SWAT Modeling of Runoff Pollution Load in Sondu Watershed, Lake Victoria Basin

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1. Introduction

Lake Victoria

- Second Largest Freshwater Lake in the World by surface area (198,000 Km^2)

- Large surface area of the Lake to that of the basin (about 1: 3)

Estimation of Pollution Load & Significance

- Economically important Lake but ecologically compromised
- Data Scarcity
- More need to know where load is coming from
- Past studies recommend incorporation of GIS & RS technologies

Study Objectives

- Simulate river flow, sediment and nutrient load in Sondu watershed using the SWAT;

- Assess temporal-spatial distribution of sources of the sediments and nutrients.

1. Introduction Continued

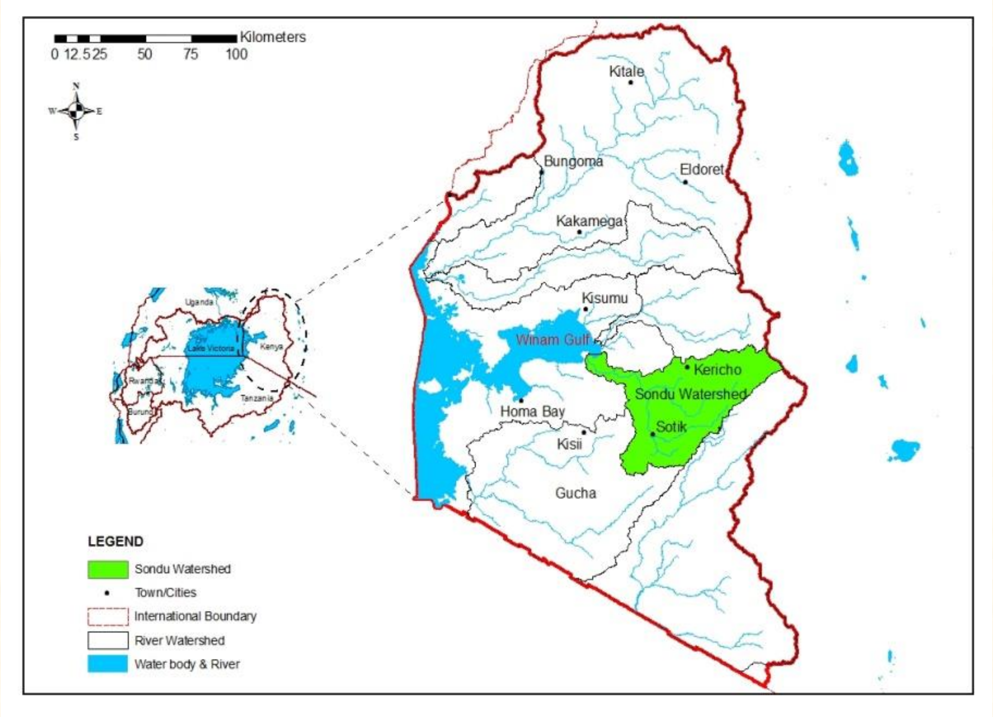
Recent Similar Projects/Studies

There are several similar studies done in the past:

- COWI (2002);
- LVEMP (2005);
- Kimwaga et al. (2011);
- Jayakrishman et al. (2005);
- Scheren et al. (2003; 2005).

Study Area: Sondu Watershed

- ✓ On Kenyan side of the basin
- ✓ The data (water quality) is scarce
- ✓ It is home to Mau forest which is currently under rehabilitation
- ✓ Watershed Area: 3,508Km^2
- ✓ Land cover: mainly forest and agriculture



2. Materials and Method

Data

Land use – Remote Sensing (European Space Agency - ESA)

Soil – FAO: International Institute for Applied System Analysis (IIASA)

Elevation – Digital Elevation Model (DEM) tiles were sourced from NASA (SRTM, 2000)

Weather,Observed river nutrients & Stream Flow – Kenya Meteorological Department (KMD), *Water Resources Management Authority (WRMA)*

