APPLICATION OF SWAT FOR WATER QUALITY MODELLING IN A CHANGING CATCHMENT AND CLIMATE CONTEXT OF RIVER SOSIANI IN WESTERN KENYA

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PRESENTATION OUTLINE

1 INTRODUCTION

2 PRELIMINARY DATA

3 SWAT WQ MODELLING (CATCHMENT)

4 CONCLUSIONS AND RECOMMENDATIONS

1. INTRODUCTION

OBJECTIVE

- **To assess and monitor pollution loading in the River Sosiani Catchment (369km^2), Eldoret City, Kenya.**

- **River Sosiani drains into Lake Victoria, the largest freshwater body in East Africa.**

- **Rivers in Kenya are experiencing high pollution levels from;**
  1. **Municipal and industrial point sources,**
  2. **Non-point sources resulting from agriculture, erosion and other commercial activities.**

- **GIS linked ArcSWAT is applied to;**
  1. **Simulate catchment hydrology and water quality,**
  2. **Identify the causes of changes in water quality and find criteria to prevent imminent water quality deteriorating trends.**

1. INTRODUCTION

CHANGING CATCHMENT AND CLIMATE CONTEXT

- Land Use/ Land Cover Area (369km^2) (2023)

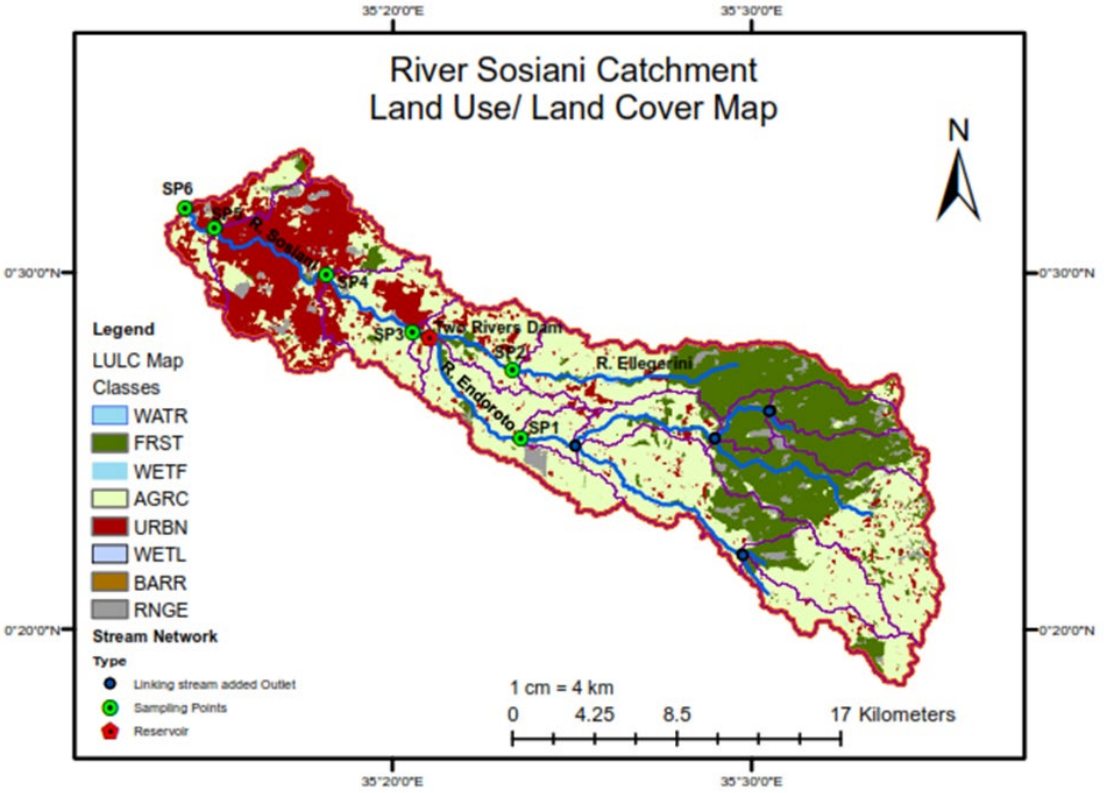
YEAR	LULC	AREA COVERED	SOURCE
1989	FOREST	37% (Natural & planted forests)	(Kibii et al., 2021)
	AGRICULTURE	32.2%	
		-Maize (7.25%) -Wheat (5.5 %) -Mixed Farming (19.42%)	
2023	FOREST	25%	SWAT modelling
	AGRICULTURE	54.1%	
		-Maize (19.4%) -Wheat (7 %) -Mixed Farming (27.66%) (potatoes-8.78%, tea-7.3%, pasture-6.5%, cabbages-5.08%)	

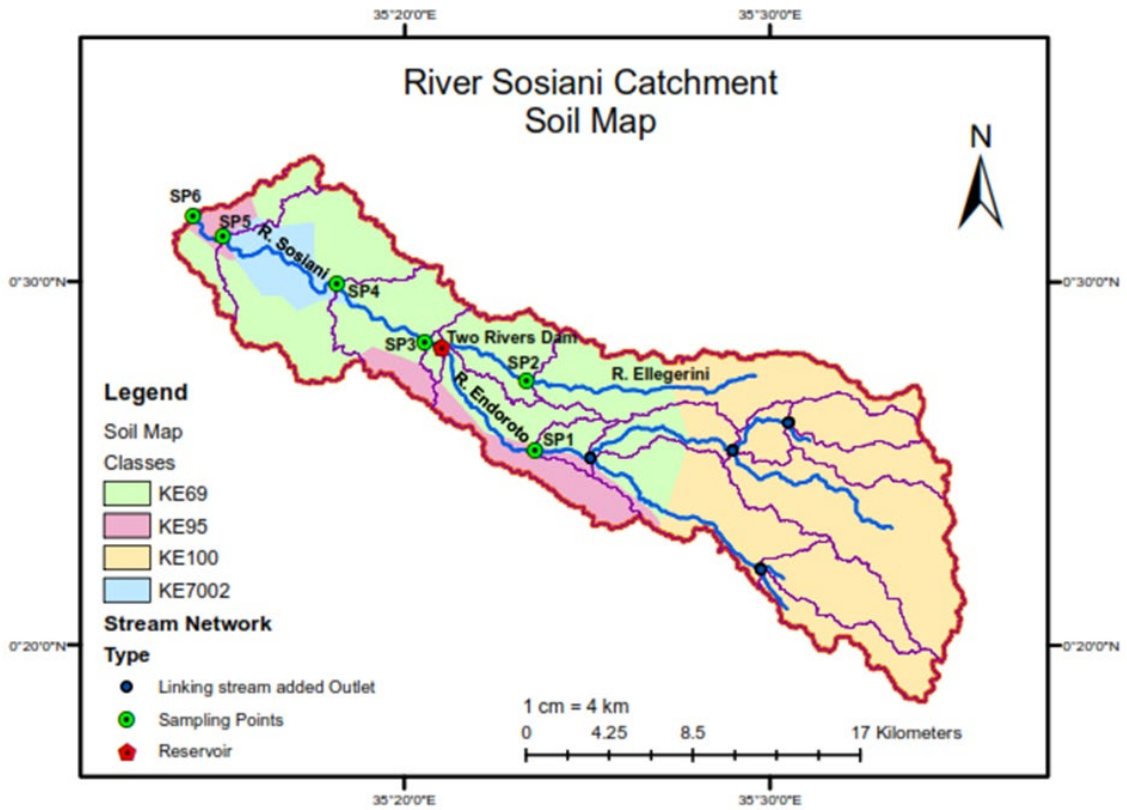
1. INTRODUCTION

CHANGING CATCHMENT AND CLIMATE CONTEXT

- Land Use/Land Cover and Soil Maps - 369km² (2023)

