

**Data Capture for Hydrological Modeling and Land Cover/  
Land Use Change Analysis in Hydrologic Services in the  
Sasumua and Adjacent Watersheds.**

**By**

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A report on Spatial Data Capture and Land cover mapping for the **“PRESA Project”** component on **“Hydrologic Services in the Sasumua Watershed”**.  
“PRESA” (Payment for Environmental Services in Africa) is a collaborative project implemented by ICRAF and partners on Payment for Environmental Services (PES).

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## 1.0 Introduction

Virtually all major modules in PRESAS (Payment for Environmental Services in Africa) project's component on Hydrologic Services in the Sasumua and adjacent watersheds require baseline data such as DEM, rivers, roads, soil, landcover\ landuse, administrative boundary, town location, and human population as inputs on specific processing and analysis of the Sasumua watershed's problems and solutions. However, some of these data such as soil, administrative, towns and human population were already available in the right format, and so were adopted as without any alterations beside projection changes to fit with other datasets. Others data sets such as DEM, rivers, roads and landcover\landuse were to be derived from series of data capture and processing procedures. For better understanding of environmental status of the watershed and other relevant hydrological modeling requirements, landcover\landuse mapping plus time series change analysis were undertaken over a period of 1985 to 2007 using available satellite images.

Land use is the term that is used to describe human uses of the land, or immediate actions modifying or converting land cover. It includes such broad categories as human settlements, protected areas and agriculture. Within those broad categories are more refined categories, such as urban and rural settlements, irrigated and rainfed fields, national parks and forest reserves, and transportation and other infrastructure. Land cover refers to the natural vegetative cover types that characterize a particular area. These are generally a reflection of the local climate and landforms, though they too can be altered by human actions. Examples of broad land cover categories include forest, tundra, savannah, desert or steppe, which in turn can be sub-divided into more refined categories representing specific plant communities (e.g., oak-pine scrublands, mangroves, seasonally flooded grassland, etc.) (CIESIN, 2002).

Land cover is continually molded and transformed by land-use changes such as, for example, when a forest is converted to pasture or crop land. Land-use change is the proximate cause of land-cover change. The underlying driving forces, however, can be

traced to a host of economic, technological, institutional, cultural and demographic factors (Geist, 2002.)

## **2.0 Methodology for baseline data capture**

**2.1 DEM** (Digital Elevation Model) (figure 4) required for watershed boundary delineation and modeling using SWAT (Soil and Water Assessment Tool) was derived from 20 metres interval contour lines (figure 2) through "TOPOGRID" tool in ArcGIS software (Cadell 2002). The contour lines were digitized from 1:50,000 topographic map sheets (figure 1) of Survey of Kenya.

**2.2 Rivers and Sasumua reservoir** (figure 3) and **road network and towns** (figure 5) dominantly required for spatial data orientation and fieldwork activities were also digitized from the topographic map sheets and then updated using current satellite image (Landsat of 2007) and 2006 Kenya road network database from Ministry of Public Works, Government of Kenya respectively. Rivers were used by modeling team to identify, quantify and analyze specific river runoffs and sediment yields.

**2.3 Watershed boundary** (figure 6) was derived from SWAT (Neitsch et al, 2001) and counterchecked with Watershed delineation tool within ArcView 3.2a software using contour lines and river systems and appropriate values for process input requirements in each tool. This boundary formed one of key input in many modules of Hydrologic Services in the Sasumua Dam Watershed and water provided to module leaders.

**2.4 Other baseline data** like administrative boundary town location (figure 5), and soil were adopted from existing national databases produced by Central Bureau of Statistics for 1999 population census, all towns from International Livestock Research Institute (ILRI) of 2000, and FAO Kensoter (FAO and ISRIC, 1988).

Figure 1: 1:50,000 topographic map



Figure 2: Digitized contour line

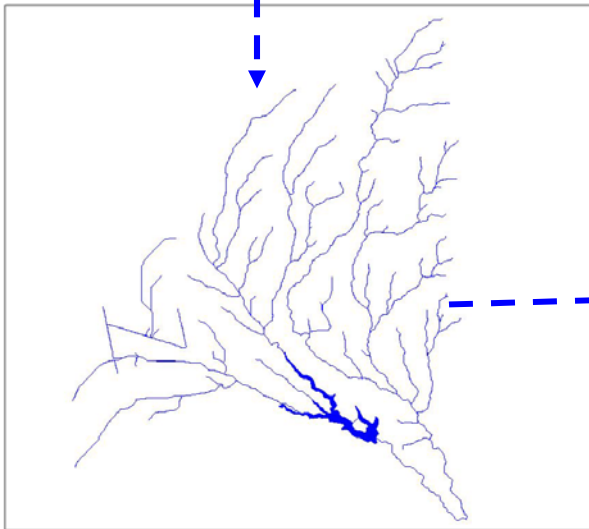
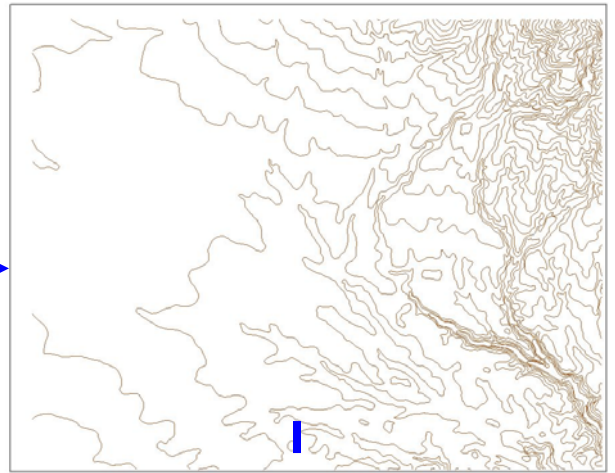