Programs & Model Features

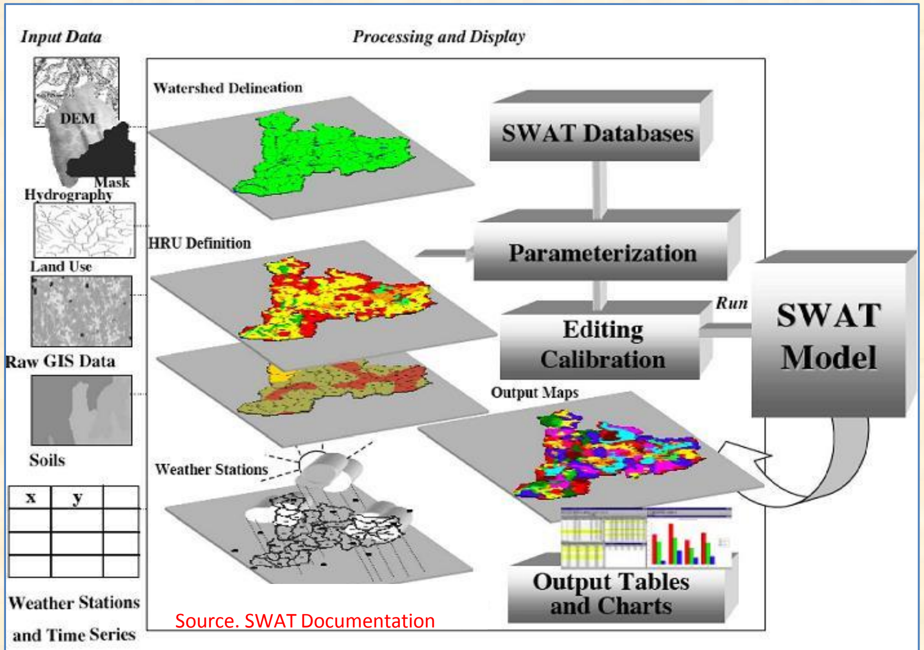
SWAT

SWAT-CUP

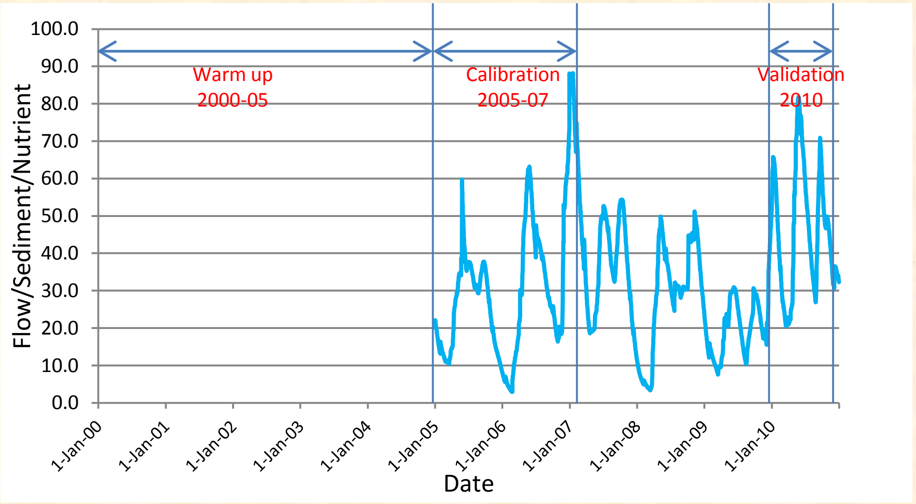
SUFI2

pcpSTAT

- Warm-up Period: 2000 – 2005
- Calibration Period: 2007 - 2010
- Validation Period: 2010
- One Variable at a time: Order - Stream Flow, Sediments, TN & TP



Source. SWAT Documentation



2. Materials and Method cont.

Data Description, Calibration, Sensitivity and Validation

- Data Challenges: Observation Frequency
- Sensitivity Analysis: run in SWAT observed data (2000 -2010)
- Monthly observed data: Calibration and Validation

Available (%) Observed daily weather data

% of No Data Days (1990 – 2010)		
Parameter	Station	Missing Data
Rainfall	Kisumu	0.4 %
	Kericho	0.8 %
	Molo	30.2 %
	Kuresoi	1.9 %
	Kisii	1.9 %
Temperature	Kisumu	8.5 %
	Kericho	11.9 %
	Kisii	21.2 %
Relative Humidity	Kericho	15.6 %
	Kisumu	82.3 %
Wind Speed	Kisumu	94.9 %

Available (%) Observed Monthly Data: Calibration and Validation

Period	Stream Flow	Sediments	TN	TP
2005 - 2007	40 %	34 %	20 %	23 %
2010	75 %	23 %	23 %	23 %

4. Results and Discussion (Sensitivity Analysis)

Sensitivity Analysis

- SCS Curve Number (Cn2) consistently sensitive across the variables. Consistency with other studies

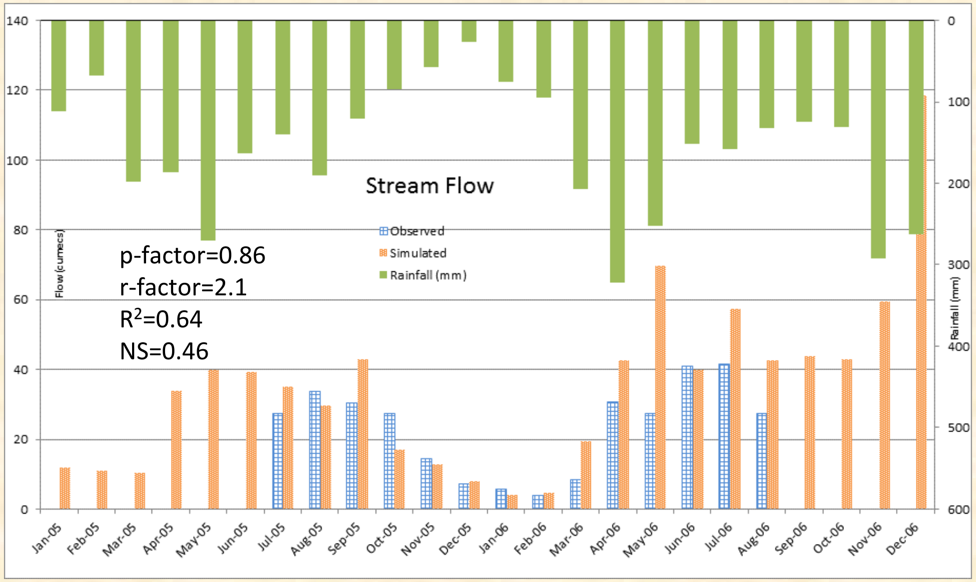
Table. Parameter Sensitivity derived using Observed Variables (Sensitivity decreases down the Table)