AGRC:54%, FRST:25%, URBN:18% KE100:47%, KE69:40%, KE95:8%,KE7002:5%



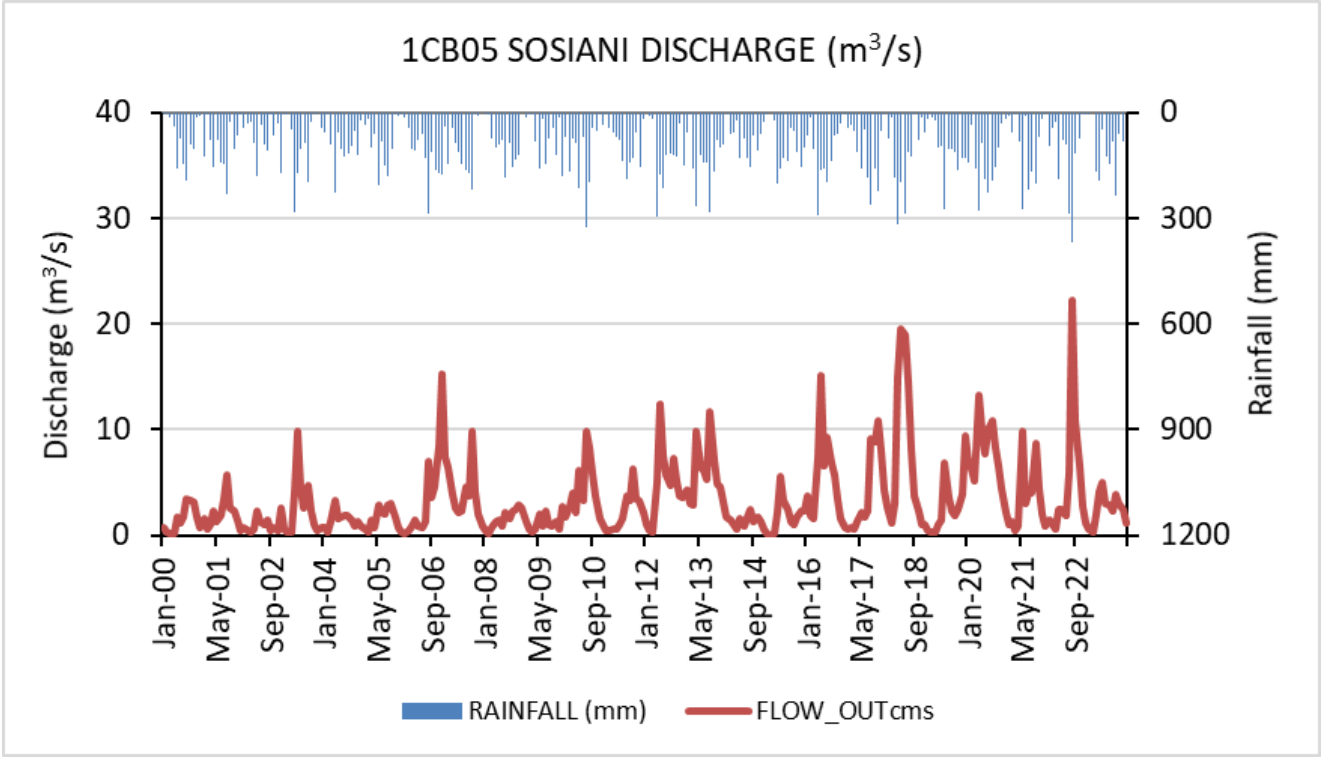


1. INTRODUCTION

CHANGING CATCHMENT AND CLIMATE CONTEXT

- **Runoff/Groundwater Recharge(high variations);impacts river flows,reservoir storage,WQ**

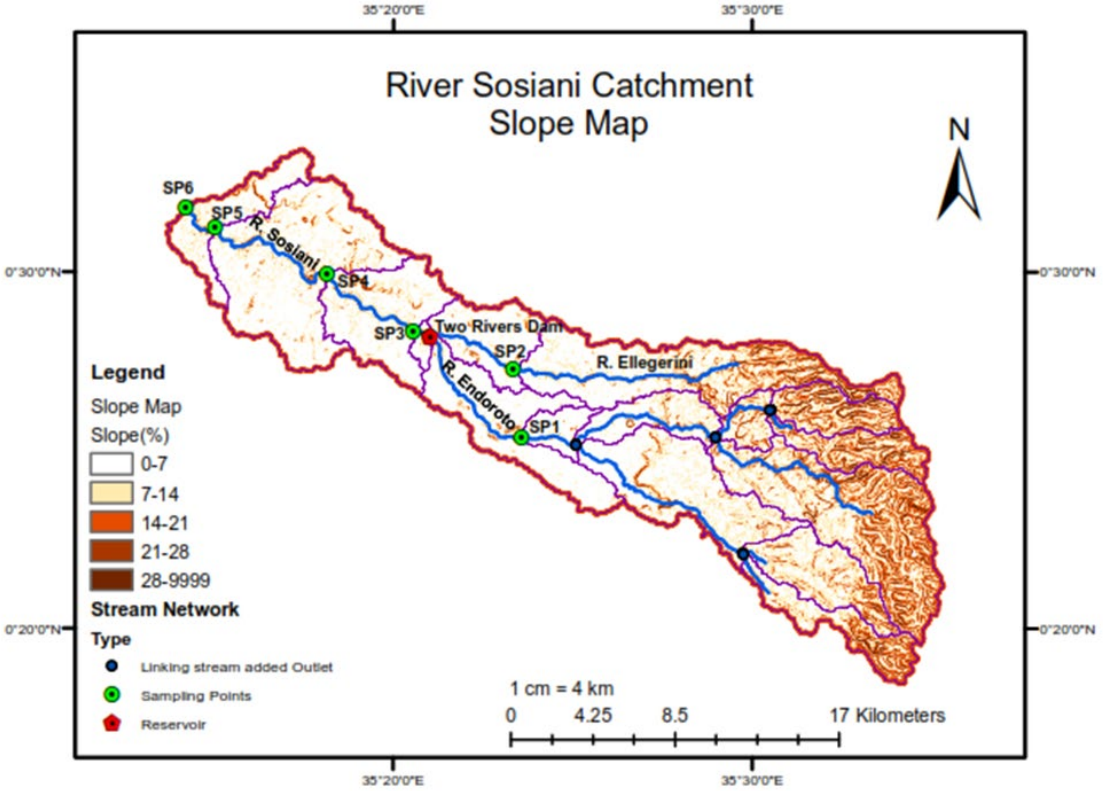
YEAR	RUNOFF (mm)	GROUNDWATER RECHARGE (mm)
2000	228.35	158.2
2009	205.81	149.61
2018	243.08	119.51
2023	168.36	115.95
Streamflow	-surface runoff -lateral flow (vadose zone)	-percolation to shallow aquifer (return flow) -Recharge to deep aquifer

