. These dispersed households are obliged to collect water directly from the river for their drinking and household water needs. While peri-urban households in the middle and lower sections of the watershed have improved water supply sources to choose from, these infrastructure are sometimes unavailable, shut-down, too expensive, or scarce relative to demands. Thus, while these households are much less likely to use river water for drinking, choosing to purchase safer supplies, they often supply the bulk of their other household water needs from river water, which is free.

Through participatory rural appraisal (PRA), watershed communities have identified water-borne diseases due to consumption of polluted river water and water scarcity among their top three priority problems. Decentralized approaches to improved water supply may be both more environmentally sustainable and operationally feasible than centralized systems in rural areas of developing countries. Among these, point of use (POU) drinking water treatment (or household water treatment) is receiving increasing attention as a way to rapidly and affordably improve water quality and health for the 1.1 billion people living in developing countries who lack access to a safe water supply, and for additional populations who may have improved supplies but for which quality is unsafe.

Table 1. Fecal Coliform Counts and Household Characteristics in the Njoro Watershed

Zone and Communities	Fecal Coliform Counts / 100 ml (Oct 2005)	Child Diarrhea 2-week prevalence (June 2004)	Water Supply & Sanitation Conditions
1. Nessuit	1555 (480-6400)	19%	No improved water supplies; 35% no latrine, poverty highest
2. Mwigito, Njokenia	4533 (2533-7200)	15%	Limited availability of improved supplies; 98% have latrine or toilet.
3. Njora Town, Rumwe	6017 (3400-8800)	13%	Improved supplies available but cost a barrier, improved sanitation.
4. Ngala	1318 (600-2720)	data missing	Improved supplies available but cost a barrier, improved sanitation.
5. Baruti, Kaptembwa	18,714 (3900-41,600)	11%	Improved supplies available but cost a barrier, improved sanitation; higher incomes and greatest employment opportunity.

A variety of POU methods have emerged as promising low-cost options for poor households in developing countries. The most appropriate, acceptable and feasible POU method varies with the large variety of situations that may be encountered in less developed countries, and must be tested, adapted, and promoted on the basis of locally satisfying water safety issues, cultural issues, cost issues, and water demand (volume) issues.

Considerations that must be taken into account when choosing an appropriate POU household drinking water treatment system for a particular developing country community context and setting include water quality, as well as non-water quality issues affecting effective treatment regime. A literature review has been undertaken of the common POU drinking water treatment options now being piloted and promoted internationally include: 1) filters (including biosand filters, ceramic filters and filters made from other locally available materials like burned rice husks or cloth); 2) chemical disinfection (including chlorine, generally in the form of sodium hypochlorite); 3) solar disinfection (SODIS) or disinfection by ultraviolet (UV) light; 4) bone-char filters; and 5) more “advanced” treatment methods such as reverse osmosis membranes that are used in homes in places like the United States. Review of evidence and of pilot testing and evaluation indicates each of these treatment techniques has advantages and disadvantages for appropriately treating drinking water in different settings.

After screening the literature, the biosand filter and chlorine were identified for further testing with the high-risk communities within the Njoro watershed. These POU units were selected to encompass the range of POU technologies available with special attention to extremely low cost, potential for local availability, and sustainability within the Njoro watershed. Unique reasons for selecting the biosand filter and chlorine were materials available locally to produce them or to purchase key inputs; effective removal of pathogenic organisms; and formation of a residual in the case of chlorine, respectively. Candle filters are also potentially appropriate for better off households, due to higher capital and recurring costs associated with regular candle replacement, and have been extensively tested

elsewhere. PUR was not to be explored further because of monetary constraints and availability. River Njoro water tends to be high in turbidity, thus SODIS was not a viable POU option.

Local public health technicians have been engaged to identify high-risk communities, communities with high diarrhea rates among children under the age of five. As a result of early engagement on these health issues with the Nakuru District Ministry of Health staff and director, the SUMAWA project has succeeded in gaining substantial commitments to this work in the form of dedicated three full-time public health technicians for the coming year to support the local testing, behavioral trials, and outreach and promotion of POU methods. This support has been formalized in a Memorandum of Understanding between the MoH, Nakuru District (DHMT) and the SUMAWA project.

Preliminary lab testing of BSF technology, experimental adaptation to local conditions taking into account sand characteristics and hydraulic loading rates has been conducted with leveraged funding at UC Davis this past year. Significant results regarding adjustments to sand processing and filter operation were identified to improve the variability of the treatment performance of the biological systems. Extended and confirmatory testing of results obtained at UC Davis in the lab is start this Fall 2006 at Egerton University in collaboration with the Civil and Environmental Engineering Department, and with the Public Health Technicians of the MOH.