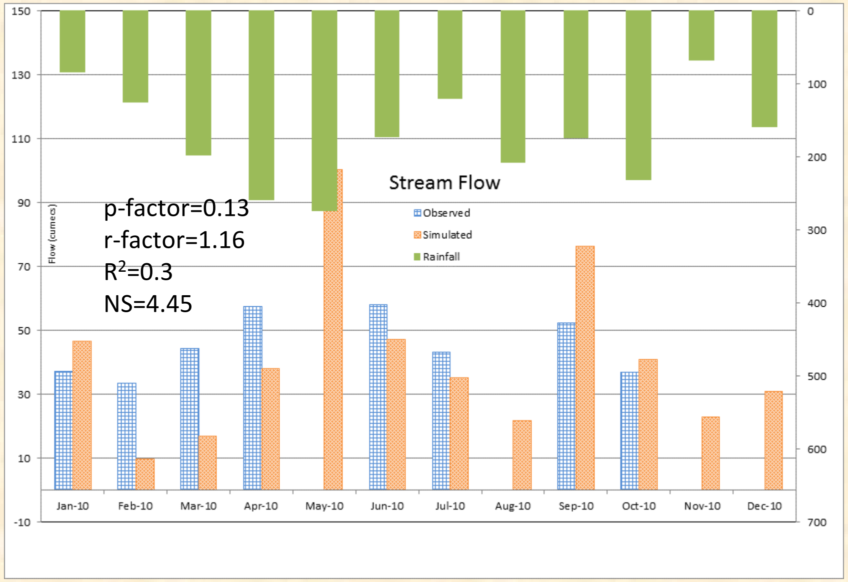
Rank	River Flow	Sediment	Total Nitrogen (TN)	Total Phosphorous (TP)
1	Cn2	Spcon	Nperco	Biomix
2	Alpha_Bf	Ch_K2	Cn2	Surlag
3	Rchrg_Dp	Ch_N2	Blai	Usle_P
4	Ch_K2	Cn2	Biomix	Canmx
5	Ch_N2	Spexp	Rchrg_Dp	Cn2
6	Esco	Alpha_Bf	Usle_P	Ch_K2

- ➢ Parameter ranking guide calibration. However, most sensitive parameters are not exclusively useful

- ➢ The peak and low flows were captured with main use on variation of RCHRG_DP, Alpha_Bf and SOL_AWC parameters