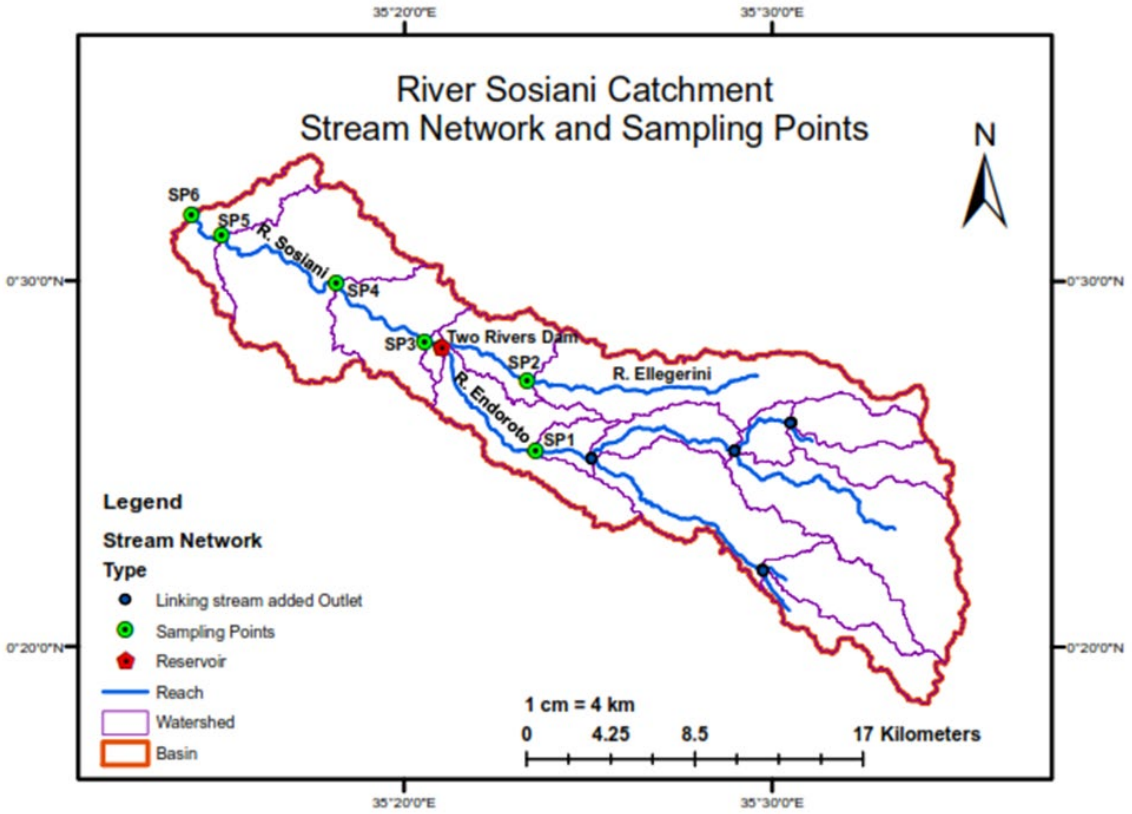


1. INTRODUCTION

CHANGING CATCHMENT AND CLIMATE CONTEXT

- **Slope Map, Stream Network and Sampling Points**
- **0-7%:Flat, 7-14%:mild, 21-28%:Steep Sampling Points: SP1 (U/S) to SP6 (D/S):(47.9km)**

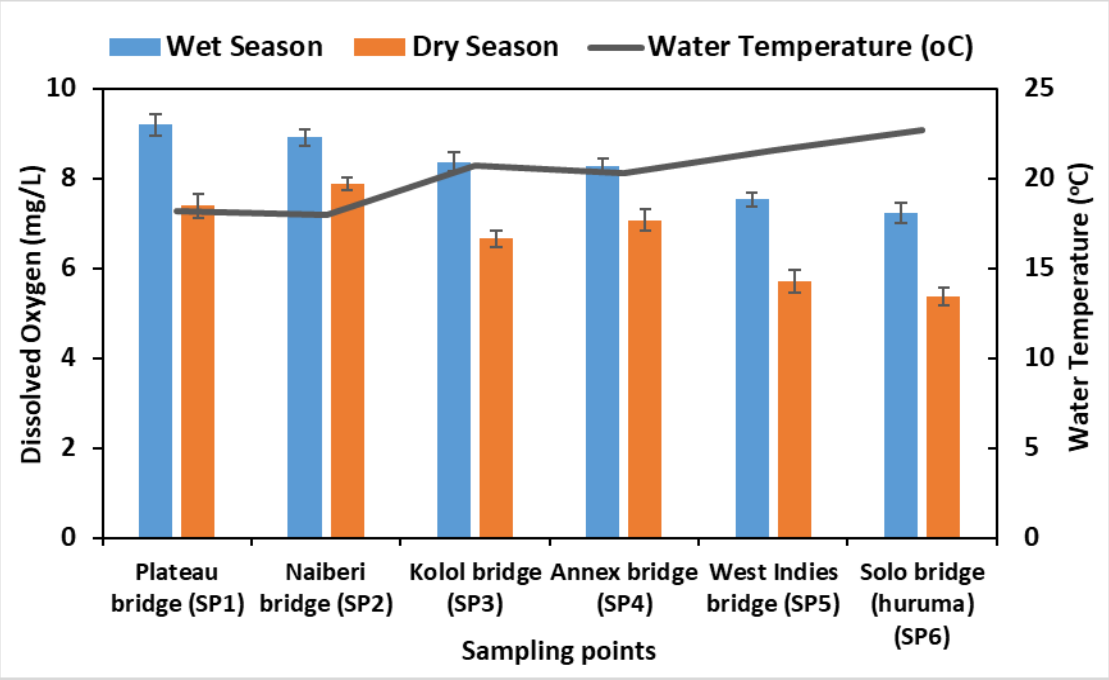




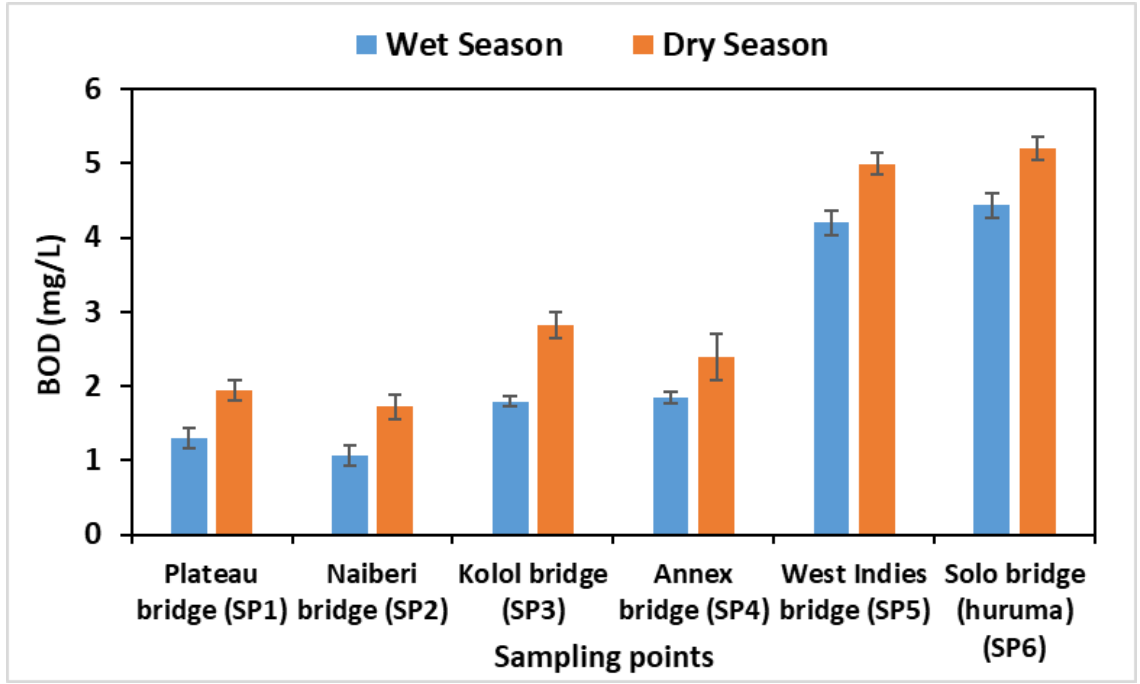
2. PRELIMINARY DATA

WET AND DRY SEASONS: Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD)
Wet Season: Apr- Jul ’23 (4 months),Dry Season: Feb- Mar’23 (2 months)