Figure 3: Rivers and Sasumua reservoir

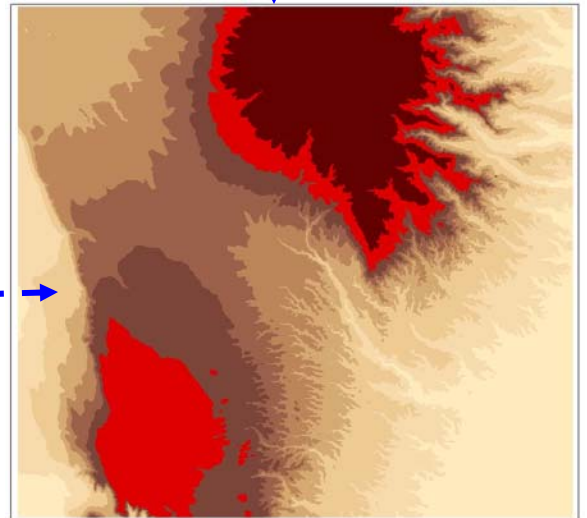


Figure 4: DEM

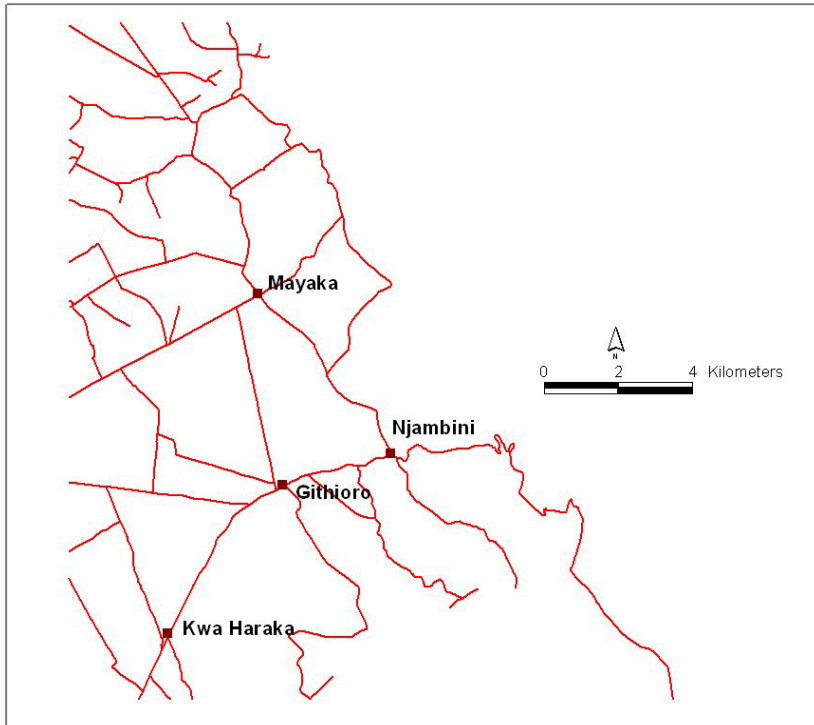


Figure 5: Road network and towns

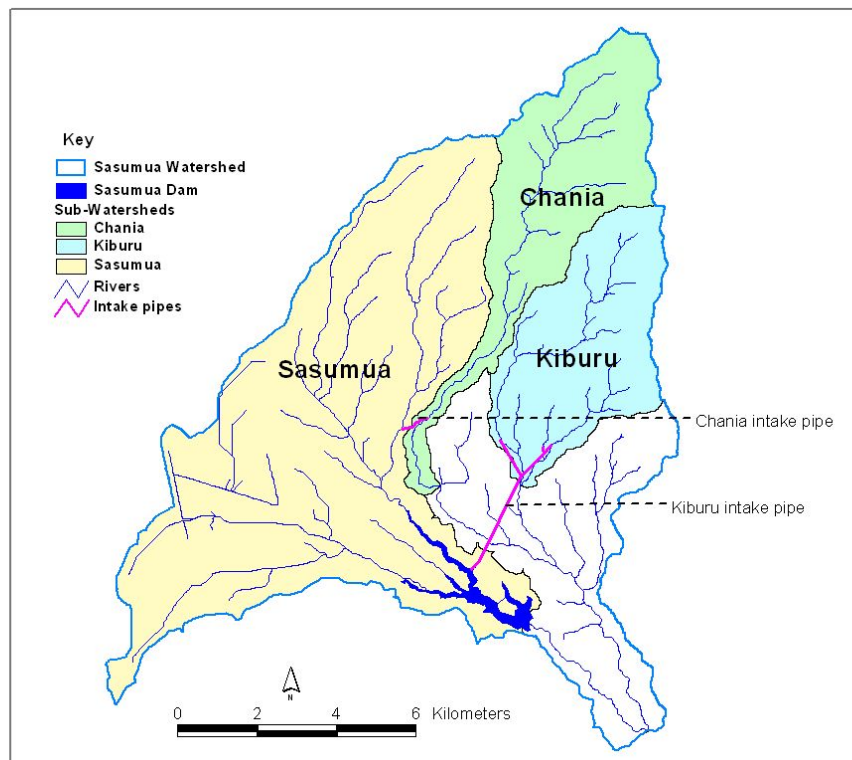
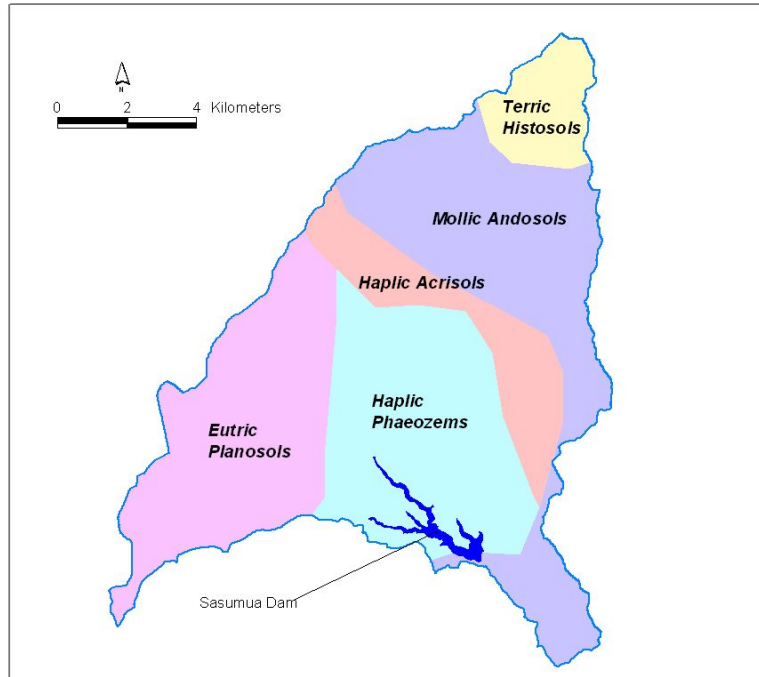


Figure 6: Watershed boundary and rivers systems

**2.4.1 Soil data** is also one of the key inputs to SWAT besides landuse for sediment and water yields processing and analysis.



**Figure 7: Soil types**

**2.4.2 Administrative boundary** (figure 8) is used to identify administration arrangement for fieldwork activities and in particular for data collection in land tenure module. Sasumua watershed is located in South Nyandarua district, which was carved out of the old Nyandarua district by combining two divisions of North and South Kinangop together and pulling it out to form the new district.