4. Results and Discussion (Stream Flow)





- High rainfall season: March – May
- High stream flow: May-July

➢ One to two months average time lag

➢ Opere & Okelo (2011): R^2=0.24

4. Results and Discussion Cont. (Water Yield by Sub-basin)

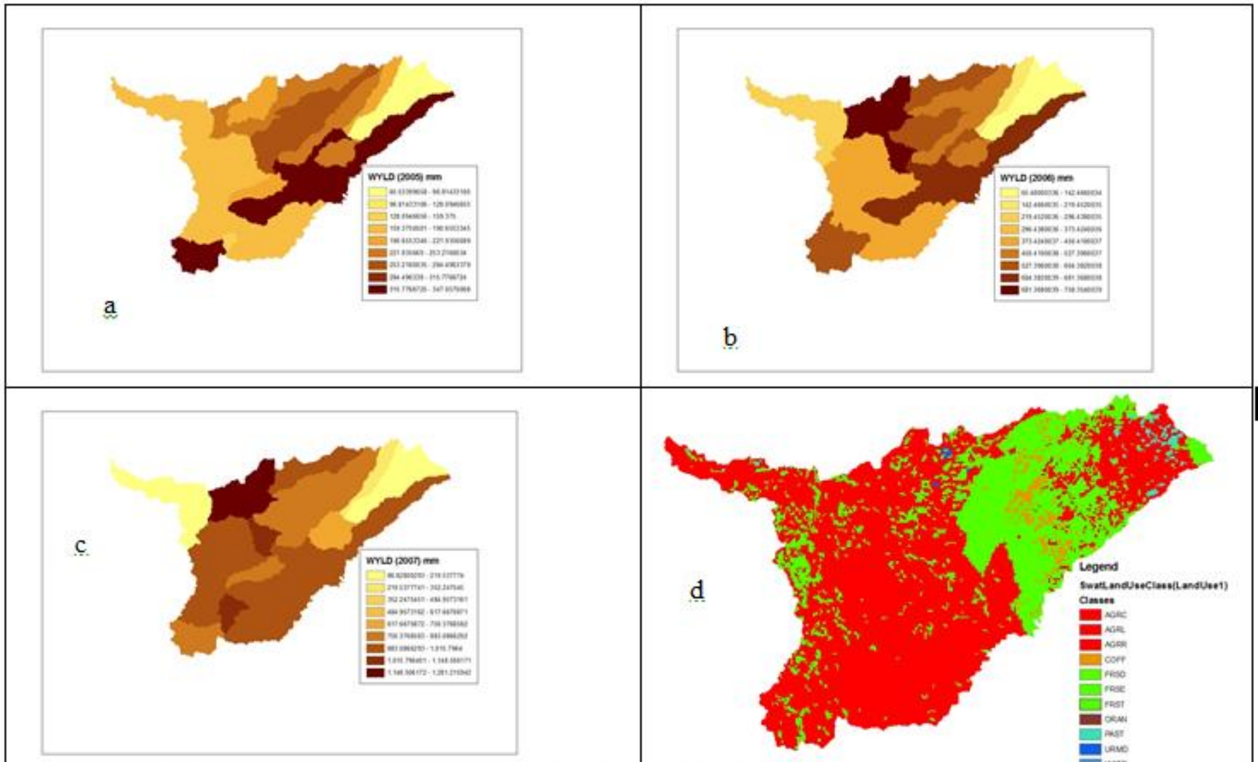


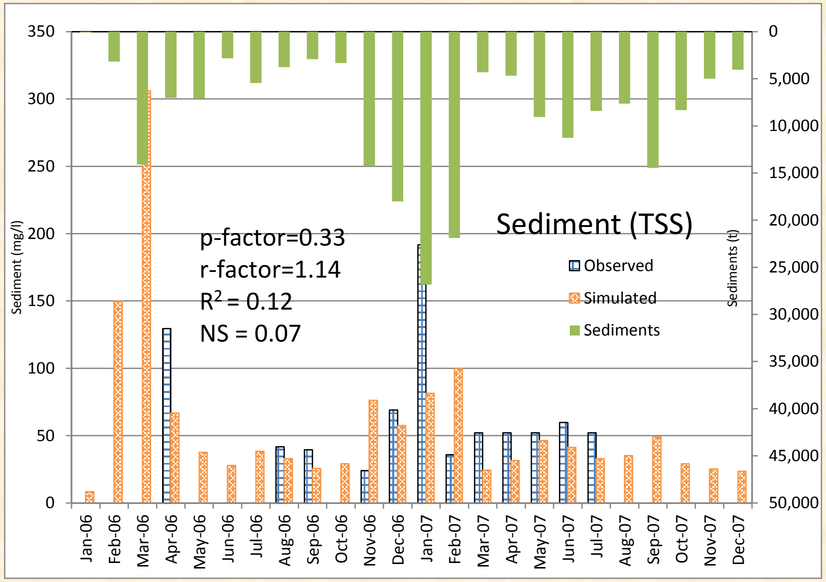
Fig. a, b, c & d. Water yield in the year 2005 (a), 2006 (b), 2007 (c) and Land Cover in the year 2009 (d)

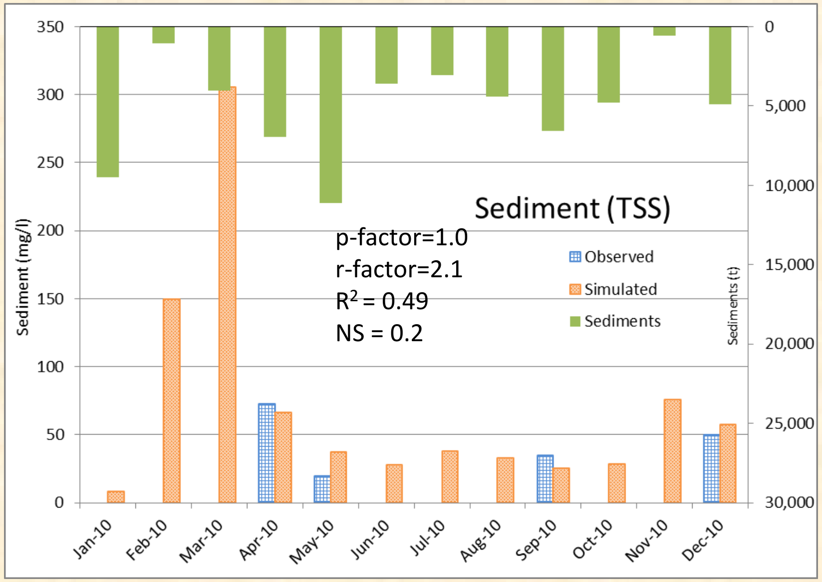
- 2006 highest water yield; 2005 least
- Water yield has similar temporal trend with Rainfall – straight line

➢ High yielding areas: North, South & South East

➢ Explanatory factors: Rainfall & slope

4. Results and Discussion Cont. (Sediment)





- High Sediment Yield season: Feb – April & Nov – Jan
- Correlate with high stream flow
- Higher fluctuations of aggregate load than concentration