-High DO, 7mg/l-good, lowest(SP6-Outlet)



-High BOD, highest (SP6-Outlet)

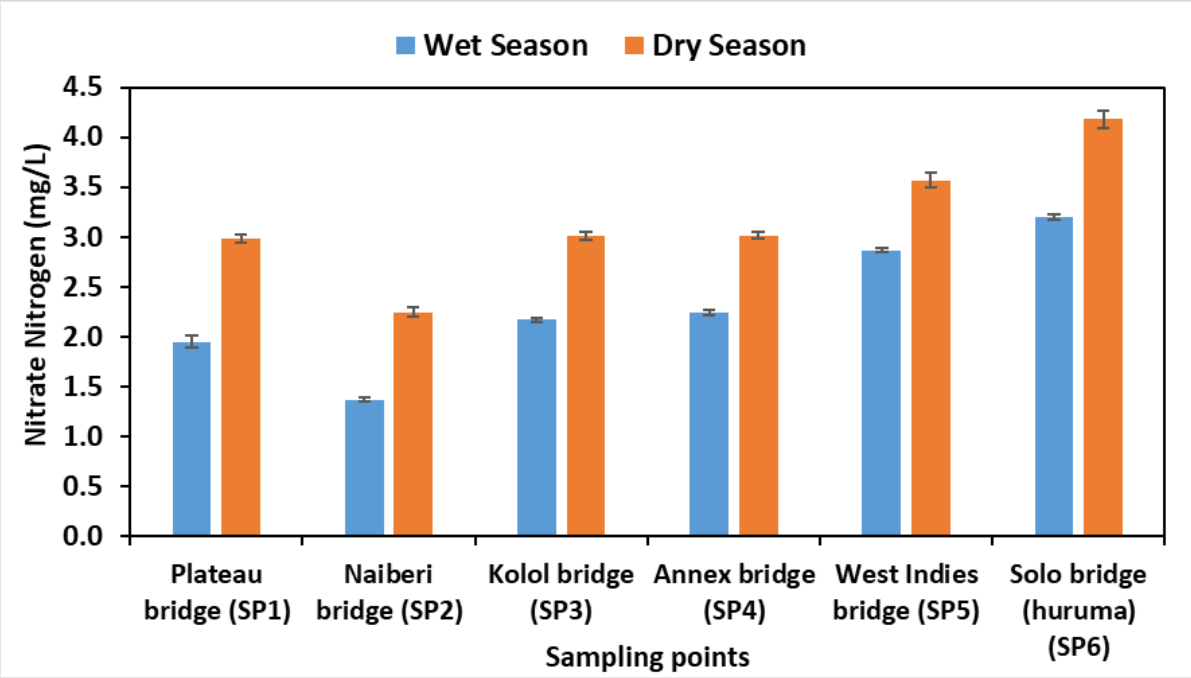


2. PRELIMINARY DATA

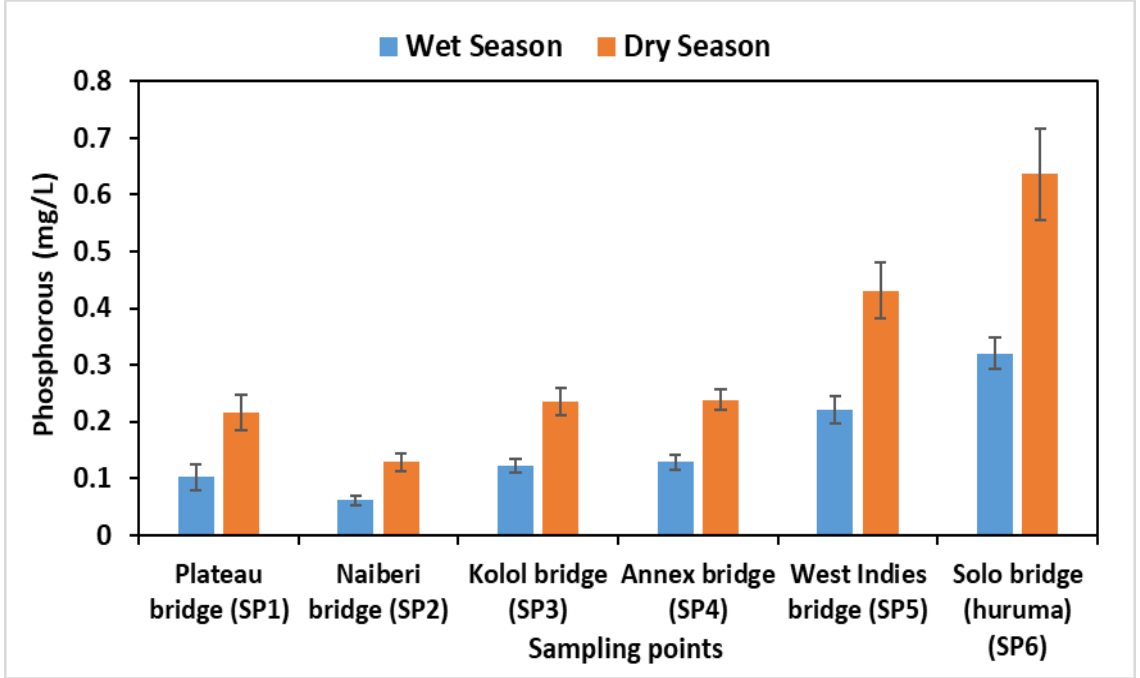
WET AND DRY SEASONS: Nitrate (NO3-N) and Phosphorous (P)

- P – limiting nutrient for eutrophication – freshwater (stagnant > 0.10 mg/l, Flowing waters > 0.25 mg/l)

-low NO3, highest: SP6-Outlet (1CB05)

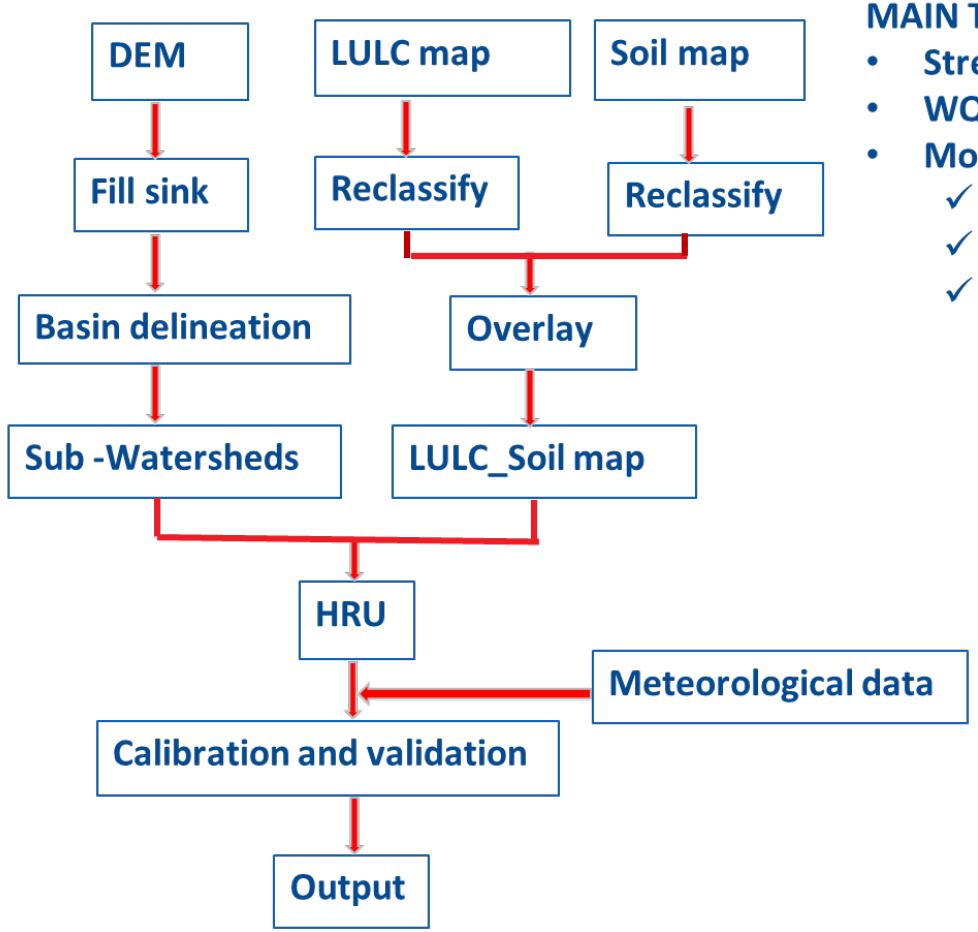


-High P, highest: SP6-Outlet (1CB05)



