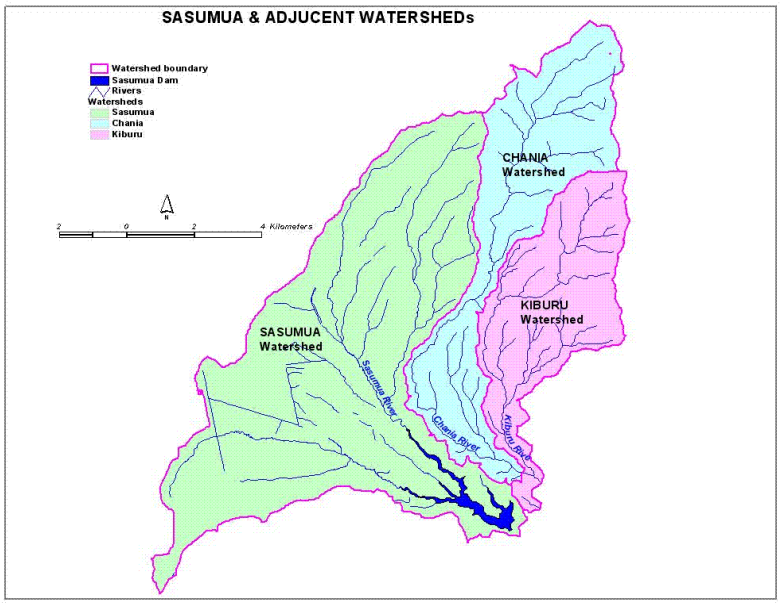
Kenya Agricultural Productivity and Sustainable Land Management project (KAPSLM)



A completion report for "A Study on Hydrological Services in Sasumua Watershed"
BY
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Background

The ICRAF-led and World Bank funded project on *"A Study on Hydrological Services in Sasumua Watershed"* is the phase I of component 4 on piloting innovative incentive mechanisms of the larger World Bank-Government of Kenya iniative on *"Kenya Agricultural productivity and Sustainable Land Management (KAPSLM) Project"*. The PES sub-component of the project will pilot the use PES in the Sasumua watershed, which supplies 20% of Nairobi's water demand. The Sasumua Water Treatment Plant near Njabini (Nyandarua District) is owned by the Athi Water Services Board and operated by the Nairobi Water and Sewerage Company. The Sasumua reservoir draws its water from three rivers: the Sasumua River, the Chania River (part of which is diverted via a diversion dam into a pipeline that flows into the Sasumua River), and the Kiburu River (from which four intakes channel water into a pipeline that flows directly into the Sasumua reservoir).The Sasumua watershed covers about 14,000 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.

However, land use changes in upstream areas of Sasumua watershed have led to increased sedimentation and water contamination while at the same time farmers report declining soil fertility and crop yields. Ensuring proper hydrological functioning of the Sasumua watershed is therefore of critical importance to the future water supply of Nairobi. Simultaneously, better land management and reduced land degradation are critical for increased and sustained agricultural productivity and livelihoods in the Sasumua watershed. Given the importance of the Sasumua watershed and the urgency of the problems affecting it, the World Bank contracted the World Agroforestry Centre (ICRAF) to undertake a study to identify sources of sediments and pollutants in order to facilitate decision making on targeting interventions. The study approach however aims at achieving this objective by adopting an incremental modular approach as discussed in section 2 below.

The Sasumua site is also an associate site for an ICRAF-led IFAD funded iniative on Pro-poor Rewards of Environmental Services in Africa (PRESA). It is a community of practice that aims to provide proactive and responsive support to the development and dissemination of assessment and monitoring tools, negotiation methodologies, and prototype mechanisms for pro-poor rewards for environmental services in the highlands of East and West Africa. The PRESA project provided co-finance to the World Bank iniative in the form of equipment and staff time for the project's staff (coordination, technical studies and spatial analysis). In this case therefore we raised funds from PRESA sources which included European Union soft core support to ICRAF for policy research, IFAD and the Government of Finland.

A brief on Sasumua watershed

The topography of the Sasumua watershed, which covers an area of 107 km^2, is characterized by steep slopes in the northern, forested, part of the watershed (bordering the Aberdares National Park) and along the lower banks of the major rivers leading into the Sasumua dam. The south-western and central parts of the watershed are relatively flat. Soils in the Sasumua watershed are predominantly Eutric Planosols and Luvic Phaeozems (FAO/UNESCO).