4. Results and Discussion Cont. (Sediment Yield by Sub-basin)

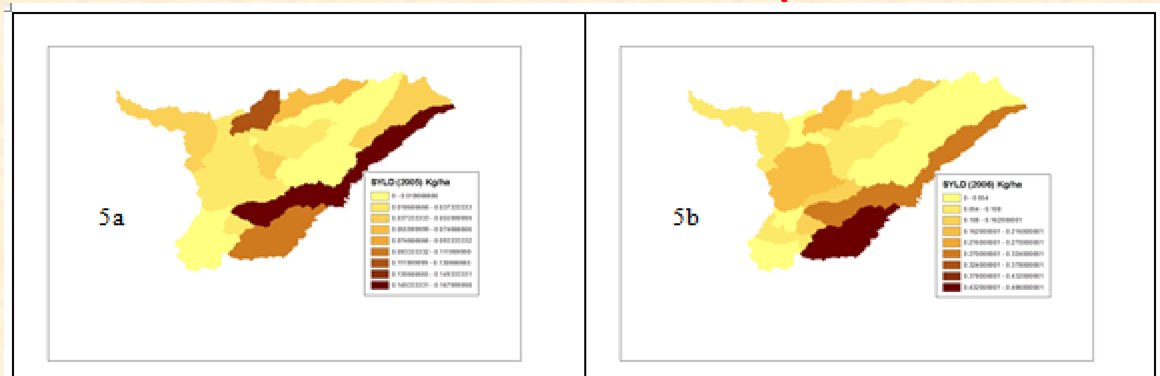


Fig. 5a & b. Sediment Yield in the Year 2005 (5a) and 2006 (5b)

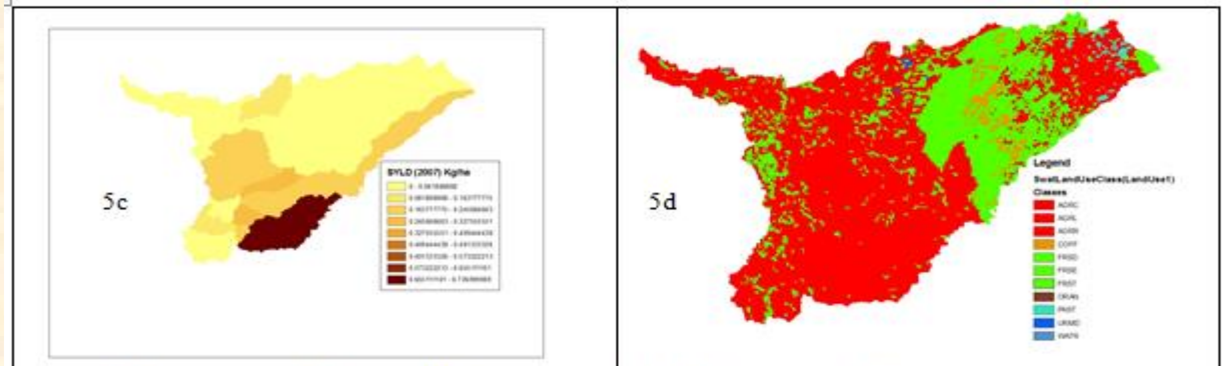


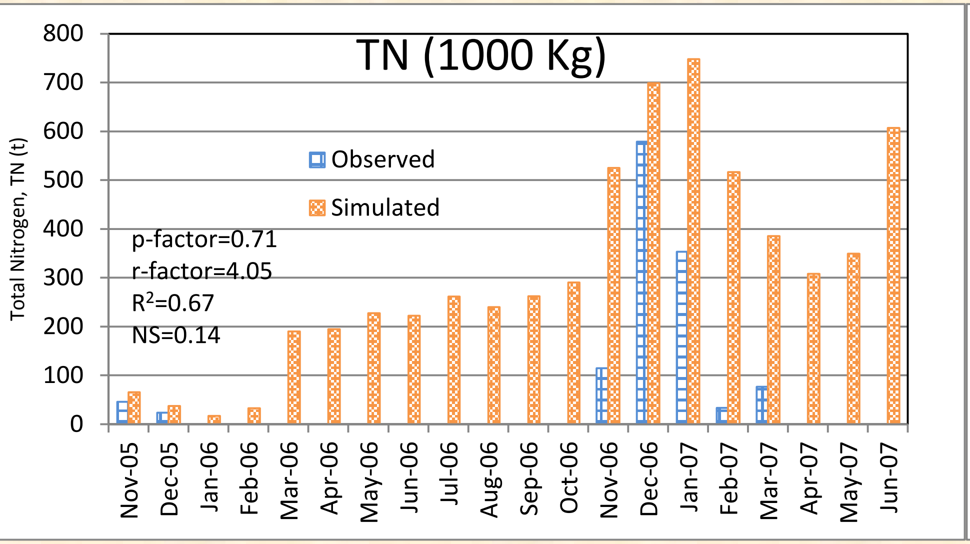
Fig. 5c & d. Sediment Yield in the Year 2007 (5c) and Land Cover in the Year 2009 (5d)