Finally, experimental work to test the usefulness of new microbial source tracking methods based on genetic markers was conducted this past year in the Njoro watershed to identify if existing genetic probes for cattle versus human and other sources of fecal pollution could be identified. Control and river water samples were collected and processed in Fall 2006, and have been analyzed in the lab. Preliminary lab measurements indicate that these new genetic methods may have potential and promise for quantifying the contributing sources of fecal pollution in order to make more effective management decisions in controlling environmental pollution sources and public health risks from infectious fecal -borne pathogens for both humans

Table 2. Economic Activities by Gender

Main Economic Activity	Gender of the Respondent		Total
	Male	Female	
Crops Production	100	133	233
Livestock Production	17	15	32
Selling Timber	2	0	2
Vending food crops	1	6	7
Vending livestock	0	1	1
Formal employment	12	19	31
Casual employment	11	10	21
Running a kiosk/shop	7	9	16

and livestock. Further processing and analysis of laboratory results and their interpretation is planned for the coming year.

4.4 Quantify and interpret economics trade-offs and potential linkages to biophysical and stakeholder outcomes: Problem Statement and Approach. A major stumbling block in this activity remains the difficulty in effectively cleaning and managing the large-scale household data collected in previous years.

Progress. A concerted effort was made in the past year to finalize the data cleaning effort with a thorough revisiting of the issue and a large-scale data re-entry and follow up error checking procedure. Following from recommendations after the error checking of the original data set in early 2005, the entire data set was re-entered during late 2005 and early 2006.

Central to this effort was the amalgamation of separate data sets into a single “master” data set – amalgamation was required because there had been three people working on data entry and each of their data sets had to be reconciled to make a single complete data set. This task was completed in April 2006, and a copy of the resulting data was sent to researchers in both the US and Kenya. A coded questionnaire was developed (i.e. post coded) to help students and faculty navigate around the new data set. A “final” version of the new codebook was created,

although it remains likely that as additional data cleaning continues, minor alterations and updates will be needed to this document. Preliminary analyses from these data sets have focused on data assessment and descriptive statistics. For example, Table 2 shows the dominant economic activities broken down by gender. These data provide a window into preliminary gender-based assessment of strategic interventions that will be important for the successful adoption of planned interventions.

Additional secondary data sources have been identified and acquired to supplement the household data sets. The Njoro agricultural field office has supplied the SUMAWA project with agricultural input and output quantities for many areas of the Njoro watershed. The project has contracted with these officers to supply these data to us.

Due to the considerable efforts and delays associated with cleaning and managing the available data, the anticipated economic modeling efforts were placed on hold as personnel and budgetary resources were redirected. Econometric and simulation models for 2005 for the Machakos region have been acquired and may serve as templates for future research in this area. Current efforts are focused on identifying areas of commonality/differences between those models and those likely needed for the Njoro region.

GENDER

Gender activities in the SUMAWA project are focused on 3 levels. The first level is the inclusion and significant participation of women in the project. Of the 8 PhD-holding research scientists on this project, 3 are women. In the past year we made a strategic decision to include the Gender and Mainstreaming Specialist (Dr. Lois Chiuri) in all management meetings and provide her with a full voting right on project management decisions as a way to ensure that the role and importance of gender was given prominent status and management authority in the project. In addition, there are several women holding positions of responsibility in research, and acting as graduate students. SUMAWA is committed to identifying and recruiting capable women, especially in areas that are historically under-represented. For example, women are in leadership

roles (co-PI status) in engineering and economics, fields in which women are under-represented. In addition, a female PhD graduate student at the University of Wyoming is pursuing her degree in the realm of GIS and uncertainty modeling, while a PhD student at UC-Davis is working on her degree in engineering and human health. Gender equity at the student level is a focus of the team, and to date we have had two female Kenya graduate students work on the project, and are actively seeking women for the coming project years.

The second level of gender activities concerns the collection and analysis of field data. In the last year SUMAWA team collected sex-disaggregated data. In the coming year analyses will continue related to gender roles and the identification of sex-based economic opportunities or barriers. SUMAWA research findings show that women in the River Njoro Watershed are centrally responsible for domestic water supplies, family health and hygiene, firewood collection, and carry out important roles in both farm and non-farm household income production activities that have implications for the sustainability of watershed resources. Furthermore, a larger portion of poorer households in rural and urban areas tends to be women-headed, further illustrating the importance of building gender and sex-based analyses into economic analyses.