Land use in the Sasumua watershed is dominated by grazing, with an estimated 70% (4,900 ha) of the area currently under grasslands. The area under cultivation (mainly potatoes, vegetables and other cash crops) is estimated at about 19% of the watershed or 1,400 ha. Intervened forest reserve is used by households to graze cattle and to collect fuel wood.

The Sasumua reservoir draws water from three sub-basins: the Sasumua sub-basin (67.4 km^2), the Chania (20.2 km^2), and the Kiburu (19.3 km^2). Approximately two-thirds of the water entering the Sasumua reservoir comes from the Sasumua catchment, which is primarily an agricultural area with limited land conservation. The Sasumua Water Treatment Plant downstream of 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.

A Recap of the Terms of References

Over the last nine months, ICRAF and partners have conducted **"A Study of Hydrological Services in Sasumua Watershed"** with the following terms of reference (TORs)**.**

A Objective of the study

The project's objective was to collect data, test and apply hydrological models to assess and quantify the nature, extent, severity and impacts of land degradation in the Sasumua watershed, thus providing technical information indispensable to the development of a PES mechanism in the watershed, as well as tested hydrological models that could be applied more widely in Kenya and in the East African highlands.

B ACTIVITIES

The project activities undertaken under phase I of the fourth component of the KAPSLM project with the BNWPP funding were aimed at moving to a more systematical approach to developing appropriate watershed plans. This phase mainly focused on: i) carefully delineating the watershed from which service users obtain their water; ii) 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); and iii) calibrating and validating hydrological models so as to be able to estimate the changes in watershed services that would result from land use changes. In order to realize these 3 objectives of KAPSLM and to lay the foundation for phase II project activities, the research team adopted a modular but broad approach that aimed at answering 3 questions:

1. What are the links between farmers' land use, sedimentation of the Sasumua intakes and reservoir, and water quality in the Sasumua reservoir? Where are the "hotspots" of erosion and which of these lead to sedimentation and water quality problems? Where are the "cold spots" of sediment sink, which are these are under threat, and what are the sources of threat? What are or could be the natural "filters" in the system, and how could those be promoted? What are the magnitudes of these relative to the overall sedimentation problems? What are the main water quality problems for the Sasumua reservoir, what are the sources of contamination, and what opportunities are there for ameliorating them?
2. What are the opportunities for ES payments or other types of compensation / reward to alter land use and contamination that will result in significant reductions in the sedimentation and contamination problems? How will different types of farmers respond to different types of payments? Are there land or forest tenure issues that would constrain the effectiveness of payments to affect farmer incentives? What are the sources of bonding social capital that would influence group approaches and what are the sources of bridging social capital that would influence institutional approaches?
3. How should a PES scheme for Sasumua be designed? The answers to questions 1 and 2 will clarify who should be involved, the land uses and land tenure types that should be targeted, and the types of payment / reward mechanisms that would be most effective. In addition, we need to know the legal frameworks and government institutions that need to be involved. We need to design appropriate monitoring and evaluation system

and identify candidate intermediary organizations that could move a PES scheme from concept to practice, through appropriate awareness raising, contractual arrangements, and monitoring and evaluation systems.

The phase 1 activities focused mainly on the first question with preliminary thoughts on how to proceed with the third questions. This however is dependent on the second questions. In order to address the first question we have collected, and analyzed legacy data, conducted a land health surveillance survey, water quality assessment, land use and tenure mapping, an environmental audit, and tested hydrological model as a basis for the design of interventions. These activities were organized into the following components as per the terms of reference which is annexed:

i) **Spatial overview and audit (SOA):** This included production of digital maps of land use and land use change, maps of land tenure, 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;

ii) **Land degradation assessment:** some of the outputs expected from this component included a map of land degradation hotspots, analysis of the statistical relation between land degradation status, land use, and land tenure, and identification of possible remedial actions to mitigation land degradation risks;

iii) **Hydrological modeling and water quality assessment**: Outputs of this component included 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.

iv) **Community and other stakeholders' involvement and training:** ICRAF and partners were expected by the World Bank to organize two mini stakeholders workshop to ensure that the project is shaped, 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. From the stakeholder workshop, reports were expected indicating 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 and that a plan for awareness raising is developed.