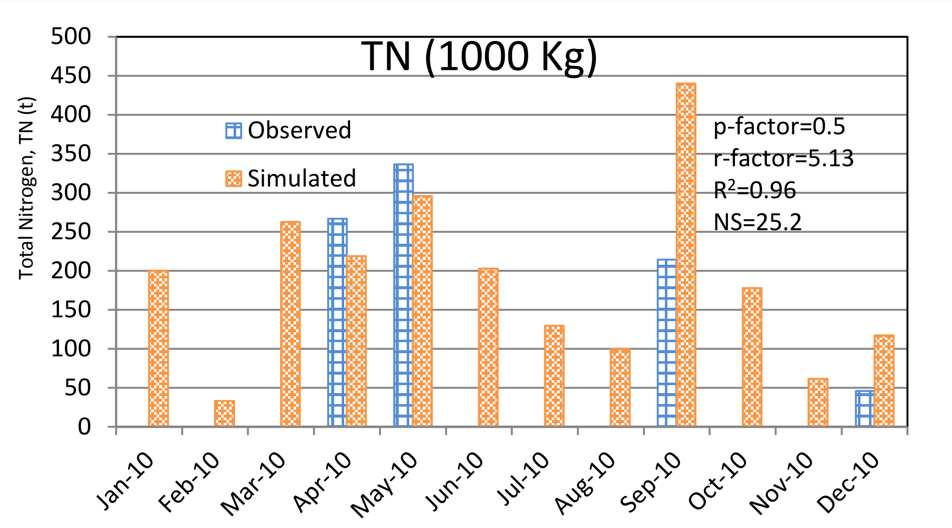
- 2007 highest Sediment yield; 2005 least
- Sediments deposited in the channels

➢ High yielding areas: North, & South of the watershed

➢ Why high Yield? Agriculture & slope

4. Results and Discussion Cont. (Total Nitrogen, TN)





- High TN season: April – May & Oct – Dec ---
- 2005 & 2010 Nov-Dec exception; low rainfall