3. SWAT WQ MODELLING

METHODOLOGY AND DATA



MAIN TASKS

- Streamflow measurements
- WQ tests
- Modelling Catchment
  - ✓ Streamflow
  - ✓ Water quality
  - ✓ Crop yields

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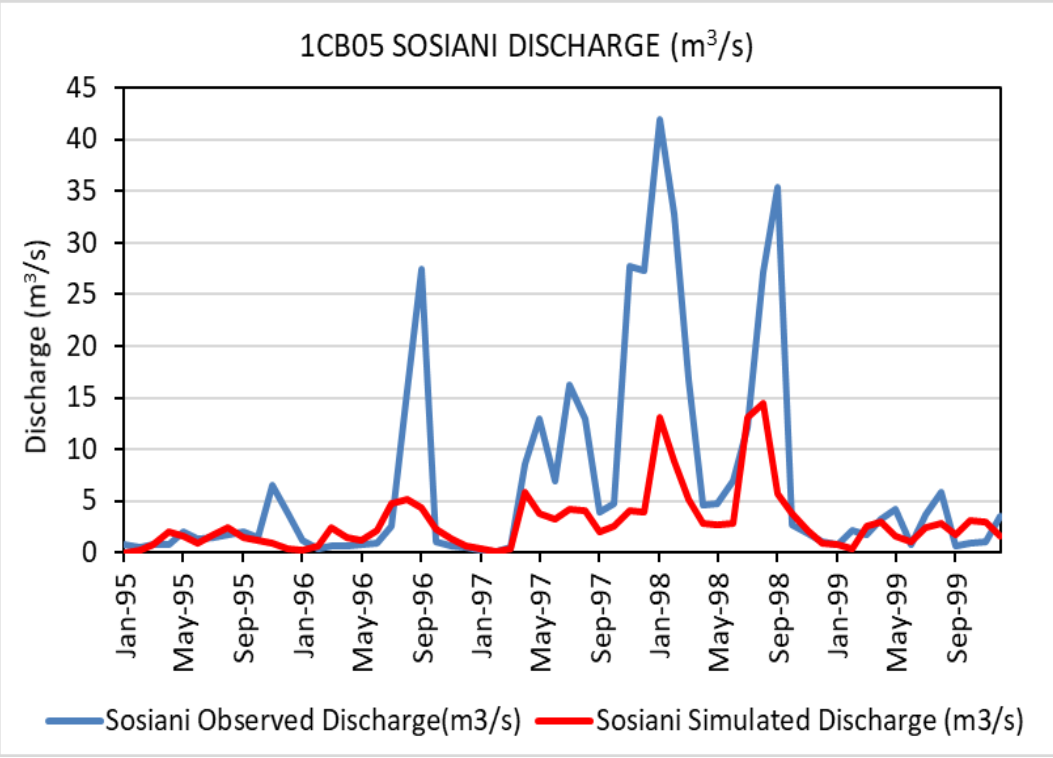
3. SWAT WQ MODELLING

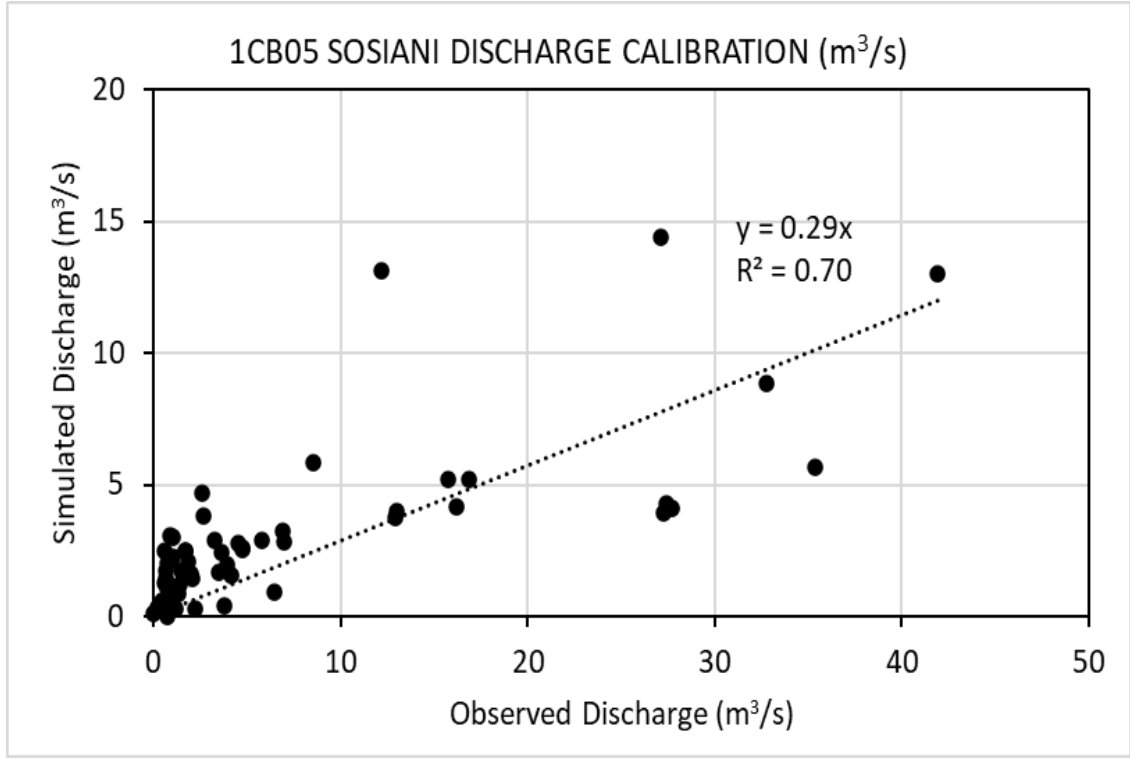
METHODOLOGY AND DATA

DATA	Parameter Explanation	Equipment/Downloads
DEM	SRTM -1 ARC-S approx. 30 m resolution; Elevation (2764 - 2004 m asl; 7 - 28 degrees)	Downloads from USGS website
LULC	Farmlands (crops), Forest, Urban (built area), others (grasslands, water bodies) etc.	Arc GIS
SOILS	KE100 -Nitisols-Humic, KE69 -Ferralsols-Haplic, KE7002 -Nitisols-Dystric & KE95 –Gleysols-Eutric.	Kensorter soil map downloads from UN-FAO website
R. NETWORK	Stream order(1,2)-Ellegerini, Endoroto, Sosiani; Sampling points (SP1 to SP6)	Arc GIS
WQ	DO, BOD, pH, EC, TEMP, NO3-N, P, TDS, TSS	HACH DR/2000 Direct Reading Spectrophotometer (In-situ), Water Quality (WQ) Labs
Others	Discharge, Cross-sectional areas, velocities, wetlands, buffer zones, reservoirs, meteorological data	River Discharge Gauge Stations, Automatic Weather Stations
MODELS	Arc SWAT & QUAL2K	Arc GIS, website downloads