Detailed TORs are annexed to this report for more information.

Component-by-component Results Highlights

The following is a summary of the results highlights from each of the components. Results of the hydrological modeling and water assessment have been summarized separately and so the land use land cover change analysis, land tenure mapping and environmental audit. These results have been discussed during a debriefing meeting and during the stakeholders' workshop. The results however are not void of mistakes and this is why under next steps we propose more field work to validate some of the results like water quality assessment. We have also reported incrementally the results of the study during the 1st and 2nd quarterly periods as well as provided an update to the Project's Task Manager. The following is a brief summary of the results per component or sub-component.

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 and the environmental audit. 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. The results of the retrospective land use land cover analysis showed that:

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-this is 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

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.

Preliminary Environmental Audit

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.

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 from the land degradation assessment indicate that:

- Woody cover outside the forested area is sparse, with about 65% of the total area having less than 20% woody cover and an average of 42 trees ha^{-1}. Woody cover has decreased in favour of herbaceous cover for livestock grazing and horticultural production.
- About 42% of the study area has high inherent risk of soil physical degradation, mainly due to the occurrence of abrupt texture gradients in the soil profile, posing a high risk of soil erosion under sparse vegetation cover.
- Initial infiltration rates are about 415 mm hr^{-1} lower in grazing areas than in areas without grazing, indicating compaction due to trampling by livestock in grazing areas, which leads to accelerated run-off. A flood risk map was prepared.
- Erosion risk, calibrated on field observations, is highest along river/stream banks in the lower parts of the watershed, along the banks of the lake, in the western part of the watershed as well as in forest clearings. In the neighboring watersheds, erosion risk is high in newly cleared forest areas.
- The combination of low initial infiltration capacity in grasslands and high erosion risk in the lower sections of the watershed is of major concern in terms of land degradation risk. Another factor of concern in terms of hydrological behaviour is extensive compacted paths, tracks and roads, as well as expanding urban areas without adequate drainage or control of surface runoff, for example in Njabini.
- Of the 320 soil samples taken, 17% were analysed using conventional reference methods and calibrated to near infrared reflectance values. The calibrations were used to predict values for all samples. Soil properties in the watershed are highly variable but predominantly moderately to strongly acid. Average topsoil organic carbon levels are moderately high (3.2%) but despite the high clay+silt levels (90%) exchangeable bases are low (<6 $cmol_c$ kg^{-1}). This presents a fragile situation whereby without adequate inputs fertility levels will decline rapidly as organic matter levels decrease due to soil disturbance and reduced litter inputs following clearance of indigenous vegetation. There is a high risk of soil acidification. Topsoil available phosphorus deficiency for crop production has a prevalence of 65%. Calcium-based phosphorus or compound fertilisers combined with organic manures are needed to maintain soil fertility and crop productivity.

- A local soil condition index was created based on soil organic carbon levels, calibrated to satellite imagery and mapped. Poor soil condition hot-spot areas (yellow) occur mainly in agricultural fields and degraded grasslands. Many of these areas are also predicted to have high risk of surface runoff (flooding) and high soil erosion risk. Areas where two or more of these risk factors occur should be targeted for further investigation and possible interventions.
- It is critical that adequate vegetation cover is maintained and/or soil and water conservation is implemented on steep slopes in the northern, forested, part of the watershed and along the lower banks of the major rivers leading into the Sasumua dam to reduce erosion risk. Vegetation buffer strips should also be maintained and/or established to reduce transport of sediments into streams and rivers in the watershed.

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Hydrological modeling

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 km^2) while Chania (20.23 km^2) and Kiburu (19.30 km^2) 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. The results of this component indicated:

- The Sasumua reservoir draws water from three sub-basins: the Sasumua sub-basin (67.4 km2), the Chania (20.2 km^2), the Kiburu (19.3 km^2). 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.

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^-, NO_3^-, NO_2^-, SO_4^{2-}, and PO_4^{2-} and also for cations; Na^+, K^+, Mg^{2+}, Ca^{2+}, Fe^{3+}, Cu^{2+}, Pb^{2+}, Mn^{2+}, Cu^{2+}, and Zn^{2+}.