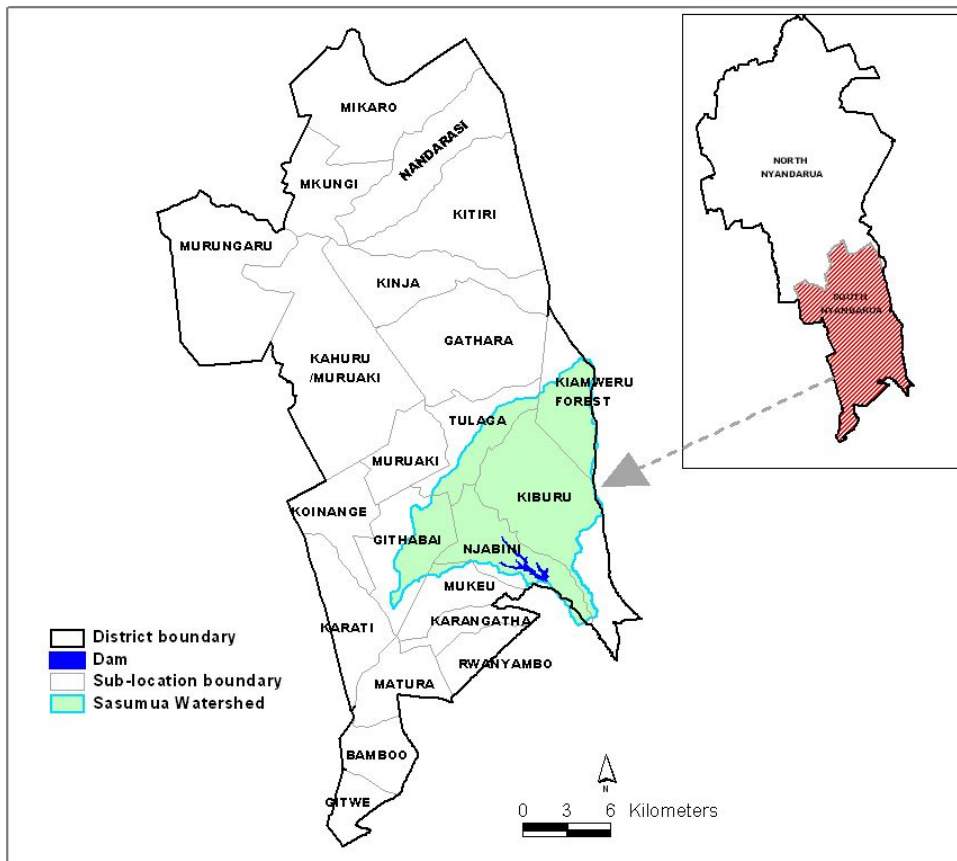
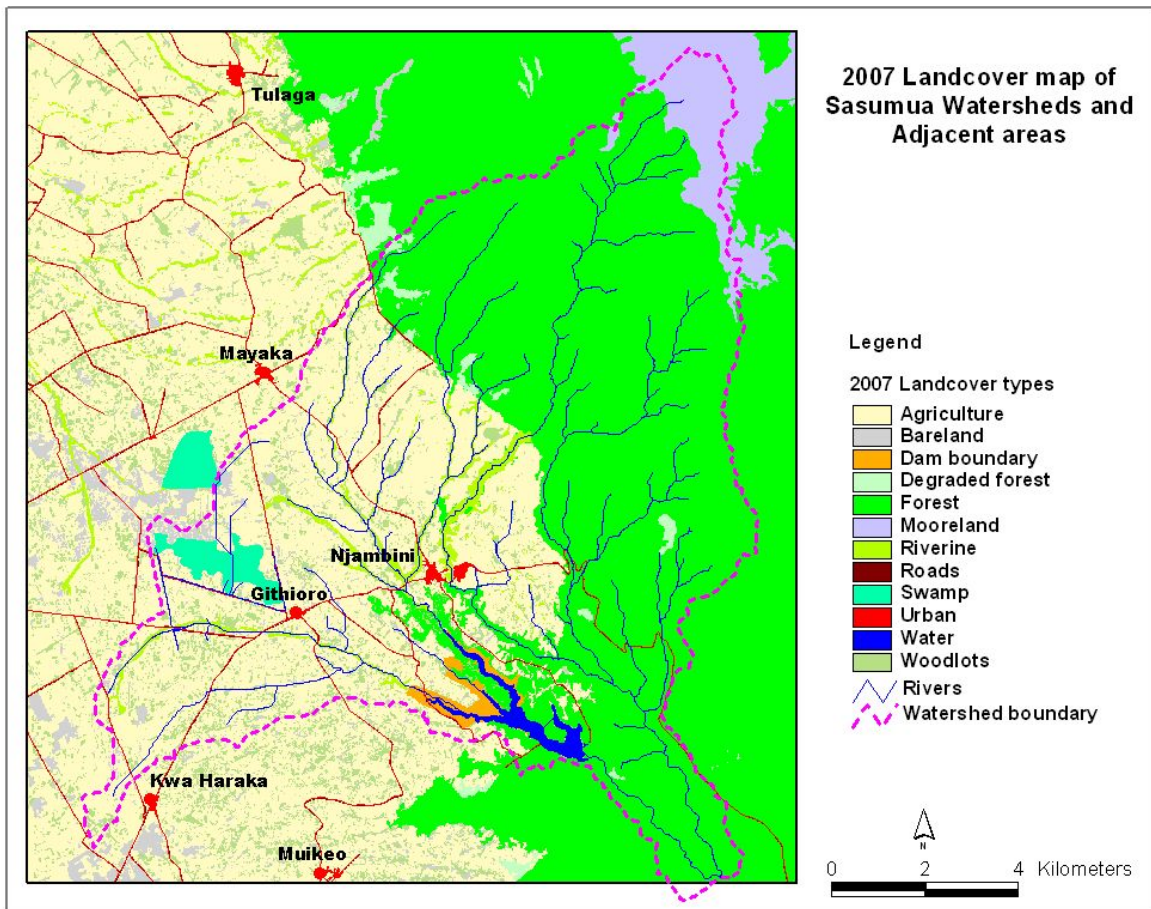


