



A report on the stakeholders Workshop on “A study of Hydrological Services in Sasumua Watershed”



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Highlights

Key findings of the hydrologic assessment:

- The Sasumua reservoir draws water from three sub-basins: the Sasumua sub-basin (67.4 km²), the Chania (20.2 km²), the Kiburu (19.3 km²). Approximately two-thirds of the water entering the Sasumua reservoir comes from the Sasumua catchment, which is primarily an agricultural area with very little conscious conservation efforts.
- Most of the physico-chemical parameters for water quality are within the acceptable guideline limits of the World Health Organization (WHO) for potable water. There is cause of concern, however. Water sourced from the forested sub-basins (Chania and Kiburu) is generally of higher quality than water coming from the Sasumua sub-basin. Samples from the Rivers Mungutio and Main Sasumua were the most polluted, with high loads of sediment and some heavy metals – iron, lead, magnesium and cadmium. There is no evidence of pesticide pollution. There is an urgent need to cross-check the results on heavy metals and to pinpoint the sources.
- From independence to the year 2000, the dominant trends in land use change were increases in areas of cultivation and degraded forest. Between 2000 and 2007, there was some recovery in forest condition and increase in woodlots in the agricultural area. Suspending the shamba system and implementing the ban on logging appears to be responsible for these changes. Horticultural production – cabbages, carrots, snow peas – is on the increase.
- The results indicate priority areas of addressing land degradation: around the reservoir itself where there has been heavy grazing pressure, in parts of the Mungutio catchment that has pluvisol soils with difficult drainage and where constructed drains has been damaged, and in parts of the Little Satsuma watershed where road construction is ongoing. There is need therefore to implement soil conservation measures along the newly constructed Njambini-Engineer Road.
- Open grazing, especially along riparian areas has been identified as a major risk factor for land degradation.
- There is major cause for concern about the threat of pollution from uncontrolled settlements in the Sasumua catchment, especially in the new parts of Njabini township that are outside of the leasehold area managed by the county council.
- The water sources that drain into the Sasumua reservoir appear to be drying up. Water abstraction for horticultural and eucalyptus production may be a major cause of this problem.

Important elements of the forum itself:

- Over 40 people participated in the stakeholders' workshop with most of them coming from quasi-government parastatals (e.g. Water Resource Management Authority (WARMA), Kenya Wildlife Service (KWS), Kenya Forest Service (KFS), National Environment Management Authority, Athi Water Service Board), research organizations (e.g. Jomo Kenyatta University of Agriculture and Technology and the World Agroforestry Centre), government agencies, Kenya Agricultural Productivity project (KAPP) and companies like Nairobi City Water and Sewerage Company (NCWSC). We also had the Kinangop Farmers Forum as well as Friends of Kinangop.
- Expressions of appreciation of the value of the research studies, especially from the WRMA, NCWSC, and the farmers' forum.

- When asked to respond to specific results, most participants endorsed the results as an accurate reflection of the situation in the catchment.
- Several organizations indicated strong concern about the results and indicated a commitment to take follow-up action.
- The stakeholders engaged in candid and open discussion, raising continuous issues, listening to different perspectives, and showing willingness to work with other stakeholders for mutual benefit.
- The presentation of results provided the basis for a very constructive dialog on the way forward.

Commitment to future action:

- Solid waste management and sewage are high priorities, particularly in the area around Njambini town and in some of the horticulture enterprises.
- There is a need for more detailed environmental audit and physical planning in and around Njambini town.
- Open grazing and tree harvesting in riverine areas and the forest reserve need to be more strictly controlled.
- Agricultural extension services should provide greater guidance to farmers in appropriate techniques for soil and water resource management.
- There is need to target interventions to the riparian areas, the little Sasumua, the areas around the reservoir, the overlay flow area to the north western part of the Sasumua Reservoir, and the new parts of Njambini town.
- Water abstraction for multiple uses – including horticulture and planting of fast-growing eucalyptus – is a major concern in the catchment with many stakeholders concerned that water supplies are drying as a result of over-abstraction.
- That ICRAF and partners work closely with Water Resources Management Authority to formulate Sasumua sub-catchment management plan which will provide a framework for addressing the identified problems as well as building a partnership for addressing the interventions.

A brief background

The proposed KAPSLM project aims at promoting sustainable natural resource use for higher productivity, increased incomes for rural farmers and sustenance of critical ecosystem functions in degraded and environmentally sensitive areas by (i) strengthening the enabling environment for SLM (policy, regulatory and institutional strengthening); (ii) building capacity for SLM; (iii) investing in community SLM micro-projects; (iv) supporting innovative incentive mechanisms; and (v) SLM program planning, monitoring, and evaluation.

This is the first phase of the 4th component of the KAPSLM project. The fourth component will explore and pilot different options that range from land use planning, environmental awareness raising, and investments in public service provision to enforcement of regulations. The Sasumua Water Treatment Plant downstream Njabini Township (Nyandarua South District) is owned by the Athi Water Services Board and operated by the Nairobi City Water and Sewerage Company (NCWSC). This plant supplies about 20 percent of Nairobi's potable water supply. It draws its water from three main rivers: the Sasumua, Chania (part of which is diverted via a diversion dam into a pipeline that flows into the Sasumua River), and the Kiburu (from which four intakes channel water into a pipeline that flows directly into the Sasumua reservoir). The Sasumua watershed covers 10,700 ha, about two-thirds of which is farmed by smallholders (mainly producing horticultural crops for the Nairobi urban market), with the rest being intervened forest reserve (which is used by many households to graze cattle and to collect fuelwood). The top end of the watershed borders the Aberdares National Park.