The third level of gender activities relates to stakeholder engagement and research linkages in the communities. The SUMAWA project was instrumental in the formation and establishment of the River Njoro Water User Association. During the formation of the Association, it was mandated that each community elect three representatives, including a woman and a young person, so as to ensure that a variety of voices and representative viewpoints were present and accounted for in watershed decision making. Exposure visits and planned outreach activities are constructed so as to encourage the participation of women, and stakeholder training workshops assure that diverse stakeholder interests, perspectives, and impacts, particularly for poor households, are represented in developing interventions and management plans for the watershed.

POLICY

One of the primary research thrusts in this project is stakeholder involvement and outreach. The problems inherent to the Njoro were initiated at the highest levels of government in the form of political favor for support. Thus, the question of public policy involvement is central to understanding the mechanisms controlling land tenure, management, and stewardship. In the past year we established formalized research and outreach Memoranda of Understanding with key policy makers in the watershed: the Water Resources Management Authority (WRMA); and the Nakuru District Health Management Team (DHMT). By linking with WRMA we were able to play a key role in community mobilization to form a water users' association (River Njoro Water User Association; RN-WRUA). The RN-WRUA now serves as the entry point to the watershed communities and has strong and formalized ties to the SUMAWA project and WRMA.

Outreach through personal communication and networking is ongoing in Kenya, and the host country PI and co-PIs as well as the Project Manager have served as science ambassadors to land managers, politicians, and policy makers. Long-term efforts are aimed at establishing professional relationships with policy makers beyond just those in the watershed, including at the National or International level, including NGO's and the Ministry of Water. In the past year, SUMAWA lead scientists (including Drs. Miller, Gichaba, and Shivoga) met with representatives of the locally active NGO's to discuss ways in which formalized relationships can be established. To date, Drs. Shivoga and Semenyé have been particularly active in meeting with interested parties, both at Egerton and in Nairobi.

OUTREACH

The primary point of contact for outreach efforts is the RN-WRUA, which was established to serve as the main point of contact between watershed communities and the scientific and policy actors in the region. Central to the successful implementation of interventions is identifying key stakeholders

and policymakers that are in positions of authority (whether that be moral, ethical, or managerial) and ensuring that they are committed to the success of the proposed intervention. We have been actively involved in providing learning opportunities for local stakeholders and land managers, including hosting a 5-day workshop within the watershed.

A series of billboards have been placed at watering sites along the River Njoro clearly identifying the risks associated with utilizing the river water for consumption due to its poor quality. Other advisory boards are planned on the improvement of the watershed health. These boards are in English and Kiswahili, and in the local language where appropriate.

DEVELOPMENTAL IMPACT

Environmental impact and relevance. There are two identifiable indicators we are using in the pursuit of the overall objectives of SUMAWA: (1) a research goal to improve the understanding of biophysical and social dynamics governing watershed health in rural areas; and (2) a development goal to improve the health of threatened/degraded upland watershed systems in East Africa on a productive and sustainable basis. The Njoro watershed system is fragile and has direct impacts on the ecological integrity of Lake Nakuru, a RAMSAR wetlands site of international importance. The upper reaches of the watershed extend into the forested reaches of the Mau escarpment. These forested areas, which have only recently lost their protected status, provided valuable stability to the ecological and watershed health of the region. The primary biophysical research areas in the SUMAWA project are watershed hydrology and ecology, both of which are focused on quantifying environmental health, and providing information to decision makers in order to maintain proper functioning condition. A suite of environmental models are being developed to better understand the environmental system as a whole. The Njoro watershed will provide a template for integrated multiple objective decision-making in which environmental concerns are weighed in consideration with human-related issues such as economics, human health, and off-site impacts.

Strategies for improved watershed conditions serve as principal intervention options. Examples include agriculture conservation practices, especially on steep slopes, improved riparian conditions for stream buffering, improved agricultural and grazing practices to reduce erosion and improve infiltration and groundwater recharge, and the application of agroforestry practices in sensitive areas.

Agricultural sustainability. One of the most significant concerns regarding the local and future condition of the Njoro watershed is the sustainability of agricultural practices. Evidence suggests that even recent immigrants are concerned with soil sustainability and the future of agriculture in this region. A lack of economic and agricultural system diversity is present in the watershed, which increases the vulnerability of the residents to economic downturns associated with agriculture. A series of sustainable practices, best management practices, and potential alternatives to present cropping systems, have been identified within the watershed and are being investigated for their potential adoption at a larger scale. Examples include agroforestry, soil conservation practices, pond aquaculture, and increased variability in crops, including the reintroduction and harvest of indigenous plants.

Biotechnology. This project does not have any component related to biotechnology.