3. SWAT WQ MODELLING

CALIBRATION (1995-1999)
Parameters:CN2, ESCO, ALPHA_BF.gw, GW_REVAP.gw, REVAPMN.gw, GWQMN.gw, SLSUBBSN.hru, and SOL_AWC.sol

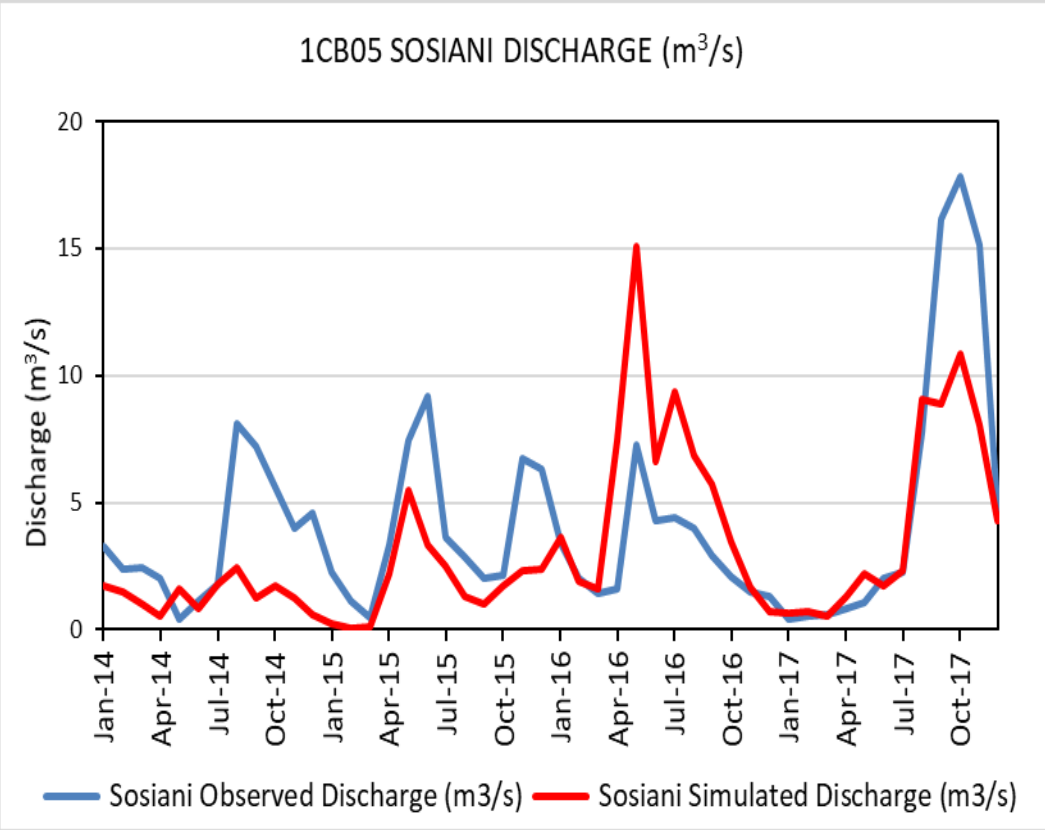


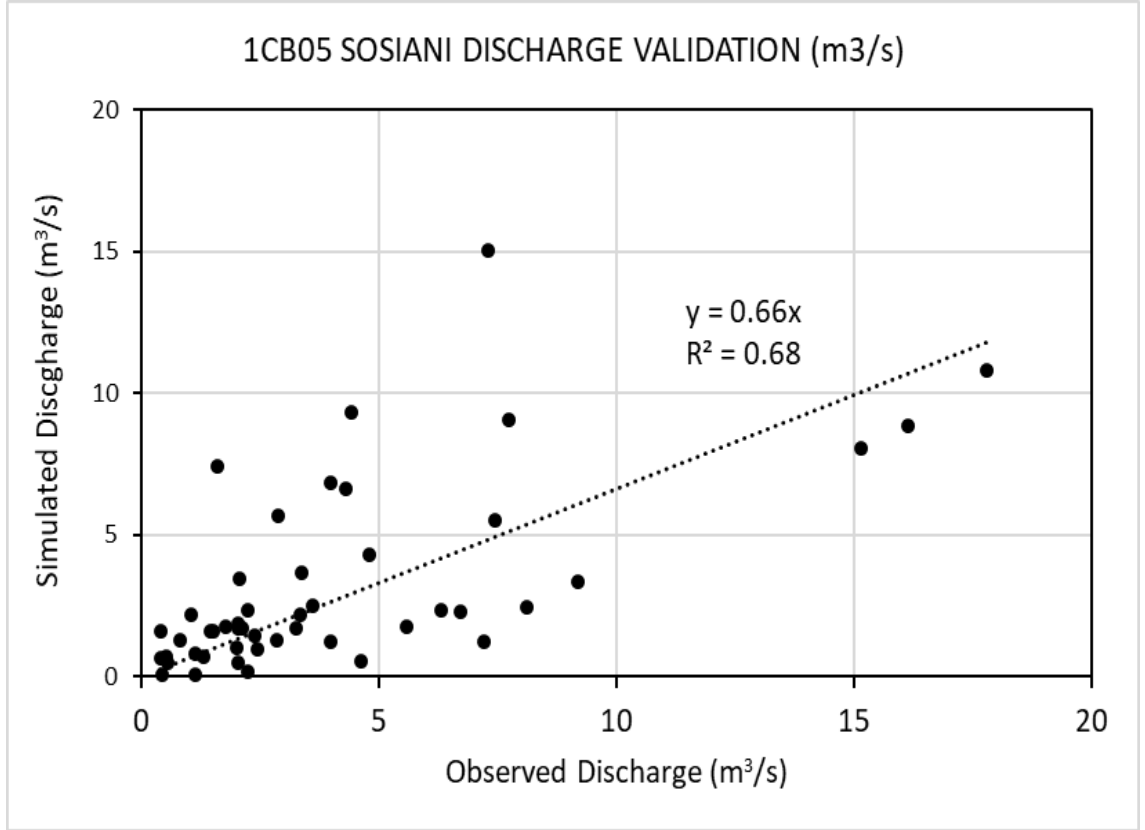


3. SWAT WQ MODELLING

VALIDATION (2014-2017)