The main activities of this sub-component will include the following:

- (a) Conducting detailed technical studies to identify the specific causes of sedimentation and water contamination problems affecting the Sasumua Reservoir and its water intakes on the Chania and Kiburu Rivers (that is, specific land uses and their location in the catchment that contribute to sedimentation or contamination) and alternatives to reduce problems
- (b) Conducting socioeconomic evaluation of upstream areas to identify the specific land users who manage the land from which problems originate, and the incentives and constraints they face in making land use decisions
- (c) Establishing an appropriate institutional structure for the follow up research and monitoring, planning and investment, awareness raising and enforcement of regulations as well as implementation of any other remedial measures
- (d) Preparing a work plan for approval by key stakeholders in the water sector, including the Nairobi City Water and Sewerage Company, the Water Resources Management Authority, the Athi River Water Services Board, and the Ministry of Water for implementation of the recommendations of the study
- (e) Drawing lessons from the pilot and developing a replication and scaling-up strategy
- (f) Capacity building in the country and in key institutions.

While most of the activities under the 4th component will be implemented through the support of KAPSLMP, the Bank-Netherlands Water Partnership Program (BNWPP) provided Trust Funds that made the technical studies possible.

OBJECTIVE OF THE STUDY

During phase one data was collected and used to test and apply hydrological models to assess and quantify the nature, extent, severity and impacts of land degradation in the Sasumua watershed as well as tested hydrological models that could be applied more widely in Kenya and in the East African highlands. Erosion risk areas as well as highly polluted zones were isolated. An environmental audit was also undertaken to identify sources of pollution and provide a framework of addressing these challenges.

ACTIVITIES

Design and implementation of watershed management activities is often constrained by lack of data on how land use in the watershed affects downstream hydrological services. Lack of data often forces project designers to rely on conventional wisdom or crude back-of-the-envelope estimates of how land use changes would affect hydrological services.

The KAPSLM Project aims to move to a more systematic approach to developing appropriate watershed plans by (i) identifying the specific services of interest to downstream water users; (ii) carefully delineating the watershed from which service users obtain their water; (iii) identifying critical areas within the watershed that are (or potentially may) affect the provision of the desired services (e.g. areas prone to erosion that may be contributing to sedimentation of waterways); (iv) calibrating and validating hydrological models so as to be able to estimate the changes in watershed services that would result from land use changes. These activities require a concerted up-front effort, for which project preparation funds are insufficient.

The BNWPP funding has been used primarily in activities (ii) to (iv) in the above list leaving out the social/institutional tracks of the 4th sub-component of the KAPSLM project. The social and institutional tracks will mainly include: (a) undertaking surveys and focus group discussions of land users to understand the costs and benefits of different land uses and the constraints they might have in changing land uses; (b) examining institutional arrangements in the watershed to develop appropriate remedial measures; etc By freeing up resources that would otherwise be used for the technical analysis, BNWPP funding would thus allow a much better job of these social/institutional tracks. Specifically the BNWPP funding has been used to undertake:

SOA. Spatial overview and audit (SOA)

Activity: Recent advances in satellite image technology, Geographic Information Systems (GIS) and Remote Sensing (RS) software permit rapid acquisition, analysis, interpretation and display of spatial phenomenon at high resolution. A range of GIS/RS software, Landsat TM and ETM, high resolution Quick Bird imagery, topographic maps and recent population census data have been used to prepare a spatial overview of Sasumua watershed.

Based on the data generated by the spatial overview, a preliminary environmental audit was undertaken in order to identify major sources of water contamination in the river catchments and overland flow area.

Outputs: (1) digital maps of land use and land use change in the Sasumua catchment area; (2) maps of land tenure in the Sasumua catchment area; and (3) preliminary assessment of the importance of roads, market places, settlement areas, agriculture and forest management as sources of contaminants in the Sasumua catchment area.

LD. Land Degradation Assessments

Activity: The principal objective of Land Degradation Assessment (LD) was to assess and quantify the nature, extent, severity and impacts of land degradation and water contamination in the Sasumua Dam catchment. The study approach included ground surveys of soils and vegetation, laboratory analysis of soil samples and statistical analysis of land degradation risk. The field sampling protocol was based on a spatial stratification and sampling scheme that considers erosion and sedimentation risks, land tenure type, and major land use type.

Detailed description of activities:

- a) Established one sentinel site using standard land degradation surveillance protocol positioned over the Sasumua catchment. The standardized protocol provided geo-referenced information on vegetation and soil condition at least 160 randomized 1000-metre-squared sample plots. Within plots, observations were made on landform, topography, visible signs of soil erosion, land use, and vegetation type and cover, vegetation density and distribution, and soils depth; and top soil and sub soil taken. Vegetation type was classified using the Food and Agriculture Organization (FAO) Land Cover Classification System (LCCS), supplemented with woody biomass estimates. Single-ring infiltration measurements were made on a selection of plots. Soil samples were characterized by infrared spectroscopy and a subset of samples submitted for conventional soil fertility and carbon analysis.
- b) Conducted statistical analysis of ground data and satellite data, and mapping of soil condition index and erosion risk. Specified sustainable soil management strategies for different areas of the catchment.
- c) Plan to compile results into an electronic atlas.

Outputs: Map of land degradation hotspots for the Sasumua catchment area, analysis of the statistical relationship between land degradation status, land use, and land tenure, and identification of possible remedial actions to mitigation land degradation risks (e.g. use of vegetative filters).

HW. Hydrologic modelling and water quality assessment

Activity: The hydrologic modeling and water quality modules provide information on the linkages between land use, runoff, erosion and sedimentation and water contamination in the Sasumua catchment area. This information also allowed for the identification of likely erosion hotspots and sinks, and predictions of the likely hydrologic consequences of implementing new land uses or land use practices. The Soil Water Assessment Tool (SWAT2000), a distributed watershed model integrating both water and sediment yield, was used for the hydrologic modelling.