Contributions to U.S. agriculture. It has long been recognized that water resources and their effective use and management for long-term sustainability are crucial to economic, human health, and environmental stability. This statement applies with equal validity to Kenya and the US. The problems facing residents of the Njoro watershed are undoubtedly more critical than those in developed nations such as the US, but parallels exist nonetheless. For example, the watershed is comprised of a mixture of stakeholders with a variety of complementary and competing interests, including agriculture, livestock grazing, business, residents, and the environment itself. Land cover is rapidly changing due to population pressures and policy decisions with resultant negative off-site impacts. Land managers and policy makers such as the BLM, State Departments of Environmental Quality, the USFS, and the National Park Service,

are charged with managing resources with both a multiple use and sustainable yield mandate, often in locations similar to the Njoro where competing interests create difficulties for the land manager.

The primary potential benefits to the US that will evolve from the SUMAWA project surround contributions in knowledge to U.S. agricultural systems. Management of landscapes, including rural areas in the United States has been shifting to a watershed-based approach. Land management agencies, including the US-EPA, NRCS, and BLM are moving resources and quantitative tools to the watershed scale in order to comply with both Federal regulations and to maintain a strong scientific footing in terms of understanding upstream-and downstream linkages in environmental health.

Contributions to host country. The Njoro watershed has been established as an experimental watershed with the addition of continuous monitoring stations for rainfall and runoff. These monitoring stations provide the means to use cutting-edge tools and models for scientific assessment and land management. There is a significant training component for Kenyan students and researchers and we recognize and maintain that successfully training students in integrated and sustainable research and decision-making will be beneficial to Kenya. An integrated decision support tool will be developed that will describe the processes governing watershed health and response to changes in land management and tenure. These tools will provide a scientific basis to interested parties, such as land managers, policy makers, and local residents interested in understanding their physical environment.

A series of interventions for the improvement of economic stability, ecologic health and hydrologic resources are planned. These interventions include demonstration plots for pond aquaculture, agroforestry, alternative agricultural practices, and water distribution. It is anticipated that these interventions will have a localized beneficial impact. An outreach component will be implemented that links local landowners to the planned interventions so as to facilitate their adoption on other regions of the watershed that would have a larger-scale impact on watershed health. A school-based outreach and education component will introduce schoolchildren

to land stewardship and environmental awareness.

Linkages and networking. The SUMAWA team has formally enjoined the Rift Valley Water Resource Management Authority, the River Njoro Water User Association, and the Nakuru District Health Management Team as collaborative partners. Memoranda of Understanding have been signed in order to cultivate long-term working relationships. The SUMAWA team has built local community linkages through the process of stakeholder engagement (PRA), and will serve as a link between the Authority, researchers, and community leaders to aid in the creation of the watershed user's group with the goal of enhancing both local knowledge and management of their system for long-term sustainability under the newly emergent Kenya law.

Collaboration with international research centers (IARCS) and other CRSPs. The SUMAWA project was initially founded through a joint effort with the Aquaculture and Global Livestock CRSPs. The formal agreement with the A-CRSP has not been maintained, but members of the research team are active with the CRSP and we have incorporated pond aquaculture into the project as a potential intervention for enhanced income and a component of the sustainable development plan. Fish demonstration ponds at Egerton University affiliated with the project attract visitors from and outside Nakuru District. The visitors are brought by Kenya Fisheries Department officers, who use the ponds for outreach and extension purposes.

In addition, a formal agreement with the Trade-off project led by John Antle and funded by the Soil CRSP is a direct outcome of the activities of the previous year. Future research directly builds on this relationship and project outcomes and activities are tied directly to the collaborative effort with this project.

OTHER CONTRIBUTIONS

Support for free markets and broad-based economic growth. Research and development as approached by the SUMAWA team is directly targeted to account for the significant and cornerstone role agriculture plays in Kenya's prospects for long-

term economic stability and sustainability. We are working with local agencies and community groups to create a comprehensive watershed plan in support of sustainable development. While the upper portion of the watershed lacks an agribusiness sector, the lower sections of the watershed are dominated by larger farms and trend towards a more urban setting; in the coming year we are targeting a better understanding of and linkage with these groups. Private enterprise and access to markets are key components of our economic development and sustainability modeling efforts. It has been clearly recognized that access to free markets and a market-driven economy with effective techniques for responding to macro-scale economic forcing is extremely supportive of rural economic development, and is a constraint in the Njoro watershed. Economic analyses and stakeholder engagement in the successful adoption of effective land management and farming practices are core constituents of our integrated modeling and decision support framework.

Contributions to and compliance with Mission objectives. The SUMAWA project is directly in line with the primary USAID/Kenya natural resources program objective, which is to prevent unsustainable natural resource management and enhance conservation. Our focus influencing change through integrated science and stakeholder engagement is aligned with the Mission's approach. The Mission supports initiatives aimed at natural resource management with a focus on activities that are included in the SUMAWA scope of work, including watershed management, soil conservation, and agroforestry. The SUMAWA goals are also in line with the Mission's agriculture support objective, which promotes enhanced stakeholder dialogue and outreach for improved agricultural production.

