## Executive Summary

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 piloting of innovative approaches for managing ecosystems is aimed at addressing problems that are affecting the sustenance of hydrological services in Sasumua watershed. 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 fuel wood). 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 on hydrological services in Sasumua catchment was aimed at collecting data, testing and applying 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. In order to provide solid scientific evidence towards the design and implementation of innovative approaches for sustaining hydrological services in Sasumua catchment, World Agroforestry Centre adopted a modular approach to answer 3 critical questions:

1. <u>What are the links between farmers' land use, sedimentation of the Sasumua intakes and reservoir, and water quality in the Sasumua reservoir?</u> 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. <u>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?</u> 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 technical reports provided for in this completion report are on the first questions. The following is a synopsis of the results of each component implement under phase 1:

i) **Preliminary environmental audit:** 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.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. Othe results inclide persistent grazing along the riparian reserve leads to increased runoff and high levels of sediment flow; pollution from livestock, planting of eucalyptus trees in proximity to the riverbanks and subsequent reduction in downstream flow into the reservoir; Lack of land use planning and development control in the urban township; and Increasing pressure from rapid urbanization and intensification of farming in areas upstream of the reservoir.

ii) **Land tenure:** Land tenure in the watershed has changed from the former „white higlands“ which were set aside for exclusive European farming in the colonial era to smallhoder agricultural land usnits. 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%. 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.

iii) **Data capture for hydrological modeling and land cover\land use change analysis in hydrologic services in the Sasumua and adjacent watersheds:** The spatial datasets from this sub-component 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. Results presented in the completion report shows that a) there has been harvesting of timber in the catchment driving land use change, b) Degraded forests were detected but they have remained fairly constant and rehabilitated and forests have been reinstated while area of forests increased between 2000 and 2007; and c) Agricultural area has also increased since 2000 at the expense of fallow land.

iv) **Assessment of land degradation in the Sasumua watershed:** 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. Results from the land degradation assessment indicate that: a) 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, b) 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., c) 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, d) 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, e) 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.

v) **Hydrologic modeling and water quality assessment:** 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: a) 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, b) 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, c) 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, d) 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, e) Open grazing, especially along riparian areas has been identified as a major risk factor for land degradation, and f) 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.

vi) **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 important elements of project implementation, coordination, their involvement and use of the research results. The second stakeholders workshop held on February 26, 2009 indicated that:
   a) 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;
   b) When asked to respond to specific results, most participants endorsed the results as an accurate reflection of the situation in the catchment;
   c) Several organizations indicated strong concern about the results and indicated a commitment to take follow-up action;
   d) 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;
   e) The presentation of results provided the basis for a very constructive dialog on the way forward.

**Commitment to the future**

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. In phase II of the project ICRAF and partners will 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 in addition to the institutional and socio-economic tracks. We have since developed a road map for the formulation of Sasumua sub-catchment Management Plan.