Water samples 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 Fe^{2+} (18.46 – 0.41), Pb^{2+} (0.23 – 0.2), Mn^{2+} (4.08 – 0.43), and Cd^{2+} (0.02 – 0.01). Potassium showed high concentrations of 234.7mg/l at river Little Sasumua – Engineer Bridge while NO_3^- 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). Water quality assessment showed that:

- Most of the physico-chemical parameters for water quality are within the acceptable guideline limits of the World Health Organization (WHO) for potable water. Water sourced from the forested sub-basins (Chania and Kiburu) is generally of higher quality than water coming from the Sasumua sub-basin. There is no evidence of pesticide pollution. However there is cause for concern in that samples from the Rivers Mungutio and Main Sasumua had high loads of sediment and heavy metals (iron, lead and cadmium). There is an urgent need to cross-check the results on heavy metals and pinpoint the sources.
- 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 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 production and eucalyptus production may be a major cause of this problem.

Highlights from the two Stakeholders' workshops and training

The first mini workshop was held on August 25, 2008 with representation from the provincial administration, departments of water, forestry, livestock, social services, development/planning, ICRAF, JKUAT and KAPP. The research team also met and held discussions with the Nyahururu Country Council administrator at Engineer Township who is also in charge of

Njambini Township. During this first mini workshop, participants raised the following issues which informed the project's implementation:

- Many departments and resource users' associations were not represented and therefore the need to involve them in subsequent meetings and project activities;
- A regional plan for the greater Nyandarua has been formulated and this study can derive input for the plan and contribute to the plan's objectives;
- Need for an implementation schedule for the different components so that the District service Unit (DSU) and government departments can offer requisite support;
- There is need for the different service providers including the new project to work together to create synergies and leverage expertise and resources;
- Use of the results to benefit people but ethics of scientific research must be observed-concentrate on identifying areas that require intervention; and
- Results of the study should inform the district planning process and the project was invited to share the results of the study as soon as ready even if preliminary.

After the first stakeholders' workshop the different project components were implemented jointly with both some members of the District Service Unit, the District technical team, farmers and leaders of the Farmers Forum. As part of the hydrological and water assessment team is one PhD student. He will be using some of the results for his PhD. The other training obligations will be integrated into phase II of the project which is expected to start in the financial year, June 2009.

On February 26, 2009 ICRAF and partners organized the second stakeholders' forum in the Njambini Farmers Agricultural centre. A separate report on this stakeholders' workshop is being appended to this project completion report. The objectives of the stakeholders' workshop were to present the results of the different components and obtain review comments and feedback from key stakeholders. During the workshop, i) elements for a catchment management plan were presented; ii) map products were presented and donated to the District Development/planning Office, iii) key messages for environmental education and awareness raising were synthesized, and iv) research results from the different components were validated.

Some of the important elements of the second stakeholders' workshop included *inter alia:*

- Expressions of appreciation of the value of the research studies, especially from the Water Resources Management Authority (WRMA), Nairobi City Water and Sewerage Company (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

Some of the commitments to the future action include the following:

- 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 a 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 overlay flow area, the little Sasumua, the areas around the 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.

ICRAF and partners will explore policy options to raise environmental awareness and spur discussion on new regulations and technologies for pollution control and supply of clean water. As the first step, ICRAF and partners will work with the Water Resources Management Authority (WARMA) both at the national, regional and sub-regional level to formulate the Sasumua Sub-catchment management plan(s) which will act as an organizing framework for investing in design and implementation of intervention measures.

