DETERMINING THE EFFECT OF LAND USE CHANGE ON STREAMFLOW USING SOIL WATER ASSESSMENT TOOL (SWAT) MODEL

Presenter

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Introduction

- Changes in watershed land use practices affect flow.

- Water availability for purposes that include irrigation, crop production, hydroelectric power generation, ground water exploration, etc.

    - determined by prevailing land use activities in watershed.

- There is need to predict potential effects of land use change on the water resources.

  - ➢For the purposes of planning and management of future water supply capabilities.

  and

  - ➢to evaluate catchment water resources

  ❑*under changing land-use scenarios*,

- The Soil Water Assessment Tool (SWAT) has been used to study the effect of land use on catchment hydrology in a number of watersheds.

(Technical brief 2,2007; Heuvelmans et al. ,2005; Tadele and Förch ,2007)

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- The purpose of this study was to determine the effect of land use change on streamflow on the Naro Moru River catchment, Kenya.

METHODOLOGY

Study Area

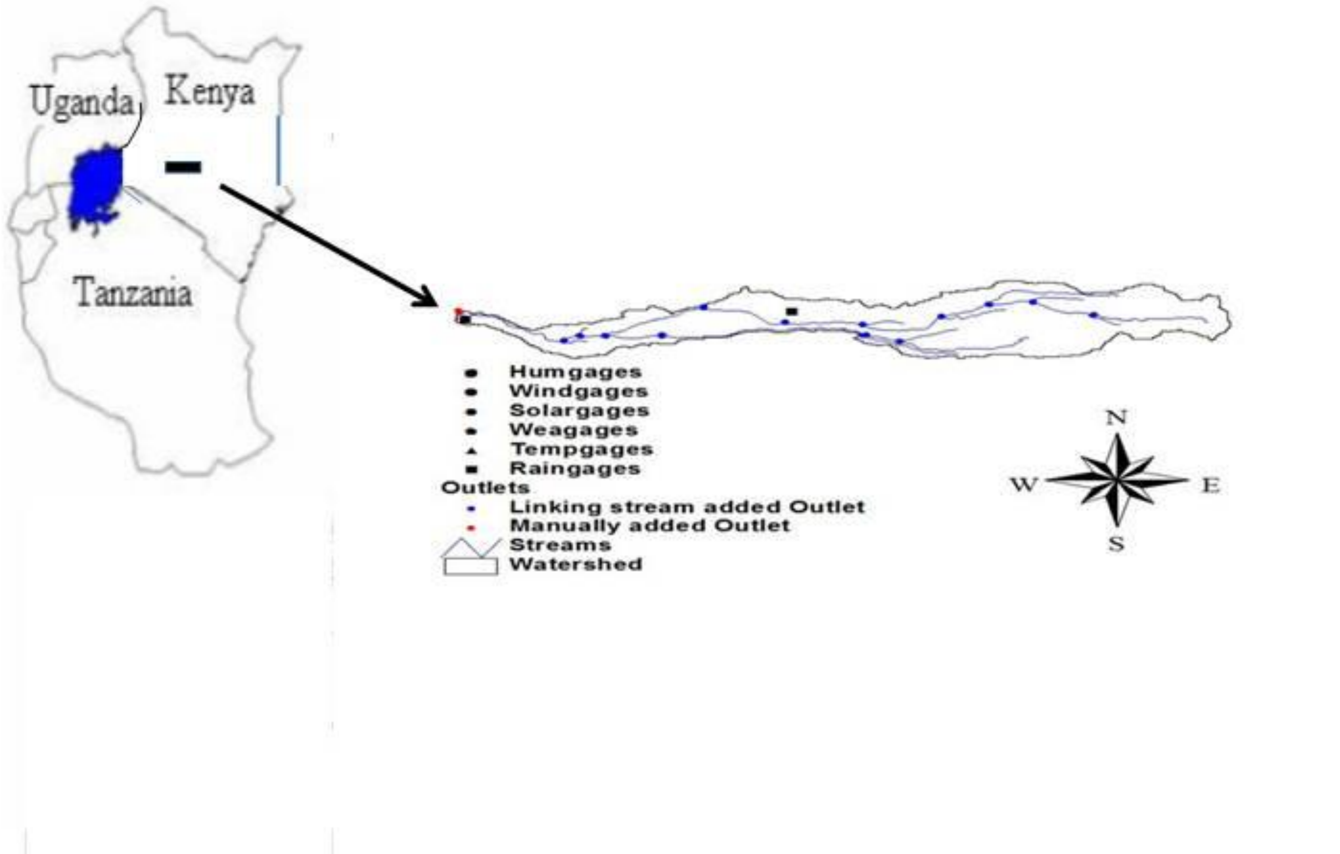
- The study was conducted on a sub catchment in the Naro Moru river, Kenya.