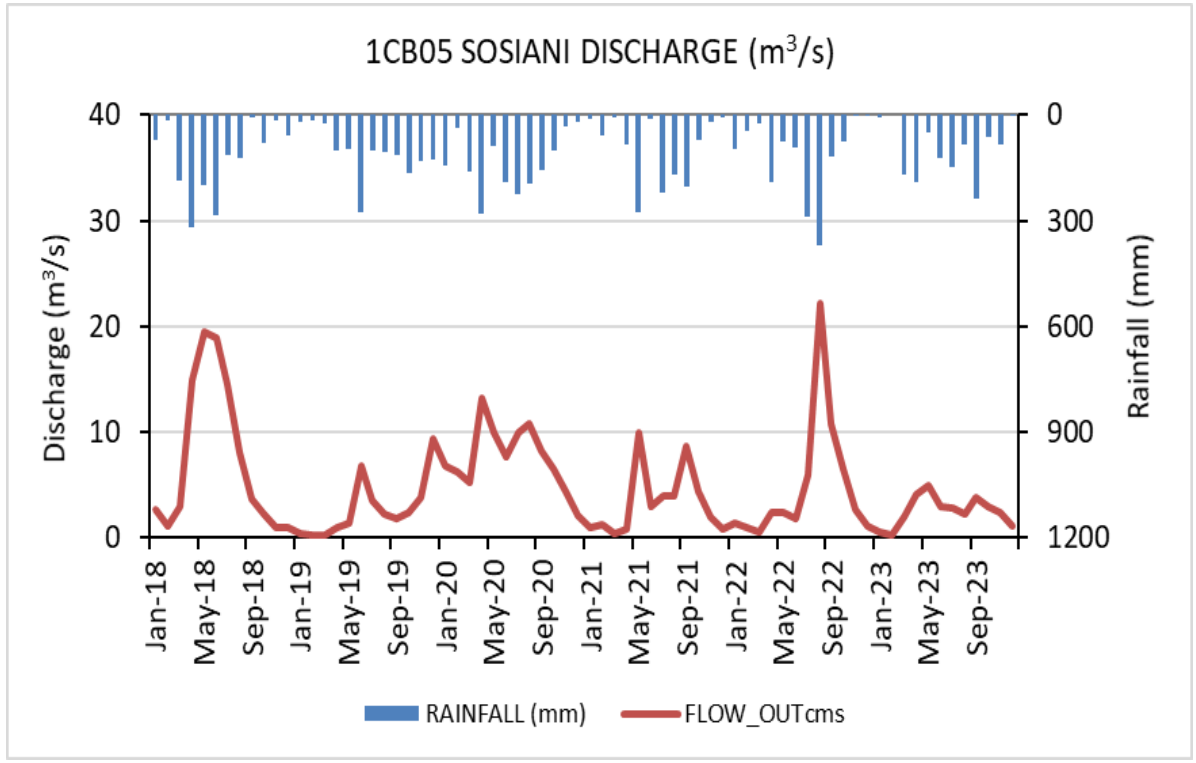
Parameters: Calibration R^2 = 0.70, Validation R^2 = 0.68

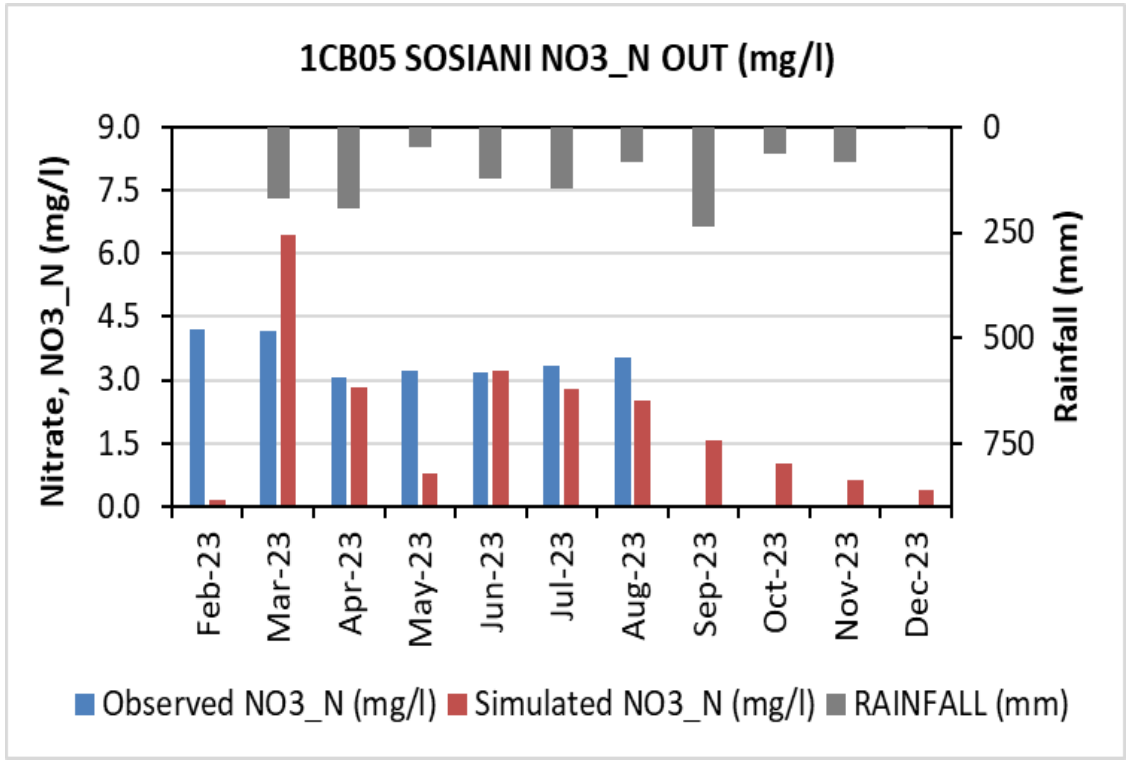




3. SWAT WQ MODELLING

SIMULATION (2018-2023)
Parameters: Nitrate (NO3_N),
Crop Yields (Maize 38bags@90kg/acre-8.4t/h, Wheat 25bags@90kg/acre-5.5t/h)