Concern for individuals. This project is aimed primarily at improving watershed condition through stakeholder interactions. These stakeholders comprise multiple tiers of scale and influence, from land managers to business owners and the individual landowner. Interventions planned in this project are concerned with improving livelihoods and directly benefiting residents. The structure of the stakeholder engagement is specifically designed to facilitate and understand rationale behind decision-making at the

household scale.

Support for democracy. One of the essential components of a free and democratic society is an informed public. Individuals, communities and institutions should be aware of governance and decision making that impacts their lives. More importantly, people should be empowered with an opportunity to make themselves heard and participate in the decision-making process. This project contains these essential ingredients, as we are disseminating both research findings and policy acts that govern watershed dynamics directly to resident stakeholders. We have an education and outreach component operating in the local school system as a mechanism for increasing education, awareness, and participation.

Humanitarian assistance. Humanitarian assistance need not be solely restricted to immediate distribution of aid. In our case, we are providing assistance in the form of information exchange and suggestions for improving livelihoods. These suggestions are intended to enhance human health, economic condition, and reduce the exposure and risk of watershed residents to seasonal and political fluctuations. These approaches are designed to reduce long-term negative impacts and reduce rural poverty.

LEVERAGED FUNDS AND LINKED PROJECTS

The total value for leveraged funds for the SUMAWA project during 2006 was \$68,060. The sources of those funds were as follows:

Jim Ellis Mentorship Program for Graduate Students, Development and Trial of Point-of-Use Treatment Systems to Improve Drinking Water Quality in High Risk Communities of the River Njoro Watershed, Kenya, 10/2005-9/2006, \$2,980.

Niels Riegel, water resources modeling capacity building and WEAP21 training, 5/2006-7/2006, \$22,000.

UC Davis Department of Civil and Environmental Engineering, undergraduate student engineering laboratory assistance with POU experimental testing, 4/2006-9/2006, \$3,500.

UC Davis Department of Civil and Environmental Engineering, graduate student support for S. Tiwari, 10/2005-5/2006, \$5,000.

UC Davis Department of Civil and Environmental Engineering, laboratory supplies, equipment, and materials for POU experimental lab testing and research, 1/2006-9/2006, \$7,000.

Granite Construction, donation of sand for BSF filter manufacture and testing, Spring 2006, \$150.

City of West Sacramento Water Supply Treatment Plant, loan of equipment and technical assistance with collection, transport, and storage of raw Sacramento River water for POU experimental lab testing and research, 4/2006-9/2006, \$350.

Ministry of Health-Nakuru District, contribution of 3 public health technicians' salary and benefits, 10/2005-9/2006, \$2,800.

University of Wyoming Graduate School, linkage with high school teaching, 9/2006, \$4,280.

NASA Space Grand Consortium, Univ. of Wyoming, graduate student support for T. Baldyga, 10/2005-5/2006, \$20,000.

University of Wyoming Graduate School, graduate student support for T. Baldyga, 6/2006-9/2006, \$500.

TRAINING

Degree Training

Completed

Bett, Eric. Kenyan, M, Egerton University, Agricultural Economics, MSc.

Kiragu, Joseph. Kenyan, M, Egerton University, Environmental Science, MSc.

Mainuri, Gichuru. Kenyan, M, Egerton University, Geography, MSc.

Njeri, Mary. Kenyan, M, Egerton University, Food and Science Technology, MSc.

In Progress

Baldyga, Tracy. American, F, University of Wyoming, Rangeland Ecology & Watershed Management, PhD.

Huckett, Stephen. American, M, Utah State University, Forest, Range, and Wildlife Sciences, PhD.

Enanga, Eric. Kenyan, M, Egerton University, Hydrology, MS.

Ogalleh, Sarah. Kenyan, F, Egerton University, PRA-Stakeholder, MS.

Ngige, Macharia. Kenyan, M, Egerton University, Hydrology, MS.

Jepyegon, Emily. Kenyan, F, Moi University, Ecology, MS.

Ngugi, Milka. Kenyan, F, Egerton University, Ecology, MS.

Tiwari, Sangam. American, F, UC Davis, Hydrology, PhD.

Macharia, Simon. Kenyan, M, Egerton University, Ecology, MS.

Jackson, Heather. American, F, UC Davis, Civil Engineering, BS.

Janolo, Martin. American, M, UC Davis, Civil Engineering, BS.

Kanninen, Morgan. American, F, UC Davis, Community and Regional Development, BS.

Chao, Hong Yu. American, M, UC Davis, Civil Engineering, BS.