Two iterations of hydrologic modeling were planned. The first iteration made use of some of the outputs of the spatial overview modules, including the DEM, Land Use / Land cover, and stream network. Additional data on soils, rainfall, evaporation and sediment yield data was also acquired, partly from past and ongoing research on the Thika Catchment and from the Nairobi City Water and Sewerage Company's treatment works at the Sasumua Reservoir. This iteration of modeling was primarily used to identify landscape patches that are likely to be important sources and sinks of sedimentation and runoff: areas given extra attention in the LD module. In the second iteration, the model was updated with new information on actual sediment source and sinks as well as the rates of erosion and sedimentation associated with different types of land use in different parts

of the landscape. The model was then used to predict the likely impacts of possible interventions on runoff, sediment yield and water balance at the catchment scale.

Water quality assessment involved preliminary assessment of relative importance of sources of contamination from different sources (agricultural chemicals, livestock wastes, human waste and urban run-off). Collection and analysis of water samples to determine total suspended solids, total dissolved solids, pH, BOD, COD, DO, nutrients, trace metal and heavy metals, pesticides, PCBs, faecal coliforms, and faecal streptococci. The samples were collected at points along the rivers where there were distinct land use boundaries, (e.g. forest boundaries), at reservoir entry and outlet points, at the sides of reservoir and at selected points inside the reservoir located on the surface and below the surface as well as on the bed of the reservoir. Two sets of samples were planned for collection: one during the dry season and the other during wet season. This was followed by: i) analysis, interpretation and mapping of water quality results, including implications for water treatment costs and remedial measures; ii) analysis and interpretation of water quality parameters; iii) development, trial application and updating of pollution monitoring and analysis protocol.

Outputs: Preliminary and updated hydrological model of the Sasumua catchment; preliminary and refined identification of water and sediment sources and sinks; report with geo-referenced data on water quality in the Sasumua catchment; identification of major water quality concerns; quantitative estimates of the potential effects of alternative land management practices on erosion and sedimentation.

Community and other stakeholder involvement, and Training

As the final output is expected to benefit and be owned by the communities in the Sasumua watershed and other key stakeholders such as Nairobi Water Company, Athi Water Services Board, Kenya Forestry Service (KFS), NEMA and other policy makers, there is need for these stakeholders to be constantly informed and appraised as the work develops. In this regard, ICRAF and the KAPSLMP team have organized the stakeholders' workshop towards this end. A mini-stakeholders workshop was organized in the beginning of the project. The objectives of the stakeholders' workshop are to present the results of the different components and obtain review comments and feedback from key stakeholders.

- i) Elements for a catchment management plan will be presented;
- ii) Map products will be provided;
- iii) Key messages for environmental education and awareness raising will be synthesized; and
- iv) Preliminary electronic atlas will be available for stakeholders.

Based on the outcomes of this stakeholders' workshop, ICRAF and partners will pursue capacity building initiatives to enhance implementation of remedial measures.

Outputs: Two reports on the stakeholders' meetings will be produced. The reports shall indicate the issues raised by the stakeholders and the proposed solutions, the involvement of the stakeholders in the overall assignment and their level of involvement in the future. A plan for awareness raising as well as catchment management will be developed

D. Summary of the key results so far

Some of the interesting results based on the debriefing meeting included *inter alia*:

- A set of spatial priorities based on existing data relative to erosion and sedimentation risk;

- High turbidity of water samples collected in different water sources indicated that some rivers are polluted-Mungutio River is highly polluted with non observable elements like lead, iron and cadmium being detected. Cadmium was detected at River Mungutio entry to the Sasumua Reservoir;
- Results on settlement/land tenure patterns during different the pre-independence and post-independence periods;
- Attempts have been made before to provide water to the local communities but without much success;
- Hydrological units/sub-basins have been mapped which can be used as land use planning and management units.

Programme

The programme of the stakeholders' workshop was designed in such a manner that stakeholders were able to listen to presentations on different components of the study and therefore set the stage for discussions. Between presentations, five minutes was a lot for questions and clarifications. Stakeholder perspectives were solicited after presentations, plenary discussions and group work. This provided an opportunity for the different stakeholders, having listened and participated in the discussions, to highlight how they have benefited and how ICRAF, partners and their institutions can work together on the next steps.

Time	Presentation	Presenter/person Responsible
Thursday 26, 2009		
08:00–09:00	Registration of workshop participants	Catherine Kimengu
Workshop Opening		
Chair: Thomas Yatich T.B.		
Rapporteur: Vanessa Meadu		
09:00-10.00	Opening Speeches from: <ol style="list-style-type: none"> 1. Dr. Brent Swallow, Principal Investigator of the Project; 2. Ms. Agatha Thuo, Coordinator, KAPP District Service Unit, Nyandarua District 3. Mr. Bernard Okumu-Oloo, District officer I, Nyandarua South District (Representative of the District Commissioner) 	
10.00-10.30	Coffee/Tea	
Spatial overview, land degradation and water resource assessment		
Chair: John Mwangi		
Rapporteur: Thomas Yatich/Miika Makela		
10:30-11:00	<i>Land use and land tenure analysis</i>	Meshack Nyabenge/Leah Onyango
11:00-11:30	<i>Assessment of land degradation</i>	Brent Swallow
11:30-12:00	Hydrological modeling	Gathenya Mwangi