Figure 8: South Nyandarua administrative boundary (sub-locations)

### 3.0 Methodology for Landcover and Landuse change Mapping

The **current landuse** was be mapped from high resolution Quickbird image, but due to persistence cloud cover during 2008 over Sasumua Watershed areas, ASTER image was then selected. The acquired ASTER image of May 2007 was further georeferenced to remove any minor spatial displacement, and radiometrically corrected to eliminate any atmospheric anomalies. Using combination of fieldwork data from other modules, local knowledge and existing data from several sources, training sites were selected and used in Maximum likelihood classification method (Richards, 1999) to produce 12 classes of landuse\landcover over Sasumua Watershed and adjusted area (figure 9). The extent of landuse\landcover deliberately was increased to allow understanding and analysis of impacts from watershed surrounding landscapes. This was used both in hydrological modeling as well as landuse change analysis.



**Figure 9: 2007 Landuse\Landcover of Sasumua Watershed and Adjacent areas**

In order to undertake landcover\ landuse change analysis, time series Landsat images of 1985, 1995, and 2000 were interpreted using similar approach as in 2007 data and the following landcover\landuse maps were produced (figures 10, 11, and 12). And with grid data subtraction tools in ArcView a landcover\landuse change map (figure 13) was also produced and analyzed using excel tables (table 2).