Zeng, Fuxiong. American, M, UC Davis, Civil Engineering, BS.

Zollinger, Ashley. American, F, UC Davis, Civil Engineering, BS.

Lorente, Mario. American, M, UC Davis, Microbiology, PhD.

Non-Degree Training

Bio Sand Filter Construction Training, September 20-26, 2006. Attended by 8 participants (7 male and 1 female).

Seminar entitled: Drinking Water Quality Improvement, September 20, 2006 at Egerton University. Facilitated by Ms. Sangam Tiwari. Attended by 15 participants (11 male and 4 female).

Awareness and Leadership Workshop Towards Formation of River Njoro, May 31, 2006-June 4, 2006. Attended by 64 participants (49 male and 15 female).

GIS and DATA Management Training, Januray

10-12, 2006 at Gate House in Nakuru. Attended by 13 participants (9 male and 4 females).

Workshop on Water Evaluation and Planning Model (WEAP) by Eng. Niels Riegels and Dr. Marion Jenkins, May 18, 2006 at Egerton University. Attended by 23 participants (19 male and 4 female).

Water Evaluation and Planning Model (WEAP) Training by Eng. Niels Riegels, held weekly from late march through mid June 2006, for 10 weeks at ERMIS Africa in Nakuru and at Egerton University. Attended by 10 participants (9 male and 1 female).

COLLABORATING PERSONNEL

Kenya

Akula, Zakayo. Egerton University, Administrator, Project Administrator
Chiuri, Lois. Egerton University, Gender Studies, PhD, Senior Lecturer
Inoti, Shadrack. Egerton University, Agroforestry, MS, Assistant Lecturer
Kariuki, Apollo. Kenya Wildlife Service, LS Ecologist, MS, Senior Researcher
Lelo, Francis. Egerton University, Stakeholder Involvement, PhD, Professor/Dean
Liti, David. Moi University, Fisheries, MS, Lecturer
Macharia, Simon. Kenya Fisheries Department, Aquaculture, BS, Biologist
Maina-Gichaba, Charles. Egerton University, Geography, Hydrology, PhD, Senior Lecturer/Head
Muchiri, Mucai. Moi University, Aquatic Ecology, PhD, Professor
Muhia, Njeri. Egerton University, Social-Economics, MS, Lecturer
Ndivo, Mary. Egerton University, Secretarial, Diploma, Admin. Assistant/Secretary
Ouma, Desterio. Egerton University, Economics, PhD, Senior Lecturer/Head
Semenye, Patterson. Egerton University, Animal Scientist, PhD, Project Coordinator
Shivoga, William. Egerton University, Ecology, PhD,

Senior Lecturer/Head

Were, Jacynter. Water Resource Management Authority, Social Mobilizer, Diploma, Water Bailiff

United States

Dalles, Laura. University of Wyoming, Renewable Resources, BS, Project Coordinator
Darby, Jeannie. University of California, Environmental Engineering, PhD, Professor
Jenkins, Marion. University of California, Water Resources/Public Health Engineering, PhD, Assistant Research Engineer
Lund, Jay. University of California, Water Resources Engineering, PhD, Professor
Miller, Scott. Egerton University, Watershed Management / Hydrology, PhD, Assistant Professor
Mooney, Sian. University of Wyoming, Agricultural and Applied Economics, PhD, Assistant Professor
Wuertz, Stefan. University of California, Environmental Engineering/Microbiology, PhD, Professor

COLLABORATING INSTITUTIONS

United States

Department of Renewable Resources
University of Wyoming
P.O. Box 3354
Laramie, Wyoming, USA 82071-3354
Telephone: 307-766-3114
FAX 307-766-6403.

Department of Agricultural and Applied Economics
University of Wyoming
P.O. Box 3354
Laramie, Wyoming, USA 82071
Telephone: 307-766-2386
FAX 307-766-6403.

Department of Civil & Environmental
Engineering
University of California, Davis
One Shields Avenue
Davis, CA, USA, 95616
Telephone: 530-752-0586

Department of Forest, Range, and Wildlife
Sciences
Utah State University
5230 Old Main Hill
Utah State University
Logan, UT 84322-5230

Department. of Agricultural and Applied
Economics
Montana State University
P.O. Box 172920
Bozeman MT 59717-2920

Kenya

Department of Environmental Science
Egerton University
P.O. Box 536
Njoro, Kenya
Telephone: 254 – 37 – 62185,

Department of Fisheries
Moi University
P.O. Box 3900
Eldoret, Kenya
Telephone: 254-321-63111

Kenya Fisheries Department
P.O. Box. 12912
Nakuru, Kenya
Telephone: 037 41123/4, 0733 705634

Kenya Wildlife Service
Lake Nakuru National Park
Nakuru, Kenya.