Conclusions and update since the 2nd stakeholders' workshop

Overall the objectives of this workshop have been achieved. We however plan to undertake i) more water sampling to validate results of the water quality assessment, ii) data collection to calibrate and validate hydrological modeling, and iii) detailed environmental audit during the second phase of the project. Since the second stakeholders' workshop:

i) ICRAF and the partners have used the results during the two-week BESSA-PRESA training help in Nairobi and Embu from March 24 to April 3, 2009 with a site visit and interaction with partners in Sasumua catchment;

ii) Given the significance of the study, study approach, partnerships formed, and programmatic focus of this study, the ICRAF Board of Trustees visited the Sasumua watershed on April 4, 2009-the conclusion made was that the programmatic focus in the study should be expanded to included marketing, Germplasm development, and exploring with farmers the possibilities of farmers participating in carbon sequestration iniatives which could earn them an alternative source of income;

iii) The "Building Ecosystem Service Research capacity in Semi-Arid Africa (BESSA) project which is implemented by a consortium consisting of Macaulay Land Use research Institute, Jomo Kenyatta University of Agriculture and Agriculture (JKUAT), ICRAF and Pretoria has chosen the Sasumua watershed as a case study site for production economics and understanding farmers' behavior under different reward schemes;

iv) A roadmap jointly formulated and agreed with the WARMA sub-regional office has been formulated as:

Table: Activities and roadmap for the realization

S/N	Activities	Proposed date
1.	Induction workshop-introducing WRUAs and other stakeholders to the process of SCMP formulation process	May 21-22, 2009
2.	Presentation of Research results and sub-catchment level planning-we stakeholders on this during the stakeholders workshop but it was not comprehensive. We will build on what is existing. This will mainly involve presentation of our results followed by identification of interventions, who does what, financial implications, obligations and timelines i.e. participatory planning	June 3-5, 2009
3.	SCMP formulation workshop-Representatives of the key stakeholders are invited to a participatory plan formulation workshop. Aim is to ensure that critical stakeholders own the	June 17-19

	process and the ultimate plan	
4.	Draft plan fine tuning by a Taskforce (The team is expected to review and finalize the first draft-team members will be left to decide on when and how many days will this take before June 30, 2009	June 19 through June 30, 2009
5.	Ratification of CMS	June 30, 2009

After the ratification by all the stakeholders the SCMP will be submitted for registration and then the government will then gazette the plan. What follows will be implementation of the management plan. These will be led by WRMA, WRUA with technical support from ICRAF and partners. With this in mind we agreed to move on with the process for the formulation of the SCMP and that:

i) ICRAF and partners can provide technical expertise as well as be part of the process as partner with WRMA;
ii) Embark on the remaining stages for the formulation of the SCMP;
iii) WRMA will facilitate all the necessary activities for the formulation of the sub-catchment management plan (SCMP).

These iniatives offers possibilities for addressing some of the research gaps which were not addressed in this study and which may not be addressed in phase II. These will also enable use to bring on board more organizations, leverage resources and expertise as well as promote collective learning and action.

Attached to this completion report are:

a) Project's terms of reference (TORs)
b) Technical reports on the different components which provide more details on the results summarized in this report;
c) Stakeholders' workshop report site should

Annex 1: The Project's Terms of Reference as Agreed with the World Bank

KENYA AGRICULTURAL PRODUCTIVITY AND SUSTAINABLE LAND MANAGEMENT PROJECT (KAPSLMP)

Terms of Reference (ToRs)

For

A Study on Hydrological Services in Sasumua Watershed

A BACKGROUND

The proposed KAPSLM project aims at promoting sustainable natural resource use for higher productivity and incomes for rural farmers and maintain 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 (such as Payment for Environmental Services -PES); and (v) SLM program planning, monitoring, and evaluation.

The PES sub-component of the project will pilot the use PES in the Sasumua watershed, which supplies 20% of Nairobi's water demand. The Sasumua Water Treatment Plant near Njabini (Nyandarua District) is owned by the Athi Water Services Board and operated by the Nairobi Water and Sewerage Company. This plant supplies about 20 percent of Nairobi's potable water supply. It draws its water from three rivers: the Sasumua River, the Chania River (part of which is diverted via a diversion dam into a pipeline that flows into the Sasumua River), and the Kiburu River (from which four intakes channel water into a pipeline that flows directly into the Sasumua reservoir).The Sasumua watershed covers about 14,000 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.

Two main outputs are expected from the PES subcomponent: (i) a functioning PES program in the catchments serving the Sasumua Reservoir, with payments financed by the beneficiaries of clean and secure water; and (ii) lessons for the implementing PES programs in Kenya and other African countries, and a specific replication strategy for Kenya. 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 payment mechanism that will persist beyond the end of the project, in particular, arrangements for payments to service providers and monitoring systems

(d) Preparing a work plan for 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 Implementing the PES program, by contracting service providers, then verifying their compliance, and paying them

(f) Drawing lessons from the pilot and developing a replication and scaling-up strategy

(g) Capacity building for PES in the country and in key institutions.