Time	Presentation	Presenter/person Responsible
12 :00-12 :30	Water quality assessment	Thuku Thiongo
12:30-13:00	Discussions	Brent Swallow to Facilitate
Setting stage for the next steps		
Chair: John Mwangi		
Rapporteur: Isabel van de Sand/Vanessa Meadu		
13:00-14:15	Preliminary audit of the sources of contaminants	Thomas Yatich
14:15-15:00	Lunch Break	
Moving towards catchment level planning and the nest steps		
Chair: Dr. Brent Swallow		
Rapporteur: Vanessa Meadu/Isabel van de Sand		
15:00-15:30	Reactions/Remarks by Invited Guests	
<ol style="list-style-type: none"> 1. Mr. Vincent Nyingi Ndiritu, Former Dam Superintendent and Resident Engineer, Sasumua Dam 2. Ms. Mary Mugo, Representative of the PS, Ministry of Agriculture 3. Mr. Geoffrey Wachira, Water Resources Management Authority (WRMA)The PS, Ministry of Water 4. Mr. Peter Mwaura Muhia, Sasumua Dam Coordinator, NCWSC Sasumua Water Treatment Works 5. Mr. Sammy Mbage, the Coordinator, Farmers Forum 		
15:30-15:45	Moving towards catchment level Planning	Brent Swallow
15:45-16:30	Group 1: Follow up research and monitoring Facilitator (s): Dr. Gathenya Mwangi Rapporteur : Isabel van de Sand	
	Group 2: priorities for planning and investment Facilitator (s): Leah Onyango/Richard Vonza Rapporteur : Miika Makela	
	Group 3: priorities for awareness and enforcement of regulations Facilitator (s): Thomas Yatich/Lydia Karanja (DEO) Rapporteur : Vanessa Meadu	
16.30-17.00	Report back from group discussions and closing of the workshop	
Friday 27,2009, 9:30am: ICRAF Boardroom A Taskforce working to finalize on the workshop proceedings and other outputs including a draft catchment Management plan World Agroforestry centre, Gigiri ICRAF Core Team, Rapporteurs and Leaders of the different project components		

Key messages from opening speeches

Thomas Yatich (of ICRAF) welcomed the participants and asked them to introduce themselves. He gave an overview of the KAPP-SLM Project and explained how ICRAF is working with KAPP-SLM to understand the links between what is happening in upstream areas and their impacts on hydrological services. He indicated that ICRAF, Jomo Kenyatta University of Agriculture (JKUAT) has build a strong evidence base and that some of the results that will be presented during the workshop included *inter alia*: watershed delineation, land degradation analysis, hydrological modeling, water quality assessment and an environmental audit to look at sources of pollution.

Ms. Agatha Thuo spoke on behalf of KAPP. She highlighted how the Nyandarua South area is very key for achieving environment and livelihood objectives. Food security is also an important concern in the area. She stated that KAPP's support towards working as a community to achieve these objectives.

Dr. Brent Swallow (ICRAF) stated that the stakeholders' workshop is "the single most important day" of the work that ICRAF is doing in Sasumua. He stated ICRAF's commitment of sharing information with all the stakeholders and having stakeholder input to determine next steps in the project. He asked stakeholders to appreciate what a "special place" the Sasumua catchment is. It is home to many people, provides runoff to Sasumua reservoir, and also the source of the Tana which drains down to the Indian Ocean. It's the source of water for the city of Nairobi, for industries, for agricultural areas, and to dams which provide Kenya's 80% of electricity.

He asked how we can ensure the survival of this "lifeline"? He gave examples of other places and situations where authorities make regulations to prevent people from living in sensitive areas. However he stated that ICRAF knows there are better ways for the people who have stakes in the lifeline to work together towards improving it. Sasumua is a special case with many opportunities for new approaches and arrangements for good management. After ICRAF builds a good understanding of the biophysical context, the scientists will work to understand the social, institutional and economic processes.

The Deputy for the District Commissioner, Mr. Oloo B. Okumu emphasized the importance of Sasumua catchment and the Aberdares forest. He outlined the different threats to the landscape including illegal logging and encroachment, and outlined the elements of the baseline analysis being conducted. He stated that the scientists must translate the results in a way that the local farmers can understand what it means to them for future agricultural productivity.

From this discussion, he expects that the stakeholders start to think carefully about the results and implications. He hopes to hear many diverse ideas and views and heated debates and emphasized the need for active participation.

Abstract of presentation

Land use analysis

The purpose of the land use sub-component was to gather and produce spatial data from the project area. The spatial datasets provided input for other technical studies, such as hydrological modeling of the Sasumua catchment. A key output was also the spatial land use change data set comparing the years 1985 and 2007. This dataset highlights hotspots of forest cover and agricultural land change. A time series of land use/cover maps from

the years 1985, 1995, 2000, and 2007 was produced using Landsat ETM and ASTER imagery.

Key findings of the spatial component include the following:

- 1) There has been harvesting of timber in the catchment driving land use change.
- 2) Degraded forests were detected (former *shamba* system areas) but they have remained fairly constant and rehabilitated - attributed to the enforcement of the law (the Forest Act, 2005 and the ban on the *shamba* system). There has been reinstatement of forests, which was detected from the time series land use/cover data. Area of forests has increased between 2000 and 2007.
- 3) Initially woodlots were converted into agriculture. As the government banned logging from the forests, the demand for timber increased. The risen demand was being met by farmers increasingly planting trees for commercial purposes, reinstating woodlots.
- 4) Agricultural area has also increased since 2000 at the expense of fallow land.

The main drivers for land use change in the catchment are population increase, intensified agriculture, land tenure issues, as the land is becoming increasingly freehold, and policy changes with the discontinuation of the *shamba* system.

Land Tenure in the Sasumua Dam Watershed

Mapping land tenure in the Sasumua dam watershed involved collecting data from the Ministry of Lands on past and present tenure status. The boundaries were obtained from the Survey of Kenya and the Physical Planning departments. Map products were produced showing land tenure in the pre-independence period (1964) and land tenure today (2008).

Pre-independence land tenure (1964)

The Sasumua watershed lies within the former “white highlands” which were set aside for exclusive European farming in the colonial era. The European settlers were allocated *agricultural leasehold land*. Within these regions land was also alienated for the development of urban settlements and forests. Land in the urban centers was allocated as *urban leasehold* while land identified for forest development was set aside as *forest reserve*. A dam site was identified and land set aside as *dam reserve* for the dam and a treatment plant. By 1955 the Sasumua dam had been constructed and was operational as a source of water for Nairobi city some 100 km away. In summary agricultural leasehold land occupied 49% of the watershed, urban leasehold 0.2%, the dam reserve 0.8% and the forest reserve 50%.