Rift Valley Water Resource Management Authority
Telephone: 254-512216169/+254-733861333
Email: rvca-wrma@africaonline.co.ke

Nakuru District Medical Officer of Health
Heath Management Team Nakuru
P. O. Box 1214
Nakuru, Kenya

PUBLICATIONS

Manuscripts and Reports

Baldyga, T.J., S.N. Miller, K.L. Driese, R. Sivanpillai, and C. Maina Gichaba, 2005. Enhanced land cover classification in a tropical Kenya landscape. Proceedings of Pecora 16: "Global Priorities in land Remote Sensing". October 23-27, 2005, Sioux Falls, SD.

Kibichii, S., W.A. Shivoga, M. Muchiri, and S.N. Miller, 2005. Physico-chemical Characteristics of Streams Draining into Lake Nakuru in relation to their Watershed Landuse. Proceedings of the 11th International Conference on the Conservation and Management of Lakes, 31 October to 4 November 2005, Nairobi, Kenya. Volume II: 411-426

Krupnik, T. M.W. Jenkins, S. Mooney, and E.K. Bett, (in press). "Net Present Value Analysis to Assess the Economic Consequences of Changing Farming Systems in the Upper Catchment of the River Njoro Watershed". Peer-reviewed paper accepted to the Tenth Biennial Scientific Conference & Agricultural Forum, Kenya Agricultural Research Institute. 12 – 17 November 2006, Nairobi, Kenya

Maina-Gichaba, C., W. A. Shivoga, E. M. Enanga, S. Kibichii and S. N. Miller, 2005. Sediment Loading on Inland Lakes/Wetlands: A Case Study of Lake Nakuru, Kenya. Proceedings of the 11th International Conference on the Conservation and Management of Lakes, 31 October to 4 November 2005, Nairobi, Kenya. Volume II: 389-392.

Milkah, F.N., W. A. Shivoga, Mucai Muchiri and S. N. Miller, 2005. Effects of Land Use Changes on Birds Composition along River Njoro: A Watershed of Lake Nakuru. Proceedings of the 11th International Conference on the Conservation and Management of Lakes, 31 October to 4 November 2005, Nairobi, Kenya. Volume II: 540-544.

Miller, S.N., T.J. Baldyga, C. Maina Gichaba, 2006. Hydrological modeling in the Njoro watershed, Kenya: assessing the impacts of land cover

change on watershed hydrology. Proceedings of the AWRA Conference on Geographic Information Systems (GIS) and Water Resources IV, Houston, Texas, May 8-10, 2006.

Okelo, M.O., J.O. Onyando, W.A. Shivoga and S. N. Miller, 2005. Analysis of Surface Runoff and Soil Loss under different Land Use Types in River Njoro Watershed Using a mini Rainfall Simulator. Proceedings of the 11th International Conference on the Conservation and Management of Lakes, 31 October to 4 November 2005, Nairobi, Kenya. Volume II: 446-450.

Riegels, N., 2006. "Njoro Watershed Population Estimates" Technical Memorandum to WEAP Njoro Modeling Team, SUMAWA Project. 21 June 2006. (Final)

Riegels, N., 2006. "Surface water hydrology development for WEAP Njoro Model" Technical Memorandum to WEAP Njoro Modeling Team, SUMAWA Project. 21 June 2006. (Final)

Shivoga, W.A., M. Muchiri, S. Kibichi, J. Odanga, S.N. Miller, T.J. Baldyga, C. Maina Gichaba, 2005. Impacts of upland land use on downstream water quality in River Njoro Watershed, Kenya. Proceedings of the 11th International Conference on the Conservation and Management of Lakes, 31 October to 4 November 2005, Nairobi, Kenya. Volume II: 472-476.

Theses

Bett, K. E. 2006. Socio-economic and Biophysical Factors Influencing Land Use: A Case Study of River Njoro Watershed, Nakuru District, Kenya. Ms Thesis Egerton University, Kenya.

Kiragu, J. M. 2005. Trends. Local Perceptions and cost of waterborne Diseases in River Njoro watershed, Nakuru District. Ms Thesis Egerton University, Kenya.

Krupnik, T.J. 2006, Linking Farmer, Forest and Watershed: Agricultural Systems and Natural Resources Management Along the Upper Njoro River, Kenya. University of California International and Area Studies Digital Collection, Article #3. <http://repositories.cdlib.org/uciaspubs/articles/3>

Mainuri, Z. G. 2006. Land Use Effects on the Spatial Distribution of Soil Aggregate Stability

within the River Njoro Watershed Kenya. Ms Thesis Egerton University.