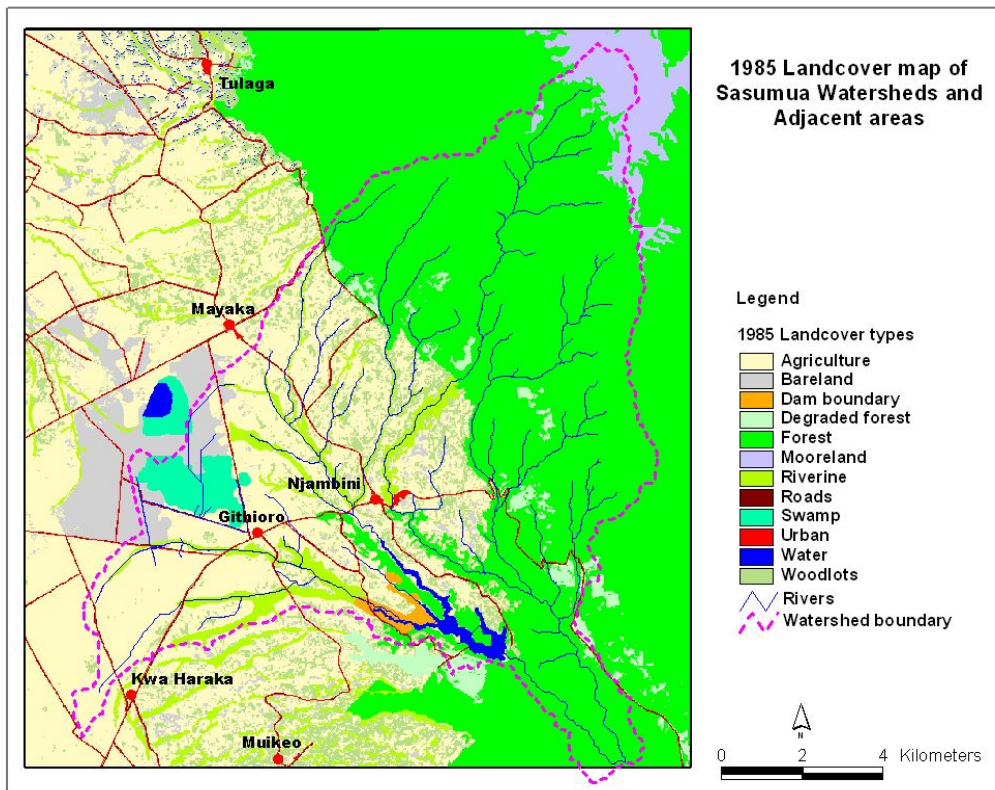


Figure 10: 1985 Landuse\Landcover of Sasumua Watershed and Adjacent areas

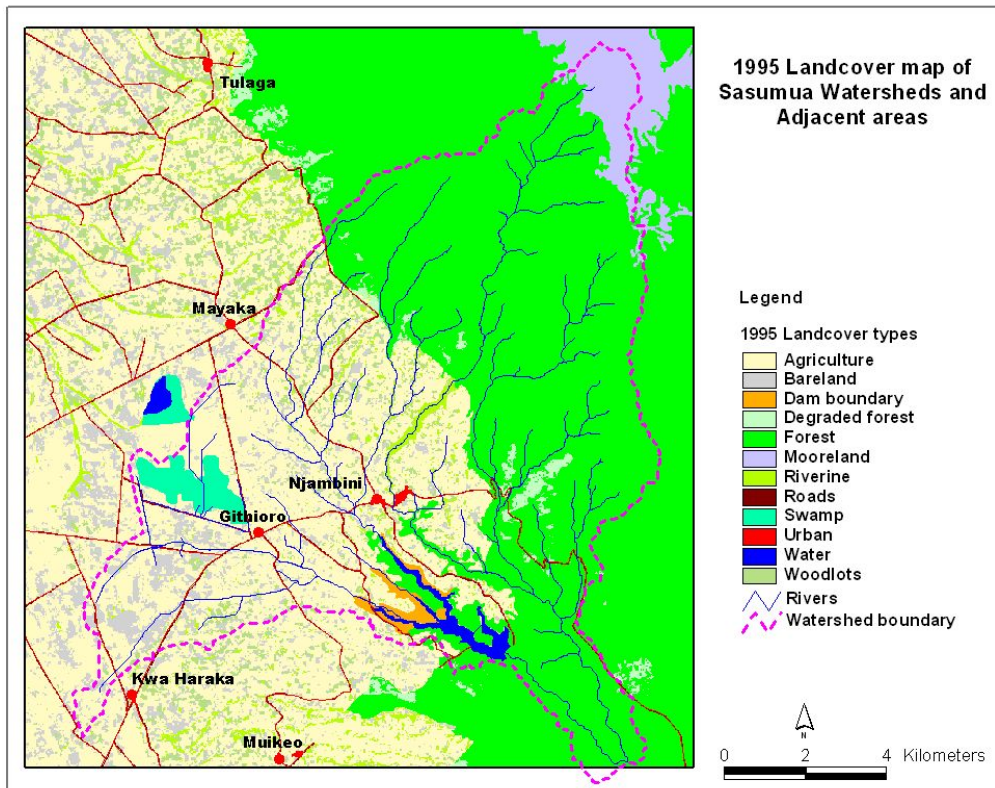


Figure 11: 1995 Landuse\Landcover of Sasumua Watershed and Adjacent areas

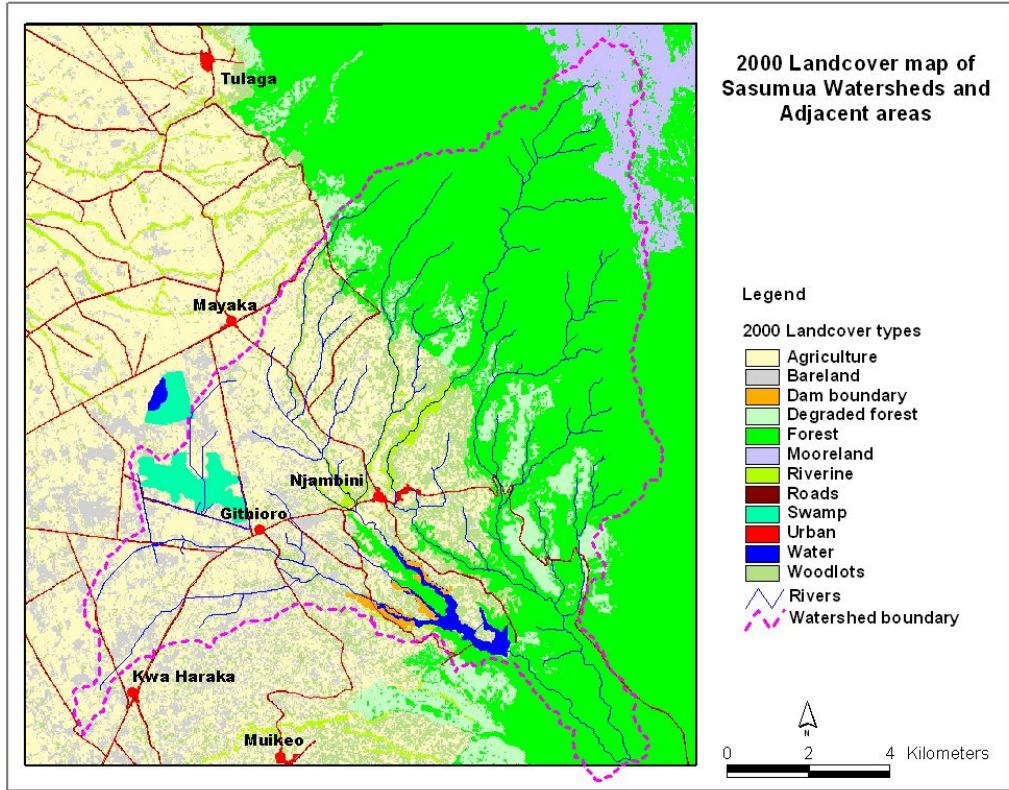


Figure 12: 2000 Landuse/Landcover of Sasumua Watershed and Adjacent areas

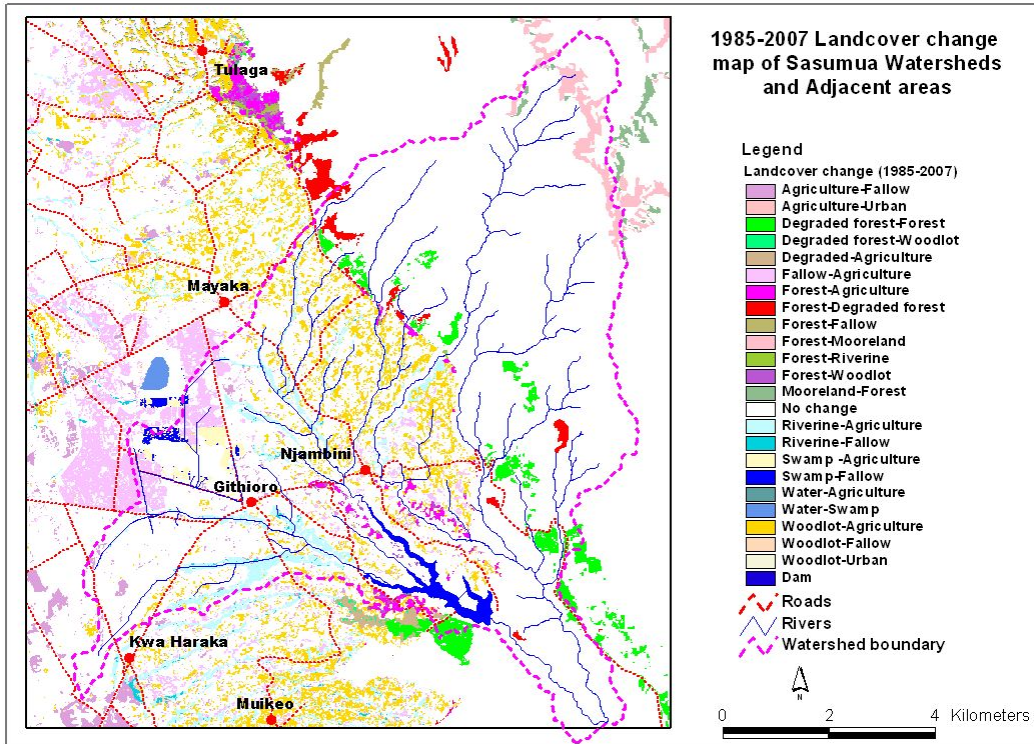


Figure 12: 1985-2007 Landcover change of Sasumua Watershed and Adjacent areas