Post-independence land tenure (2008)

At independence the Kenya government embarked on a land redistribution programme whose objective was to involve local farmers in commercial agriculture. This led to the establishment of the settlement schemes. The leasehold farms were converted to *freehold settlement schemes*. They occupy 48% of the watershed. The town boundary remained the same but urban sprawl increased without corresponding change of user. *Urban leasehold land* occupied 1% of the watershed. The *forest reserve* boundaries remained the same (50%) while there was a small increase in the *Sasumua dam reserve* for expansion and it now occupies 1% of the watershed.

Land Degradation Assessment

Over the last ten years, scientists at the World Agroforestry Centre have developed an integrated set of methods for assessment of land degradation and soil health. These methods,

inspired by rigorous studies of human health surveillance, are suitable for scaling up from detailed ground-level measurements to national and regional levels. One of the key building blocks of the assessment is the fact that the reflectance properties of soils and vegetation are highly correlated with vegetation type and soil condition. These methods were applied in a 100 km² area overlaid with the Sasumua catchment, making it a sentinel site of a larger Africa-wide study of soil health. In the Sasumua setinel site, the field studies were done with assistance from the local Farmers' Forum. The Chairman and several members of the Farmers' Forum were directly involved in the field studies.

In the Sasumua area, 16 sample clusters were randomly located across the 100 km² area, and 10 sampling plots randomly selected within those 16 clusters. In each sample plot of 100 m², measurements were made of a number of soil and vegetation properties, and samples taken of surface and surface soil. Infiltration tests were done in 3 plots in each cluster. These samples and data are analyzed in the lab, with ground-level measurements scaled up to the landscape scale through analysis of satellite images.

A total of 312 soil samples were taken (surface soil and sub-soil) and analyzed using reflectance spectrometry, 48 infiltration tests done in the field (3 / cluster), recent ASTER and Landsat ETM satellite images of the area were acquired and analyzed, 64 soil samples were submitted to the ICRAF soils laboratory for analysis, and shuttle radar data were acquired to generate a high-resolution digital elevation model of the area.

Results generated so far were presented to the stakeholders' workshop:

- Woody cover density maps of the area, showing hot spots of degradation in the Aberdares National Park and the relatively sparse woody cover density in some parts of the park
- A statistical model relating actual infiltration rate to land properties provides very accurate predictions of infiltration rate. The model shows that grazing and cultivation cause significant reductions in infiltration.
- Small hotspots of soil erosion are located throughout the catchment, especially in the area directly adjacent to the Sasumua reservoir and in a larger area in the north-western side of the Sasumua catchment, in the Mungutio sub-catchment.

Once laboratory results are available for soil samples, researchers will be able to complete a full analysis of soil condition, which will measure soil quality across the area.

Hydrological modeling of Sasumua Watershed

The aim of module HW1 was to determine spatial estimates of runoff and sediment yield for the existing land use conditions and assess the impact of alternative land use management options on sediment and water yield. Digital Elevation Model and land cover data from spatial overview module SO1 was used to prepare input data for SWAT watershed model. Other secondary data sets used for modeling are digital soil map (KENSOTER) and daily rainfall and weather data for Sasumua station for the period 1970-1990. Total suspended sediment load was measured at 13 points in the river system during the dry and wet season.

Mingutii stream SW of Njabini town and Little Sasumua stream North of Njabini had the highest TSS during the wet season of 109 mg/l and 63 mg/l respectively. The sediment load was contributed by the waterway traversing the farms, the roads,

upcoming market centres like Kwa Haraka, Kanyenya-ini, and Githioro, unprotected river banks and the crop land. About 66% of the flow into Sasumua reservoir comes from Sasumua subbasin (67.44 km²) while Chania (20.23 km²) and Kiburu (19.30 km²) subbasins provide 21% and 13% respectively. River Sasumua is highly seasonal and the flow is mainly surface runoff coming during and soon after the rains hence enhancing the erosion risk. In addition, the Planosols which are found in the SW part of Sasumua subbasin are poorly drained and erodible. Strategies to reduce erosion and sedimentation include planting grass on the waterways, stabilizing river banks, enhancing infiltration on cropland, improving drainage of roads and market centres, and installing sediment traps.

Water Quality Assessment

Physical and chemical characteristics and also nutrient levels of surface water sampled from various points along rivers; Mungutio, Little Sasumua, Sausumua and Kiboro were determined. The same parameters were also determined from surface water sampled from a number of points in Sasumua dam. Thirteen sampling points were selected for the dry season and fifteen sampling points were selected for the wet season. Five sampling points were selected for pesticidal analysis. Parameters measured on site were conductivity, pH, temperature, Total dissolved solids (TDS) and Dissolved Oxygen (DO) for the wet season only. Turbidity was determined in the laboratory. The samples were all analyzed for anions; Cl⁻, NO₃⁻, NO₂⁻, SO₄²⁻, and PO₄²⁻ and also for cations; Na⁺, K⁺, Mg²⁺, Ca²⁺, Fe³⁺, Cu²⁺, Pb²⁺, Mn²⁺, Cu²⁺, and Zn²⁺.

The results showed that most of the physico-chemical parameters were within the acceptable guideline limits of the World Health Organization (WHO) for potable water. For the sample from little Sasumua and Chania Tunnel Junction (SCJ 06) all parameters analysed were within the WHO standard. The samples from Rivers Mungutio and Main Sasumua were the most polluted. Turbidity was high for most sampled points. The critical pollutants that showed higher concentrations than the recommended WHO (in mg/l) were Fe²⁺ (18.46 – 0.41), Pb²⁺ (0.23 – 0.2), Mn²⁺ (4.08 – 0.43), and Cd²⁺ (0.02 – 0.01). Potassium showed high concentrations of 234.7mg/l at river Little Sasumua – Engineer Bridge while NO₃⁻ showed high concentrations of 477.38mg/l at Kwaharaka Town exit. Samples were analysed for organochlorines and organophosphates using GC-ECD and GC-NPD/FPD respectively and showed concentrations lower than the Detection limit (<LOD).