While most of the activities under the PES sub-component will be implemented through the support of KAPSLMP, the Bank-Netherlands Water Partnership Program (BNWPP) Trust Fund will fund initial detailed hydrological and land degradation studies in the Sasumua catchment.

B OBJECTIVE OF THE STUDY

The proposed activity will collect data, test and apply hydrological models to assess and quantify the nature, extent, severity and impacts of land degradation in the Sasumua watershed, thus providing technical information indispensable to the development of a PES mechanism in the watershed, as well as tested hydrological models that could be applied more widely in Kenya and in the East African highlands more generally

C 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 (which in this case would be implemented through a PES approach), 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 would be used primarily in activities (ii) to (iv)in the above list. Basically, BNWPP funding would be used to undertake all detailed technical analyses that are planned. This would allow other funding to be re-allocated to the parallel social/institutional tracks of preparing the PES mechanism, such as (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 payment mechanisms; 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 will be used for the following activities and outputs;

1. **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 will be used to prepare a spatial overview of the proposed project site.

Based on the data generated by the spatial overview, a preliminary environmental audit will be undertaken in order to identify major sources of water contamination in the river catchments and overland flow area. Participatory GIS and other relevant environmental audit techniques will be used in the preliminary environmental audit.

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.

2. **LD. Land Degradation Assessments :**

Activity: The principal objective of Land Degradation Assessment (LD) is to assess and quantify the nature, extent, severity and impacts of land degradation and water contamination in the Sasumua Dam catchment. The study approach will include participatory GIS, ground surveys of soils and vegetation, laboratory analysis of soil samples and statistical analysis of land degradation risk. The field sampling protocol will be 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) Establish one sentinel site using standard land degradation surveillance protocol positioned over the Sasumua catchment. The standardized protocol will provide geo-referenced information on vegetation and soil condition at least 160 randomized 1000-metre-squared sample plots. Within plots, observations are 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 samples will be taken. Vegetation type is classified using the Food and Agriculture Organization (FAO) Land Cover Classification System (LCCS), supplemented with woody biomass estimates. Single-ring infiltration measurements are made on a selection of plots. Soil samples are characterized by infrared spectroscopy and a subset of samples submitted for conventional soil fertility and carbon analysis. A fine resolution QuickBird satellite image is also acquired for the site and digital elevation and ancillary GIS layers compiled.

b) Conduct statistical analysis of ground data and satellite data, and mapping of soil condition index and erosion risk. Specify sustainable soil management strategies for different areas of the catchment.

c) Compile results into an electronic atlas.

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

3 HW. Hydrologic modelling and water quality assessment

Activity: The hydrologic modeling and water quality modules will provide information on the linkages between land use, runoff, erosion and sedimentation and water contamination in the Sasumua catchment area. This information will allow 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, will be used for the hydrologic modelling.

Two iterations of hydrologic modeling are planned. The first iteration will make 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 will also be 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 will primarily be used to identify landscape patches that are likely to be important sources and sinks of sedimentation and runoff: those areas will then be given extra attention in the LD module. In the second iteration, the model will be 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 will then be used to predict the likely impacts of possible interventions on runoff, sediment yield and water balance at the catchment scale.

Water quality assessment will involve 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 will be collected at points along the rivers where there are 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 will be collected, one during the dry season and the other during wet season. This will be 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.

4 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 shall organize various awareness raising and advocacy activities targeting the communities and other stakeholders. Two mini-workshops shall be organized, one at the beginning and another at the conclusion of the assignment.

ICRAF shall facilitate short and long term training of GOK officers and others who will be identified by their respective agencies in respect to PES pilot work. Such training shall be costed and funded separately.