**Table 1: Landcover changes from 1985 to 2007**

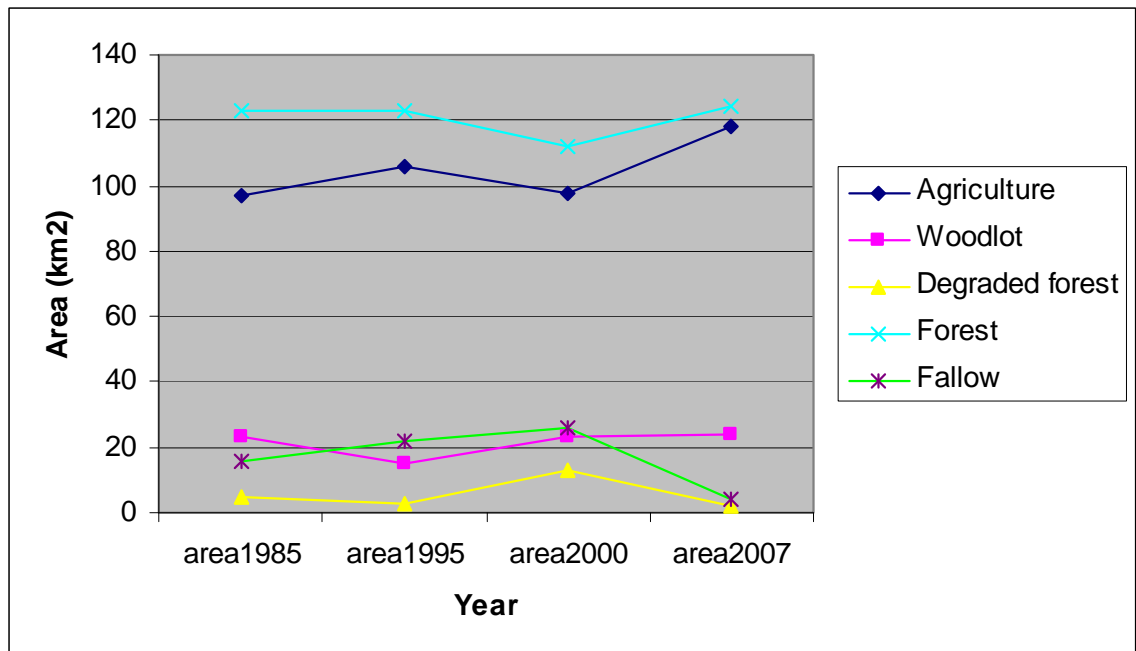
No	Change type	Value in sq km	%
1	No change	238.74	80.51
2	Woodlots to Agriculture	16.68	5.62
3	Fallow to Agriculture	12.13	4.09
4	Riverine to Agriculture	7.06	2.38
5	Agriculture to Fallow	4.22	1.42
6	Agriculture to Urban	0.26	0.09
7	Degraded forest to Forest	4.20	1.41
8	Degraded forest to Woodlots	0.23	0.08
9	Degraded forest to Agriculture	0.75	0.25
10	Forest to Degraded forest	1.96	0.66
11	Forest to Fallow	0.52	0.18
12	Forest to Mooreland	2.82	0.95
13	Forest to Riverine	0.27	0.09
14	Forest to Woodlot	0.67	0.22
15	Mooreland to Forest	0.95	0.32
16	Riverine to Fallow	0.53	0.18
17	Swamp to Agriculture	2.00	0.67
18	Swamp to Fallow	0.57	0.19
19	Water to Agriculture	0.47	0.16
20	Water to Swamp	0.44	0.15
21	Woodlots to Fallow	0.89	0.30
22	Woodlot to Urban	0.19	0.07
	<b>Total</b>	<b>296.54</b>	<b>100.00</b>