Preliminary Environmental Audit of Sasumua Watershed

Reservoirs located downstream critical watersheds like Sasumua are threatened by increased population and effects of land use and land cover changes. The location of the Sasumua reservoir downstream of Njambini township, intensive farmlands and agro-processing factory represents a major challenge to its conservation. Land use changes in upstream areas have led to increased sedimentation and water contamination. In order to address these challenges a preliminary environmental audit was undertaken to capture key environmental issues that should be considered in the process of improving environmental management as a basis for improved livelihoods at the local level and provision of hydrological services for Nairobi City.

Data used in this study was obtained through interviewing of key informants, farmers, focused group discussions and review of literature. This study also benefited from the outputs of all other sub-components: land use and land tenure analysis, watershed degradation assessments, hydrological modeling and water quality assessment.

Preliminary results show that intensive horticultural (potatoes, cabbages, carrots etc) and livestock farming, an upcoming horticultural industry, urban settlements and associated activities (markets, petrol stations, garages and shopping) are affecting the integrity of the reservoir. Other key challenges to the conservation of the Sasumua Reservoir include *inter alia*:

- Persistent grazing along the riparian reserve leads to increased runoff and high levels of sediment flow;
- Pollution from livestock, especially those grazing along the riparian reserve
- Planting of eucalyptus trees in proximity to the riverbanks and subsequent reduction in downstream flow into the reservoir;
- Inadequate physical infrastructure, especially heavy reliance on pit latrines and weak solid waste management mechanisms
- Lack of land use planning and development control in the urban township;
- Weak community participation in natural resource management; Reintroduction/illegal farming in the forest areas;
- Dwindling water resources against rising demand and the community's perception on the need for Nairobi City Water and Sewerage Company (NCWSC) to supply treated water to adjacent community, and
- Increasing pressure from rapid urbanization and intensification of farming in areas upstream of the reservoir.

These challenges occurring in the absence of planning and weak infrastructure represents a real threat to the sustainability of the dam. Urbanization without development control and increased intensification affect water quality. Inadequate baseline information to benchmark monitoring and evaluation for informed decision making is likely to impede the reservoir's conservation. Establishing a framework for the dam's management that is based on solid scientific base is urgent. These results are critical in such a process and provides provides guidance on dealing with the key environmental issues.

Question and Answers for each presentation

Following the presentations participants were given the opportunity to raise questions and comment on the results presented.

Questions related to the results from the *land use and land tenure analysis and maps* were mainly related to the reasons for changes in land use over time, for example with regards to the increase in woodlots over time, but also with regard to reasons for the increase of degraded forestland in 2000 and the subsequent decrease in 2007.

Participants in the audience confirmed the results that came out of the land use analysis.

Reasons provided included the fact that forest harvesting was stopped in 2000 as well as the abolishment of the shamba system in 2004. The increase in woodlots was explained by the fact that farmers have realized the value of planting trees after harvesting of trees from the forest was stopped. It was also stressed that the community was involved in forestry policy and policing and that they were educated about the importance of the forest. This might also have contributed to the increase in woodlots.

Following the results presented of the *assessments on land degradation*, the audience was eager to learn more about potential measures to stabilize areas with high erosion risks. The presenter responded that potential measures could include the control of grazing as well as the conversion of cultivated land into shrub land and the introduction of remedial structures to stop the sediments from entering into the water system. However, he also made clear that

the analysis done so far can help to identify on where to target intervention but that more work needs to be done on the type of possible interventions.

Another question with regard to land degradation concerned the impact of wildlife on soil erosion and the potential effect of introducing electric fencing to confine the wildlife. The respondent answered that the impact of wildlife on soil erosion has not been specifically taken into account, but he assumes that wildlife would not have a significant effect on soil erosion. Participants inquired on the possibility of using boreholes to monitor some of the parameters like water level fluctuations. The respondent indicated that this was not explored but it was not advisable to develop boreholes because there is a lot of surface runoff. It was also indicated that many farmers have ponds and the water is not of good quality even for livestock. The respondent advised that farmers need to adopt good farming practices so as not affect the quality of water.

Following the presentation on *hydrological modelling* the question was raised on whether the monetary value of the water was also assessed. It was indicated that this was not undertaken. Monetary figures that are available, however, are the treatment costs for the reservoir as well as the costs for unclogging the intakes. Furthermore, when also considering the importance of the water from Sasumua for the economic development and growth in Nairobi the value could run into billions of dollars.

Questions related to the presentation on *water quality assessment* included the factors that determined the location of the sampling points as well as the justification for using the WHO standard instead of the more stringent Kenyan standards.

The presenter responded that the sampling points included targeted sampling points (e.g. around the bridges) as well as neutral sampling points. Results could also be compared to the Kenyan standards.

The Nairobi City Water and Sewerage Company also commented that the company itself is undertaking water quality assessments and offered to compare and share the results of the tests

A number of questions and comments were also raised with regard to one of the recommendations made to redirect the waste of food processing industry from the Sasumua river into the Chania river. In general the feeling from the audience was that this was not an acceptable solution. The respondent argued that the waste from the food processing industry are organic materials that degrade and are diluted as they are transported further downstream.

A number of participants in the audience also requested the Nairobi City Water and Sewerage Company to provide water for the residents in the area.

Questions directed to the presentation of the *preliminary environmental audit* included a clarification on the extent of the area covered, the role of the flower industry in the area as well as a clarification on the absence of local planning for the new township. With regard to the area covered it was asserted that the coverage includes the whole watershed. The flower industry growing in the area and there is an indication that farmers are changing practices because of expected increase in income. A number of people in the audience confirmed that the lack of planning for the township is a problem. Although there was an initial plan for the town, it has now grown beyond the area included in the plan. However there are “plans to develop a plan for the township”. A final question regarded the source of water for the town. Participants answered that there were a number of intakes built,

which do however not serve the majority of the people. A number of currently ongoing and planned projects that aimed at improving the water supply for the Kinangop South District were also mentioned.