➢ Data gaps/limitation weigh down model calibration

4. Results and Discussion Cont. (TN Yield by Sub-basin)

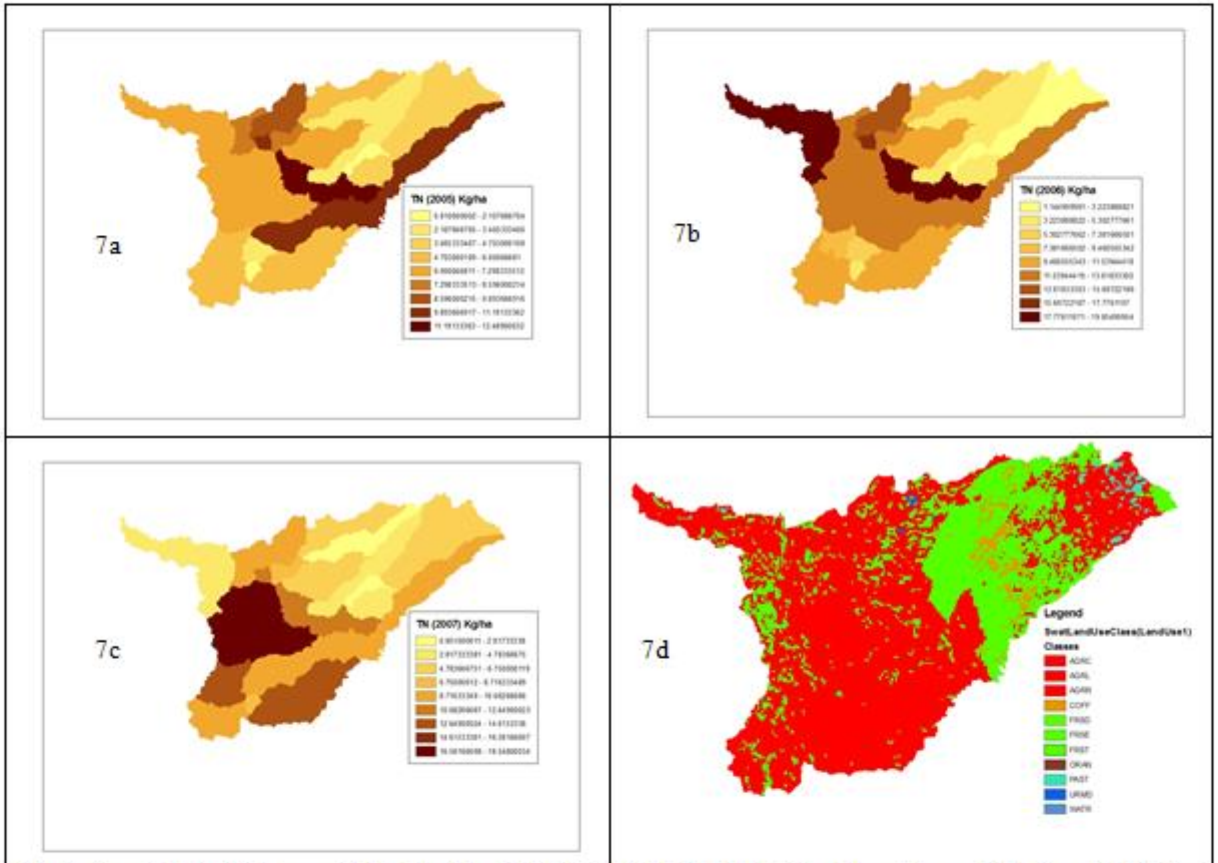
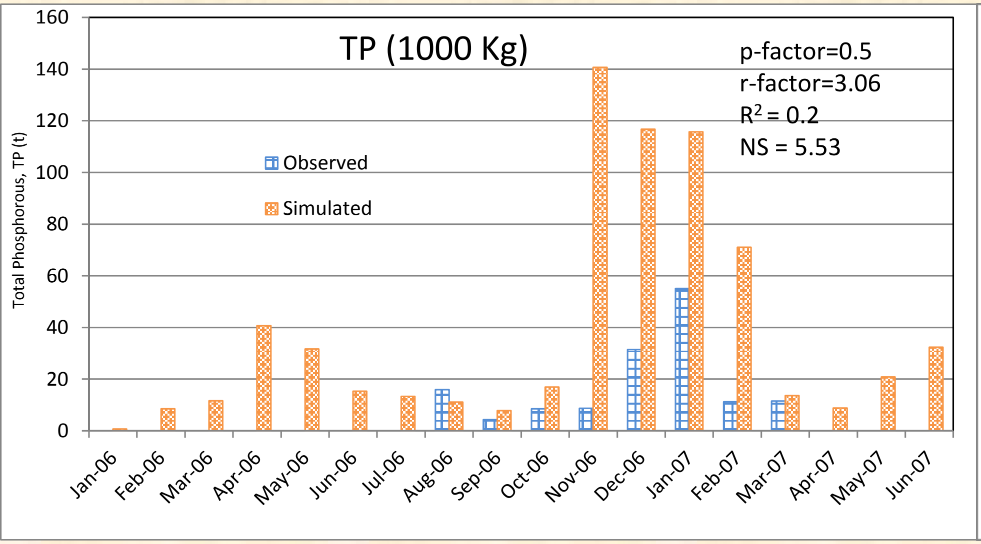
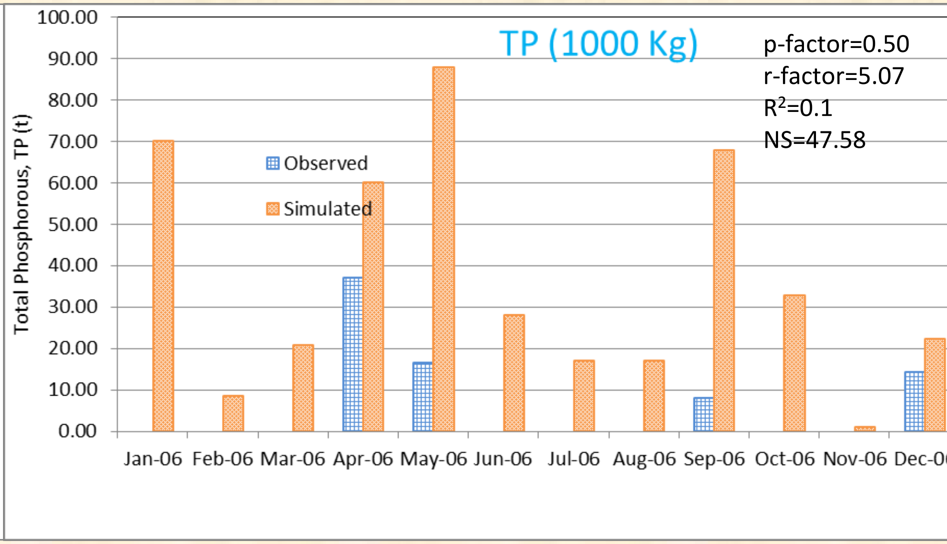


Fig. 7a, b, c & d. Total Nitrogen Yield in the Year 2005 (7a), 2006 (7b), 2007 (7c) and Land Cover in the Year 2009 (7d)

- 2007 highest TN yield; 2005 least
- High yielding areas: downstream, & Central to West of the watershed
- Explanation? Agriculture & high population densities

4. Results and Discussion (Total Phosphorous, TP)





- Seasonal Variations – same as TP: High TP season: April – May & Oct – Dec ---
- 2005 & 2010 Nov-Dec exception; low rainfall
- Data gaps/limitation weigh down model calibration