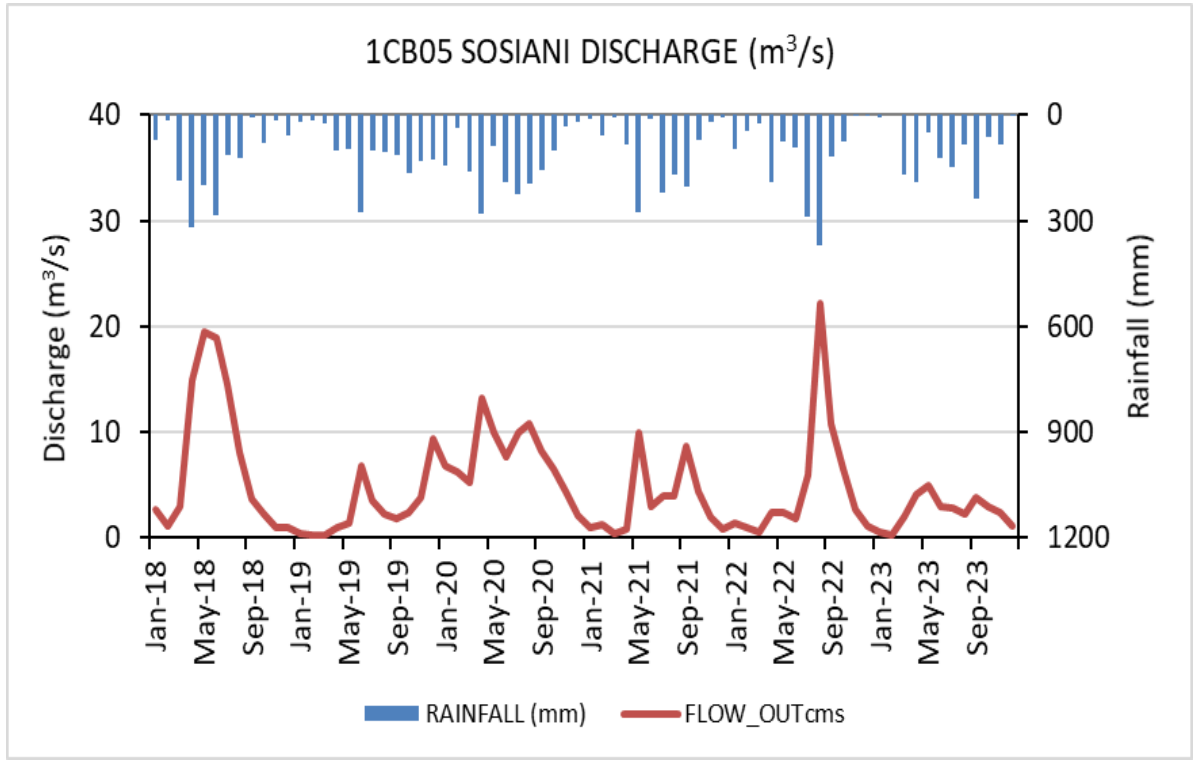


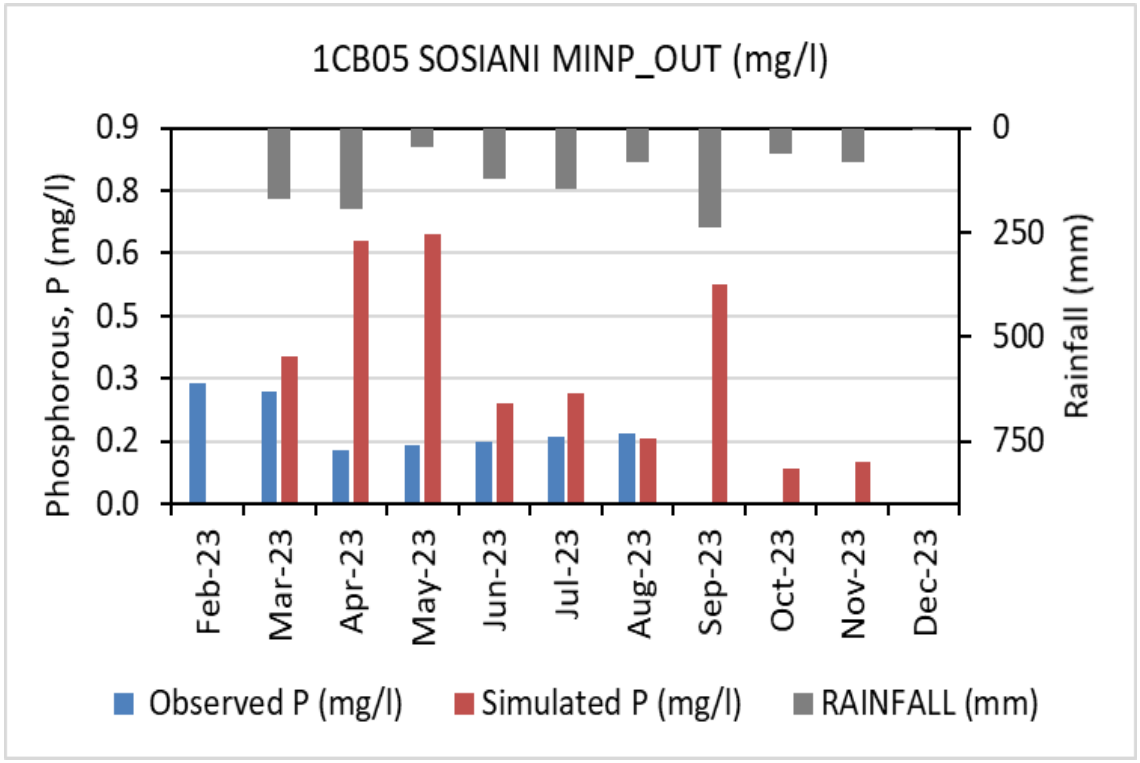
3. SWAT WQ MODELLING

SIMULATION (2018-2023)

Parameters: Phosphorous (P)

Crop Yields (Maize 38 bags@90kg/acre-8.4t/h, Wheat 25 bags@90kg/acre-5.5t/h)





4.CONCLUSIONS/RECOMMENDATIONS

CONCLUSIONS

- The River Sosiani's WQ deteriorates downstream due to industrial and municipal effluent discharge (reduced DO, increased BOD, increased NO3-N and P pollutants downstream).
- Wet season variations are attributed to increased surface runoff, leaching and lateral flow.
- Dry seasons show higher concentrations of WQ parameters, some of which are WHO permissible.
- SWAT modelling results can be used for future sustainable water management - Urban-Rural Catchments (changing catchment and climate context).

RECOMMENDATIONS

- Re-afforestation to reduce runoff and increase groundwater recharge.
- Optimal fertilizer use to sustain crop yields and protect environment.
- Integration of models for data scarce basins where WQ modelling is a challenge (e.g SWAT and QUAL2K)

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THANKS FOR YOUR ATTENTION!

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MANAGEMENT SCHEDULE

CROP/DATE	TILLAGE	FERTILIZER	CROP/DATE	TILLAGE	FERTILIZER	CROP/DATE	TILLAGE	FERTILIZER
MAIZE (190 days)			PASTURE (180 days)			WHEAT (120 days)		
FEB 1	Mouldboard		FEB 1	Mouldboard		FEB 1	Mouldboard	
MAR 21	Harrow/ Planting	DAP (18:46:0) (185.25kg/ha)	MAR 21	Harrow/ Planting	DAP (18:46:0) (168.4kg/ha)	JUN 21	Harrow/ Planting	DAP (18:46:0) (200kg/ha)
MAY 21		UREA (185.25kg/ha)	MAY 21		UREA (168.4kg/ha)	JUL 21		UREA (200kg/ha)
JUN 21		UREA (185.25kg/ha)	JUN 21		UREA (168.4kg/ha)	AUG 21		UREA (200kg/ha)
OCT 1	Harvest & Kill		SEP 21	Harvest only		OCT 21	Harvest & Kill	

MANAGEMENT SCHEDULE

CROP/DATE	TILLAGE	FERTILIZER	CROP/DATE	TILLAGE	FERTILIZER	CROP/DATE	TILLAGE	FERTILIZER
TEA (Perennial)			CABBAGES (90 days)			POTATOES (120 days)		
FEB 1	Mouldboard		FEB 1	Mouldboard		FEB 1	Mouldboard	
MAR 21	Planting	None	MAY 21	Harrow/ Planting	DAP (18:46:0) (197.6kg/ha)	MAR 21	Harrow/ Planting	DAP (18:46:0) (500kg/ha)
MAY 1		DAP (18:46:0) (80kg/ha)	JUN 14		UREA (247kg/ha)	APR 21		UREA (300kg/ha)
AUG 1		NPK(25:5:0) (160kg/ha)	JUL 14		UREA (494kg/ha)	MAY 21		UREA (300kg/ha)
OCT 1		UREA (120kg/ha)						
DEC 1		NPK(25:5:0) (240kg/ha)						
DEC 31	Harvest only		AUG 21	Harvest & Kill		JUL 21	Harvest & Kill	

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MANUAL CALIBRATION

PARAMETER	ORIGINAL	FINAL	PARAMETER	ORIGINAL	FINAL	
CN			REVAPMN.gw	1000	525	
▪ AGRC	84	45	SLSUBBSN.hru	7.8	14 (Max),1.4 (min)	
▪ RNGE	84	40	SOL_AWC .sol	LOWER PLATEAU	SOL_AWC .sol	UPPER PLATEAU
▪ FRST	79	37	▪ FERRALSOLS 1 (KE69)	0.140	▪ NITISOLS 1 (KE100)	0.160
▪ URBN	79	67	▪ FERRALSOLS 2 (KE69)	0.125	▪ NITISOLS 2 (KE100)	0.150
ESCO	0.95	0.01	▪ FERRALSOLS 3 (KE69)	0.120	▪ NITISOLS 3 (KE7002)	0.150
GWQMN.gw	1000	500	▪ GLEYSOLS 1 (KE95)	0.110	▪ GLEYSOLS 1 (KE95)	0.100
ALPHA_BF.gw	0.048	0.56	▪ GLEYSOLS 2 (KE95)	0.120		
GW_REVAP.gw	0.05	0.02	RCN (mg/l)	0.02	CHTMX (Tea), m	0.7