General discussion

After the technical presentations that participants engaged in general discussion to clarify some issues and state their positions. Recommendations that emerged included

- using different hydrological models in addition to the SWAT model;
- encouraging the farmers to reduce pollution by using ponds to catch runoff and harvest rainwater (District Officer)
- building public awareness to reduce pollution, and using the district stakeholders' forum to deal with these issues; providing farmers with alternate sources of water for livestock, to avoid bringing livestock to river, which causes pollution (district officer livestock)
- reconsidering recommendations to redirect factory waste into the Chania river; taking account of the farmers who grow along the Chania (Rep from Farmers' Forum)
- questions about how farmers can cooperate and co-exist with the Nairobi Water company when they are not necessarily benefiting from the water and yet land in the catchment area is being degraded.

Stakeholders' Perspectives from various ministries/farmers' forum

Vincent Nyingi Ndiritu, Former Sasumua Dam Superintendent and Resident Engineer:

Vincent has worked before for the City Council of Nairobi as the Dam's superintendent as well as Resident Engineer from 1964 to 1993. In his presentation he retrospectively provided an overview of some of the issues that came up in during the stakeholders' workshop. He indicated that the Dam was constructed in 1947, but in 1951 the City Council acquired the land on which the reserve lie on and the riparian floodplain. During the initial stages the arrangement was to provide water to adjacent communities. Treated water was being pumped to Heifer and York Davies). This was aimed at aimed at controlling livestock watering along Sasumua River. When Heifer and Davis left their land was subdivided and distributed to African farmers. Water provision continued but meeting was introduced. Vincent also introduced the need to develop a reticulation system from the Kiburu intakes, but this was also abandoned at some point. This was because the managers who spearheaded such initiative left and so the project stopped. During Vincent's tenure the water company had put in place elaborate plan for measuring flows but this has also ceased to be implemented. Vincent also observed that nowadays there is a lot of pollution from farmlands and that the iron and manganese detected by the study team had been a problem before and they could not know how to treat it. They undertook depth sampling and identified that the water was polluted. In response to Vincent's historical perspectives on the Dam, Mr. Peter Mwaura emphasized that the water works is fully owned by the City Council of Nairobi and is operated under the provisions of the Water Act, 2002. It is only licensed to supply water to Nairobi City and not to the local residents. Other options available for water provision include the initiatives by the water users association.

Eng. Mwaura on behalf of Engineer Njambi

NCWSC is fully owned by City Council of Nairobi and its operations are fully guided by the Water Act, 2002 and that NCWSC manages the facility on behalf of the Athi Water Service Board and therefore the provision or otherwise of water services to farmers adjacent to the Dam rests with the AWSB. Peter advised the community to form groups and approached the Athi Water Service Board and negotiates for water provision. He indicated that the issue of water provision for adjacent communities would be dependent on the investments that are being made on the rehabilitation of the dam. He indicated that the City Council has already invested 3 billion shillings loan from the French

Development Agency. Peter Mwaura appreciated the work being done by ICRAF and its partners and it these as providing opportunities for addressing some of the challenges that the company has faced over the years. He indicated that the dam is silted because of the land use changes in the upstream areas. He indicated that in order to address some of the challenges, NCWSC through the City Council has requested tariff increases from the Min. of water and Agriculture. As a result of land use change, there is a lot of pollutants flowing downstream (based on water quality assessment that has been undertaken by the dam) into the dam from the farmlands as well as ongoing deforestation in upland areas. Finally, Peter urged the stakeholders to appreciate the significance of the dam.

Mrs. Mary Mugo, on behalf of the PS, Ministry of Agriculture

Mary appreciated the work that ICRAF has been doing and that contributing to solutions focused on addressing water scarcities is critical. She urged stakeholders to collaborate with farmers in water provision. She indicated that the Ministry of Agriculture is working closely with farmers to develop water pans. She indicated that the Ministry will work with ICRAF and other collaborators in promoting adoption of agricultural practices.

Mr. Geoffrey Wachira, Water Resource Management Authority:

Mr. Wachira emphasized that the stakeholders' workshop is very timely and that all the issues being addressed are in line with WRMA mandate and that the issues being discussed will shape water resource management and that WRMA has developed relevant policy documents to enhance water management. Given the significance of the Dam, there is need to address some of the key challenges that it currently faces including deforestation, catchment degradation and pollution. He recognized that catchment management cannot be undertaken by one institution and emphasizes on the need to include public participation. He emphasized the need for collection action-water Resource Users Association bring several institutions together and if well organized they can access funds from the Water resources trust fund. NCWSC is also a member of the WRUA

Mr. Sammy Mbage, The Coordinator, Farmers' Forum

Mr. Mbage was happy that the government recognizes farmers and their contributions in development. He emphasized the need for a quick implementation of initiatives to address some of the key challenges already identified e.g. pollution. He observed that water scarcity related problems could be attributed to the eucalyptus. He proposed that eucalyptus trees should be removed. He proposed that the Farmers' Forum would be a good entry point for the implementation of remedial measures that are being proposed and that the dam is important given that many people are exposed to some of the problems being discussed during the stakeholders. NCWSC should join hands with farmers to find a way to work with farmers and explore opportunities of ensuring that the farmers are supplied with water;

Working Group discussions and summary of action points

Follow up research and monitoring

The follow up research and monitoring will involve understanding the institutional context and the socio-economic baseline conditions of the farmers living in the watershed. A detailed environmental audit was also recommended to be undertaken. Studies on production economics will also be undertaken as well as farmers' levels of vulnerability to climate variability and exploring the potential of innovative approaches like payments for ecosystem services could be used to improve farmers' resilience to climate variability.

Priorities for planning and investment

In a group discussion held during the meeting, three general planning and investment priorities were identified: water, agriculture, and urban development.

Water

For water management planning, **Water Resources Management Authority (WRMA)** was identified as the organization which should take the lead. Other stakeholders to involve include the Tana service board, Kenya Forestry Service (KFS), Kenya Wildlife Service (KWS), and the Nairobi Water and Sewerage Company.