- The sub-catchment covers an area of about 85km^2 falling within the broader catchment of 172 km^2

- The catchment lies on the leeward side of Mt Kenya.
- Catchment lies between latitudes 0^{o} 03' and 0^{o} 11' South and longitudes 36^{o} 55' and 37^{o} 15' East.

- The catchment altitude ranges from 5200m at the peak of the mountain to 1800m above mean sea level at its confluence with *Ewaso Ng’iro river.*

- Location of the study area in Kenya is shown in **Figure**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Model choice and set up

- The SWAT model was used for simulation of streamflow in this study.
- Model has been used worldwide for modeling impact of land use and land cover changes on catchment hydrologic response.

- Watershed was divided into 27 sub basins.

  - Surface runoff predicted using the US Soil Conservation Service (SCS) curve number technique.

Data acquisition and processing

- Data on land use was obtained the years 1984, 2000 and 2010.

  - Satellite image for the years 1984 and 2010 were acquired from the Regional Centre for Mapping Research and Development, Nairobi, Kenya.

- The land use types for the year 2000 was obtained directly from the Kenya Soil Survey.

- The satellite images were classified to obtain the land use maps in the said years (1984 & 2010).

- The land uses types were then reclassified into SWAT land uses to be used in streamflow simulation.

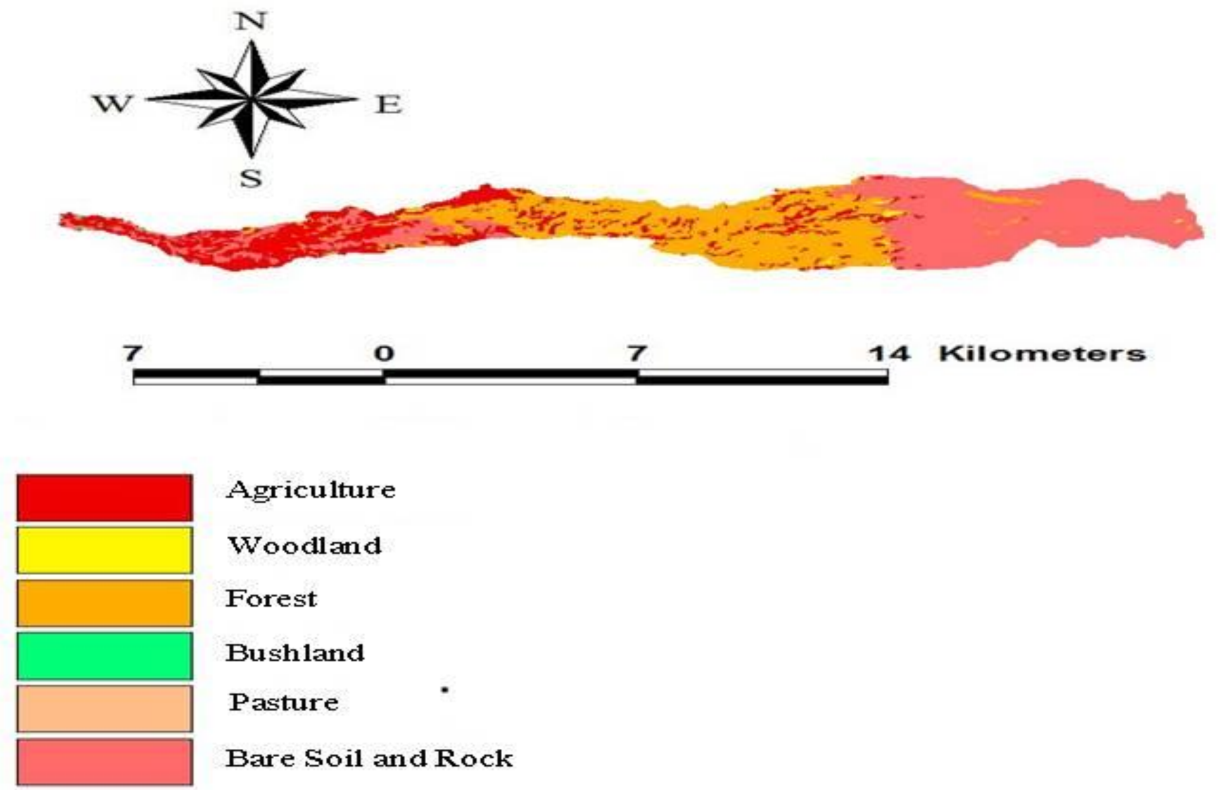

Figure 2. Land use classes for the year 1984

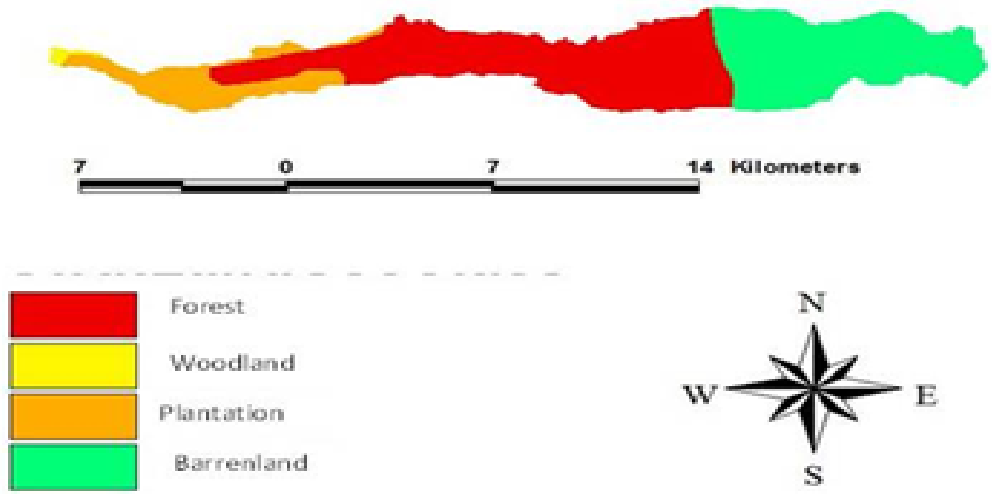

Figure 3. Land use classes for the year 2000

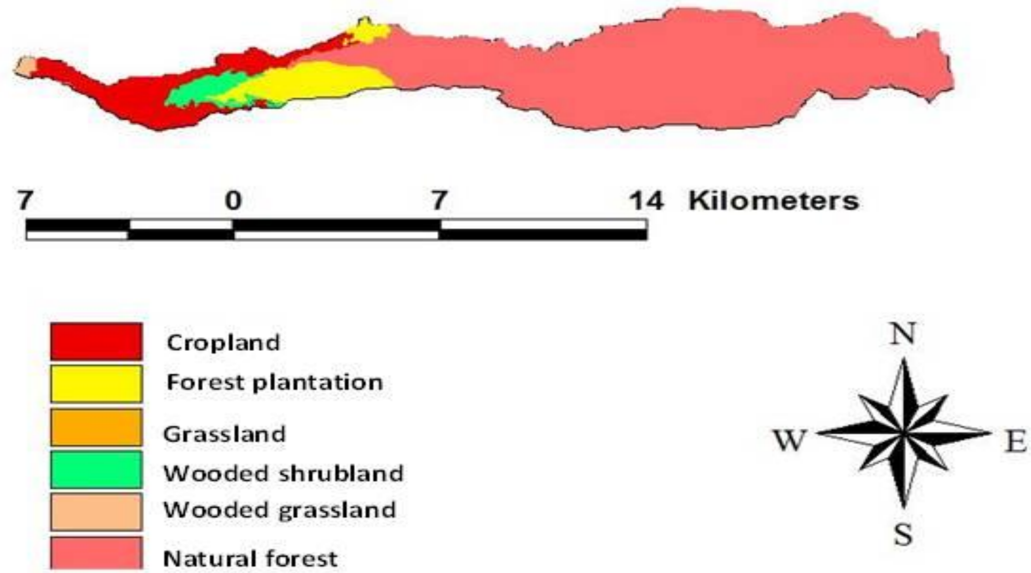

Figure 4. Land use classes for the year 2010

Table 1 Reclassification of land use types in SWAT land use for the year 1984

	1984			2000			2010		
No	**Kenya land use**	**SWAT Landuse**	**SWAT landuse code**	**Kenya land use**	**SWAT Landuse**	**SWAT landuse code**	**Kenya land use**	**SWAT Landuse**	**SWAT landuse code**
1	Agriculture	Agric. land-generic	AGRL	Plantation	Mixed forest Land	FRST	Grassland	Pasture	PAST
							Forest plantation	Forest-mixed	FRST
2	Bare soil or rock	Strip mines	SWRN	Agriculture (sparse)	Cropland and pasture	AGRL	Cropland	Agricultural Land- Generic	AGRL
3	Bushland	Hay	HAY	Woodland	Evergreen Forest Land	FRSE	Wooded shrubland	Range - brush	RNGB
4	Forest	Forest-mixed	FRST				Shrubbed grassland	Bermuda Grass	BERM
5	Grassland	Pasture	PAST	Forest	Deciduous Forest Land	FRSD	Wooded grassland	Range-grasses	RNGE
6	Water	Water	WATR				Built up area	Residential-Medium density	URMD
7	Woodland	Evergreen forestland	FRSE	Barren Land	Strip Mines	SWRN	Natural forest	Forest-Evergreen	FRSE
							Rangeland	Range -brush	SWRN
							Cultivated land	Agricultural land-rowcrops	AGRR

Data input and streamflow simulation.

- The data used as input for streamflow simulation using the SWAT model included
  - daily rainfall,
  - maximum and minimum temperatures,
  - relative humidity,
  - digital elevation model (DEM)
  - land use,
  - soils information and
  - digitized stream network

- obtained from different sources.

- Swat model was *calibrated* for the years 1992 to 1995 and

- *Validated* for the years 1998 to 2000

at

- a gauging station located at the outlet of the catchment (85km^2).

- Streamflow simulation was carried out for the years 1992 to 2000 using input parameters that were obtained after model validation.

- Flow simulations were conducted using land use data for the years 1984, 2000 and 2010 while keeping all the other parameters constant.

- The curve numbers were changed for each of the 27 sub basins based on the soil and land use type combination.