Njeri, M.M. 2006. A Comparative Study on Growth and Nutritional Value of Farmed and Wild Nile Tilapia (*Oreochromis Niloticus*). Ms Thesis Egerton University

ABSTRACTS AND PRESENTATIONS

Baldyga, T.J. and S.N. Miller. (2006) Estimating the effects of land cover misclassification derived from remotely sensed imagery on distributed hydrologic models. University of Wyoming Graduate Student Symposium, 3 – 4 April, 2006.

Baldyga, T.J., S.N. Miller, K.L. Driese, R. Sivanpillai, and C. Maina Gichaba, 2005. Enhanced land cover classification in a tropical Kenya landscape. Oral Presentation at Pecora 16: "Global Priorities in land Remote Sensing". October 23-27, 2005, Sioux Falls, SD.

Jenkins, M.W., and N. Riegels, 2006. "Computer Models for Water Resources Planning: The WEAP Njoro Application" Seminar presented at SUMAWA Project public colloquium on water resources decision-support modeling tools. CMRT, Egerton University, Njoro, Kenya, May 18, 2006.

Kibichii, S., W.A. Shivoga, M. Muchiri, and S.N. Miller, 2005. Physico-chemical Characteristics of Streams Draining into Lake Nakuru in relation to their Watershed Landuse. Presentation at the 11th International Conference on the Conservation and Management of Lakes, 31 October to 4 November 2005, Nairobi, Kenya.

Kibichii, S., W.A. Shivoga, M. Muchiri, T.J. Baldyga, and S.N. Miller, 2006. Impact of landuse on the physicochemical characteristics and the structure of benthic macroinvertebrates of the upper River Njoro, Kenya. Environ06: 16th Irish Environmental Researchers Colloquium, Dublin, University College Dublin, January 2-8, 2006.

Maina-Gichaba, C. W. A. Shivoga, E. M. Enanga, S. Kibichii and S. N. Miller, 2005. Sediment Loading on Inland Lakes/Wetlands: A Case Study of Lake Nakuru, Kenya. Presentation at the 11th International Conference on the Conservation and Management of Lakes, 31 October to 4 November 2005, Nairobi, Kenya.

Milkah, F.N., W. A. Shivoga, Mucai Muchiri and S. N. Miller, 2005. Effects of Land Use Changes on Birds Composition along River Njoro: A Watershed of Lake Nakuru. Presentation at the 11th International Conference on the Conservation and Management of Lakes, 31 October to 4 November 2005, Nairobi, Kenya.

Miller, S.N., and H.R. Griscom, 2006. Watershed and River Management in Africa: Njoro Watershed, Kenya and the Luvuvhu River, South Africa. Invited speaker to Geography 4080: Management of Major River Basins, Univ. of Wyoming, Laramie, WY, March 28, 2006.

Miller, S.N., T.J. Baldyga, C. Maina Gichaba, 2006. Hydrological modeling in the Njoro watershed, Kenya: assessing the impacts of land cover change on watershed hydrology. Abstract and oral presentation at AWRA Conference on Geographic Information Systems (GIS) and Water Resources IV, Houston, Texas, May 8-10, 2006.

Okelo, M.O., J.O. Onyando, W.A. Shivoga and S. N. Miller, 2005. Analysis of Surface Runoff and Soil Loss under different Land Use Types in River Njoro Watershed Using a mini Rainfall Simulator. Presentation at the 11th International Conference on the Conservation and Management of Lakes, 31 October to 4 November 2005, Nairobi, Kenya.

Shivoga, W.A., M. Muchiri, S. Kibichi, J. Odanga, S.N. Miller, T.J. Baldyga, C. Maina Gichaba, 2005. Impacts of upland land use on downstream water quality in River Njoro Watershed, Kenya. Presentation at the 11th International Conference on the Conservation and Management of Lakes, 31 October to 4 November 2005, Nairobi, Kenya.

Tiwari, S. K., 2006. "Point-of-Use Water Treatment to Improve Drinking Water in the River Njoro Watershed." Seminar presented at SUMAWA Project public colloquium, CMRT, Egerton University, Njoro. Kenya, September 20, 2006.

Tiwari, S.K., 2006. "Point-of-Use Water Treatment for Improved Drinking Water in the River Njoro Watershed, Kenya." Research presentation at the California-Nevada Section Meeting of the American Water Works Association, Burlingame, California, April 24-28, 2006.

LEAD PRINCIPAL INVESTIGATOR

Scott N. Miller, Assistant Professor, University of Wyoming, Department of Renewable Resources, P.O. Box 3354, Laramie, Wyoming, USA 80271-3354, Tele: 307-766-3114, FAS 307-766-6403. Email: smiller@uwyo.edu.