4. Results and Discussion Cont. (TP Yield by Sub-basin)

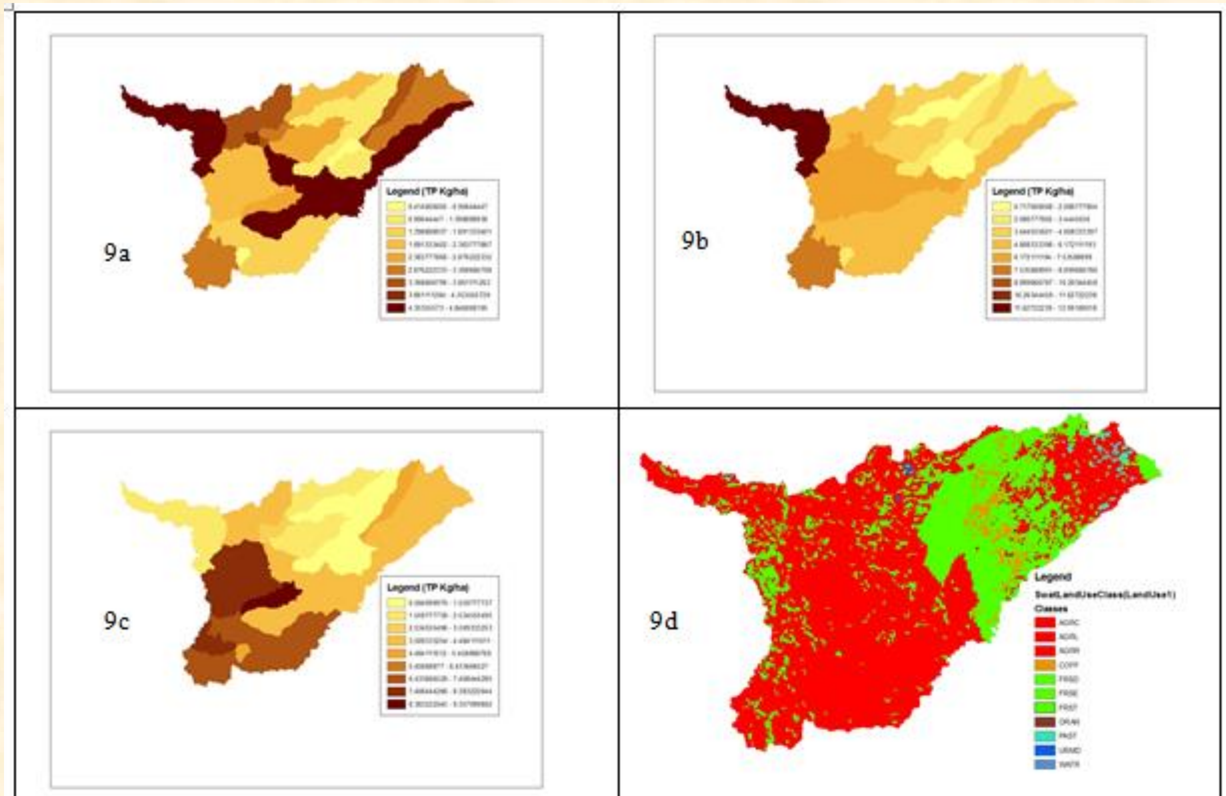


Fig. 9 a, b, c & d. Total Phosphorous yield in the year 2005 (9a), 2006 (9b), 2007 (9c) and Land Cover in the year 2009 (9d)

- Temporal Variation: 2006 highest TP yield; 2005 least
- High yielding areas: downstream, & Central-west of the watershed
- Agriculture & high population densities

4. Results and Discussion Cont. (Comparative Analysis)

Calibration Variables (Concentration)

Study/ Variable	This Study (2005-07)		LVEMP (2005) 2003	COWI (2002) 2000
	Simulated	Observed		
Average Flow (m^3/s)	23.2	23.5	42.2	40.3
TSS (Mg/l)	63.1	66.6	94.8	-

Calibration Variables (Aggregate)

Study/ Variable	TSS (2005)	TSS (2006)	TSS (2007)	TN (2005)	TN (2006)	TN (2007)	TP (2005)	TP (2006)	TP (2007)
Simulated (This Study)	32,250 t	82,020 t	125,900 t	1,335 t	3,157 t	5,673 t	154 t	416 t	370 t
Observed (This Study)	-			2,675 t/yr			312 t/yr		
LVEMP (2005)	145,192 t (2003)			1,821 t (2003)			183 t (2003)		
COWI (2002)	-			1,374 t (2000)			318 t (2000)		

- Differences in stream flow explained by rainfall characteristic --- derivative explanation to slight difference in TSS, TN & TP
- However, the studies used different methods, and were based on data for different periods of time
- Distributed and non distributed methods

5. Conclusions

- Sensitivity. Cn2 consistently sensitive across variables. However, they are not necessarily exclusively useful in calibration. e.g. SOL_AWC & RCHRG_DP were not among the most sensitive but was useful in calibrating peak flows;
- Comparative analysis. The calibrated results compared well with past studies;
- Temporal distribution. Rainfall: 2005 was low rainfall year - had low sediment & nutrient yield;
- Variable correlation. High sediment and nutrient yield seasons directly correlated with rainfall seasons; – cultivation season?
- Spatial distribution. Downstream, central – west of the watershed are high sediment and nutrient yield zones;

6. References

- COWI Consulting Engineers (2002). *The Integrated Water Quality/Limnology Study.* LVEMP, Part II Technical Report, East African Community, Arusha, Tanzania.
- Kimwaga R. J., Mashauri, D. A., Bukirwa, F. (2011). Modeling of Non-Point Source Pollution Around Lake Victoria Using SWAT Model: A case of Simiyu Catchment Tanzania. *The Open Environmetal Engineering Journal*, **4**, 112-123.
- Lake Victoria Environmental Management Project, LVEMP (2005). *Lake Victoria Environment Report on Water Quality and Ecosystems Status: Winam Gulf and River Basins in Kenya*, Ministry of Water and Irrigation, Kisumu, Kenya.

Thanks