Outputs- Two stakeholder workshop held and reports prepared. 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 will be developed

D THE CONSULTANT

Due to the technical nature of the assignment and given the need to build on experiences learned elsewhere (e.g. experience with its Rewarding the Upland Poor for Environmental Services (RUPES) Program and the Pan-Tropical Scoping Study of Compensation and Rewards for Environmental Services), the entire work will be contacted to the World Agroforestry Centre (ICRAF) who shall be the lead agency. ICRAF shall provide and retain the necessary experts with the prerequisite qualifications for the assignment. ICRAF shall sub-contact Jomo Kenyatta University for Agriculture and Technology (JKUAT) to undertake the hydrological and water quality assessment studies. In undertaking the work ICRAF shall work closely and report to the Ministry of Environment and Mineral Resources (MEMR) and the National Environmental Management Authority (NEMA) on technical matters. ICRAF will also work closely with Nairobi Water and Sewerage Co. Ltd, the Athi Water Services Board, and the Water Resource Management Authority, who are the likely end users of the PES model. The World Bank PES team will also offer technical support and guidance as required.

E REPORTING

a) In all contractual matters related to this assignment, ICRAF shall report directly to the World Bank KAPSLMP Task Team Leader (TTL) - Andrew M. Karanja- and to MEMR/ NEMA as relates to technical matters.
b) ICRAF shall provide Quarterly progress reports to the TTL copied to the PS MEMR and Director of NEMA. The Quarterly reports shall give details on each of the activities being executed under C1-C4 above. Each Quarterly report shall be submitted 10 days before the end of each quarter.
c) ICRAF shall provide an end of project report consolidating all the activities undertaken and their outputs.
d) ICRAF shall provide technical reports on each of the activity areas listed in C1 to C4 above that shall detail, *inter alia*, background information, data collection methods, analytical methods, results and recommendations.
e) ALL reports under (b) to (d) above shall be submitted as hard copies and as electronic files.

F TIME LINE

The assignment is planned to be undertaken from 1st May, 2008 to December 31, 2008. ALL the outputs are expected to be completed and draft reports prepared and submitted by 30th October, 2008 while the final reports shall be submitted before 20th December, 2008. A final financial report will be submitted within 3 months of the conclusion of the project.

G PUBLICATIONS OF RESULTS AND ACCESS TO INFORMATION

ICRAF shall not publish any information related to this contact without informing the World Bank and the MENR. The material to be published shall be shared well in advance to give each party adequate time to review and comment as necessary. The vice-versa shall apply. After any publication each party shall provide at least three copies of such a publication and make the electronic version of the output available for reproduction as to other interested institutions that may request.

In case of communications to the Press and other media, such a communication shall be shared in advance to MEMR, NEMA, MOA, KS and WB and the role of each party shall be fully and properly acknowledged.

Data and information collected during this project shall be shared freely without any hindrance among the parties.

H COST ESTIMATE AND PAYMENT SCHEDULE

Cost Summary

Activity	Budget (USD)
SO1. Land use and land cover change	11,693
SO2. Land Tenure Maps	3,729
SO3. Preliminary environmental audit	4,429
LD1 Assessment of erosion, sedimentation and contamination risk	31,052
HW1 hydrological modeling	9,370
HW2 Water Quality Analyses	17,920
Stakeholder workshops	6,000
ICRAF overheads	17,808
TOTAL	**102,000**

Payment Schedule

25% on contract Signing
Ist Quarter- June 30th, 2008- 20%
2nd Quarter – October 30th, 2008- 20%
Final payment (after submission of final reports) - 35%

G DISSEMINATION

The primary audience for the study's outputs is the MENR team implementing the PES sub-component of the KAPSLM project, NEMA, Nairobi Water and Sewerage Company Ltd, Ministry of Water and Irrigation, the ICRAF, and the World Bank. Results from the study will

also be useful for demonstrating the potential of the PES approach to the various institutions involved in water resource and catchment management in Kenya (Ministry of Water and Irrigation, Water Resource Management Authority, Water Service Providers), as well as to other agencies and donors operating in the East Africa region who have active programs or interest in watershed management. The methodology and results will be carefully documented in working papers and other formats and made available to PES innovators and other practitioners working on similar issues in Kenya and elsewhere in Africa.

The broader project that this BNWPP-funded activity will contribute to already includes a variety of dissemination activities, including preparation of guides and workshops. The dissemination of the results generated by the BNWPP-funded work will be included in the dissemination strategy of the project. The work will also be disseminated to the wider Bank audience through the Watershed Management Community of Practice group.

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