Results and discussion

Land use change analysis

Table 2: Land use types for various years between 1984 and 2010

	1984		2000		2010	
Land use	Area (ha)	%	Area	%	Area	%
Grassland	0.932	0.01	0	0	2.1638	0.03
Wooded shrubland (grazing)	0	0	0	0	311.79	3.65
Natural Forest	3047.13	35.67	4239.35	49.56	6452.1367	75.49
Plantation (mixed forest land)	0	0	1153.59	13.49	727.0565	8.51
Bare soil or rock	3644.73	42.67	3102.57	36.27	0	0
Bushland	10.20	0.12	0	0	0	0
Agriculture/ Cropland	1782.65	20.87	0	0	1053.3637	12.33
Woodland	56.55	0.66	58.4213	0.68	0	0
Total					8553.93	

- Land area under natural forest increased by 14 % of total area during the period 1984 to 2000.

- Area under agriculture was decreased by about 21% in the same period.

    - This resulted from change in land use from agriculture to mainly forest plantation which increased by about 13% during the same period particularly at the lower end of the sub catchment.

- The area under grassland occupied negligible area of less than 1% in the years 1984, 2000 and 2010.

- The proportion of land area under forest plantation decreased from 13.5% in 2000 to 8.5% in 2010 (5 % decrease).

- Between 2000 and 2010 ,there was a further increase in proportion of forest cover by 25%.

- Proportion of agricultural land increased between 2000 and 2010 by about 12%.

  - This may have been as a result of replacement of parts of area under woodland and plantation by agriculture.

- The increase in agricultural land between 2000 and 2010, however was relatively smaller compared to the increase in natural forest cover.

Simulated streamflow response to land use change

- Average daily flow in month based on monthly flow simulation for the years 1984, 2000 and 2010 is shown in the table below

Year of land use data input	1984	2000	2010
Average daily flow in month (m^3/s)	2.47	1.49	1.28

- The average daily flow decreased from 2.47m^3/s to 1.49m^3/s between the years 1985 and 2000.

  - This reflected a decrease of about 40%.

  - This was was attributed to the increase in forest cover and decrease in area under agriculture.

- Forests have the effect of reducing runoff .

and

- higher runoff flows are expected in cropland than in forests.

(Githui, et al. 2009)

- Rainfall satisfies the soil moisture deficit in agricultural more quickly than in forests thereby generating more runoff in agricultural land.

- Less runoff was generated in the year 2000 than in 1984 as a result of increase in forest cover and reduction in agricultural land area.

- Forest cover intercepts precipitation and increases the infiltration opportunity time thereby resulting into more water being infiltrated into the soil.

  - The resulting effect is a decrease in surface runoff and hence streamflow.

- Lower infiltration rates are associated with agricultural land due to soil compaction and increase in bulk density arising from tillage activities.

- Between the years 2000 and 2010, there was a further decrease in average daily streamflow in from $1.49 m^3/s$ to $1.28 m^3/s$ amounting to about 14% decrease.

- This was attributed to a further enormous increase in the forest cover.
- The percentage increase in streamflow between the period 2000 and 2010 was lower that between 1985 and 2000 by 26%.

- The relatively lesser decrease in streamflow between2000 and 2010 compared to between 1985 to 2000 may have been as a result of the increase in agricultural land between 2000 and 2010, which is associated with increased runoff thereby moderating the effect of forest cover.

Conclusion

- Increased forest cover and replacement of agricultural land by forests yielded an increase in streamflow.
  - Attributed mainly to the fact that forests generate less runoff than agricultural land.

- Relatively less reduction in streamflow between 2000 and 2010 due to increased forest cover attributed to increase in cropland which generated more runoff and hence adding to streamflow.

- The findings may not necessarily reflect the exact true picture on the ground due to model limitations and input data deficiencies.

- In SWAT model set up, the subbasins were loaded with the dorminant land use implying that the areal coverage for the various land use practices may not have been exact but based on approximations.

- Classification of satellite images and further reclassification of land use practices to SWAT land uses may not have been as accurate as anticipated.

- Findings provided a general view in land use change analysis which may be used in water resources planning.

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- Special thanks to the Kenya Soil Survey for processing of satellite images to produce land use maps used in the study.

End of Presentation

Thank you for listening