Between 1985 and 2007 the area has experienced less than 20% change of landcover with woodlots, fallow (grassland) and riverine vegetation converted to agricultural lands catered for 12% of the whole landscape changes. Time series landcover changes revealed mixed scenarios seem over 22 years according to the data used (table 2)

Table 2: Times series area cover of landcover types

No	Landcover	Area-1985 in sq km	Area-1995 in sq km	Area-2000 in sq km	Area-2007 in sq km
1	Agriculture	96.71	106.26	97.64	118.05
2	Fallow	16.42	21.97	26.05	8.24
3	Dam boundary	0.86	0.89	0.79	0.73
4	Degraded forest	5.25	3.32	12.95	2.42
5	Forest	123.09	123.60	111.89	123.38
6	Mooreland	7.65	8.30	9.59	9.47
7	Riverine vegetation	12.85	7.30	5.28	5.01
8	Roads	4.55	4.55	4.63	4.64
9	Swamp	3.79	2.97	3.09	2.80
10	Urban	0.26	0.33	0.45	0.65
11	Water bodies	2.27	1.82	1.61	1.13
12	Woodlots	22.84	15.23	22.57	20.02
	<b>Total</b>	<b>296.54</b>	<b>296.54</b>	<b>296.54</b>	<b>296.54</b>

Figure 14: Times series area cover of dominant landcover types



By selecting of dominant cover types from time series image interpretation in excel table 2 and plotting them in a graph (figure 14), give similar revelation of change fluctuation, which could attributed the following reasons:-

- Population increase resulting intensity in agriculture.
- Land tenure changes from leasehold to freehold leading to further subdivision of large track of under original ownership white settlers and also giving new land owners full freedom of the their land parcel.
- Policy changes in use of forest resources and in particular in the *Shamba* system, which a form of "*Taungya*" where agricultural crops are grown together with forest tree species and has been quite widespread in the high-potential areas of Kenya since the early 1900s, and still is very popular ((Oduol 1986). When properly practiced, the system allows sustained, optimum production of food crops along with forestry species from the same land and thus meets most of the social and economic needs of the shamba farmer. By 1988, when the Government evicted the forest dwellers, there were schools, health centres and shopping centres within the forest stations. In fact, there were chiefs and their assistants in every location (Omondi 2007). The Government realized it had no labour for its plantations after the 1988 evictions and introduced what was referred to as the non-resident shamba system, where the landless were allowed to cultivate plots in the forests but leave the forests before dusk. White eminent failure in shamba system, government finally abolished this by 2004.

The following technical challenges could also contribute to minor fluctuation in the resultant landcover data:-

- Temporal variation in satellite data acquisition, ASTER data was acquired in May 2007, while Landsat ETM and TM images were acquired in January 2000 and February 1995 and 1985 respectively. These differences in months of images acquisition also could harbor annual physiological changes in landscapes and

impact on final landcover changes, despite using radiometric correction before interpretation.

- Differences in satellite platforms inherited from Landsat and ASTER due to their difference in spectral and spatial resolutions could also contribute insignificantly to landcover change scenarios presented in this output.
- Limited fieldwork for training dataset for image interpretation is another factor could impact on final output.

#### 4.0 Conclusion and Recommendation

During all stakeholder workshops in February 2009 at Njabini, Kenya, these findings were presented and it was approved that these output reflect the overall reality to what has happened in Sasumua watershed region over the period of times. However, there was no conclusive evidence that all changes reflected in the output occurred correspondingly to spatial location captured in the output. It was therefore, recommended to undertake another image interpretation analysis using current Quickbird image to support further evidence of change analysis and also to support environmental audit module.

#### 5.0 Reference

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