Three priorities in water management planning were identified:

1. Catchment conservation
 - Vegetation of the waterways. Suitable grasses should be planted on the waterways that cut across farms. This should be planned and implemented in consultation with the farmers. This should be led by the Ministry of Agriculture. The Ministry of Agriculture should work with Ministry of Livestock and WRMA.
 - Improvement of road drainage. The road from Kwaharaka to Njabini and the road from Njabini to Engineer (2 kilometers from the bridge) and the road from Githioro to Naivasha (2 kilometer stretch from Githioro). The Nairobi water company should facilitate a meeting between the roads engineer, county council, the Nairobi water company. The administration and the community should come up with ways with addressing the problem of erosion along the roads.
 - Initiate the development of a watershed management plan
2. Formation of a Water Resource Users Association (WRUA)
 - The vegetation of water ways can be used as an activity to kick start the formation of a WRUA.
 - The Water Resource Management Authority (WRMA) should initiate the formation of a WRUA through sensitization of the community members. Other stakeholders would include the Nairobi Water and Sewerage Company, the business community, the farmers, local Community Based Organizations (CBO's), KFS, and KWS.

Agriculture

For engaging in agriculture planning the **Ministry of Agriculture** was identified as the organization to take the lead. Other stakeholder to involve include: Ministry of Livestock, co-operatives, fisheries and the whole agricultural sector in general.

Two priorities in agricultural planning were identified:

1. Water harvesting
 - Ponds should be constructed on farms to harvest water. As the infiltration of the soils is poor, there is no need for much lining in the ponds. Thus expenses for construction are low. There are problems associated to this regarding e.g. algae growth when the amount of water is low in the ponds. Plastic lining could improve the quality of the water, plastic is also not too expensive compared to alternative lining materials.
 - Demonstrate the use of Moringa in the use of improving the quality of water.
 - The main institutions to take the lead in water harvesting should include the Min. of Agriculture and Min. of Water.
2. Encouraging agroforestry

- forage for livestock
- replace eucalyptus
- plant fruit trees, especially apple trees.
- Fire wood
- Improvement of infiltration of water in to the soils

Urban development

For engaging in urban planning the **Ministry of Lands / local government** was identified as the lead organization. Other stakeholders should include: NEMA, Ministry of Public Works, the County Council, and Ministry of Housing.

Three priorities in urban development planning were identified:

1. Waste management, lead agency should be **NEMA**.
 - identify proper sites for waste disposal
2. latrines near water ways
 - single out latrines that are near water ways
 - see to the quality of latrines, over flowing latrines is a problem, what can you do about storm run off, which fills the latrines?
 - Demonstrate cheap to build, good quality, alternative sanitation facilities
 - Lead organizations: Public health, local authority, NEMA
3. Planning the town (long term priority)

Priorities for awareness and enforcement of regulations

In order to facilitate the identification of priority actions a list of issues that came up during the discussions of the morning session was provided to the participants. This was then supplemented during subsequent discussions, resulting in the following list of priorities for awareness and enforcement of regulation.

- Illegal loggings and encroachment, both on forest and river riparian area
- Unplanned urban expansion (i.e development control)
- Building awareness of involving community e.g. in forestry policy
- Grazing control
- Pollution and pollutants,
 - option more public awareness
 - better agricultural practices
 - domestic waste management policies
 - food processing and industrial waste mgt
 - more monitoring,
 - use of district stakeholders forum to deal with pollution issues
- removal of eucalyptus
- Environmental impact assessments new establishments in the area related to pollution and environmental audit on existing establishments
- governance and rights of the community
- illegal abstraction of water (as people do not have permits for water abstraction)
- corporate social responsibility
- wildlife break down trees, cause erosion , implications of the Aberdare resources fencing and its implications
- impact of markets on land use and alternative land use activities

Each participant was then asked to allocate three points to those areas he/she deemed most important, based on the following set of criteria.

- Risk
- Realistic/achievable within 6 months
- Awareness and enforcement
- Building on success of past initiatives
- link to research, planning and investment

In a final group discussion the entities that should take the lead responsibility for action were identified. In case representatives of these entities were also present at the workshop they were also asked whether they would be willing and able to do so.

Results of the group exercise are shown in table 1 showing the different actors for the different activities.

Table 1: Proposed actors for the different activities

	Points	By whom (in bold lead agency)
Short run		
Illegal loggings and encroachment, both on forest and river riparian area	6	Kenya forest service Community forest association WRMA (water resource management authority) WRUA (water resource user association) Provincial administration Agriculture Nairobi city water and sewerage company
Grazing control (both short term and long term)	6	Kenya forest service (in forest) Ministry of livestock (for riparian) Provincial administration Farmers forum District stakeholders forum Nairobi company
Options for managing domestic waste (awareness raising and enforcing regulation)	5	County council (but there were no representatives in the meeting) Public health NEMA Kenya association of manufactures Business community Provincial administration Nairobi city and water Local schools
Long term		

Corporate social responsibility (underlies a lot of the issues that are going on in the area)	8	
Promotion of agricultural practices	5	
Building awareness	3	

Summary of next steps

The workshop concluded with exploration for the next steps for the project which included *inter alia*:

- More research and monitoring activities: These mainly included research on the institutional and socio-economic tracks which have been provided for component 4 of the Kenya Agricultural Productivity and Sustainable Land Management project (KAPSLM);
- Wet season sampling to validate the results of the water quality assessment
- Collection of more data to calibrate and validate the soil and water assessment tool (SWAT) for hydrological modelling;
- ICRAF and partners to work with the water Resources Management Authority (WARMA) sub-regional office to start the process of the formulation and ratification of Sasumua sub-catchment management plans which will build on the results of the group work during the workshop.

Annex:

Annex 1: Presentation handouts

Annex 2: List of participants (Names and organizations)

Annex 3: Photos