LASER PULSE

Long-term Assistance and SErvices for Research (LASER)
Partners for University-Led Solutions Engine (PULSE)

EAST AFRICA WATER SECURITY PROJECT MODELING APPLICATIONS SNAPSHOTS: MODEL RESULTS, BASE PARAMETERS, SCENARIO EVALUATIONS

Sasumua River Watershed, Kenya; Simiyu River Watershed, Tanzania; Murchison Bay Watershed, Uganda

Farm visit River Sasumua Watershed. Photo credit: Margaret Gitau, 2021

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Project Information

ABOUT LASER PULSE

LASER (Long-term Assistance and SErvices for Research) PULSE (Partners for University-Led Solutions Engine) is a $70M program funded through USAID's Innovation, Technology, and Research Hub, that delivers research-driven solutions to field-sourced development challenges in USAID partner countries.

A consortium led by Purdue University, with core partners Catholic Relief Services, Indiana University, Makerere University, and the University of Notre Dame, implements the LASER PULSE program through a growing network of 3,000+ researchers and development practitioners in 74 countries.

LASER PULSE collaborates with USAID missions, bureaus, and independent offices, and other local stakeholders to identify research needs for critical development challenges, and funds and strengthens the capacity of researcher-practitioner teams to co-design solutions that translate into policy and practice.

ABOUT THE PROJECT

The LASER PULSE East Africa Water Security project aims to provide water information, data access, and decision support to improve water resources (quantity, quality) management and, ultimately, water security in East Africa. Case studies have been conducted in three key watersheds—representing a variety of climatic and landscape regions, and threats to water security—using a combination of existing climate data, recently developed rainfall data, and a modeling approach. This document is intended for use by researchers, practitioners, and water resources managers. Products described herein, along with products accessible through companion resources provided, can be used in a variety of water resources applications. In particular, these products are important for use with hydrologic and water quality modeling, and to inform water resources decision making and management in general.

ACKNOWLEDGEMENTS

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ACRONYMS

Acronym	Definition
CMIP	Coupled Model Intercomparison Project
CN	Curve Number
ET	Evapotranspiration
K	Hydraulic Conductivity
LULCC	Land Use Land Cover Change
N	Nitrogen
NSE	Nash-Sutcliffe Efficiency
P	Phosphorus
PBIAS	Percent Bias
RSR	Ratio of root mean square error and standard deviation of measured data
SSP	Shared Socio-economic Pathway (CMIP 6 scenarios)
SWAT	Soil and Water Assessment Tool
USAID	United States Agency for International Development
USLE C	Universal Soil Loss Equation Cropping Factor

1. Project Highlights

Sasumua River Watershed

Stream flow values for three of four future scenarios are in excess of double the 2011-2020 values.

The management practice scenario which was most successful at reducing basin losses was that which combined several practices together.

The single practice which resulted in the greatest positive impact when modeled was filter strips, suggesting the implementation of this practice at minimum.

Simiyu River Watershed

Projected climate shows increase in surface runoff and the total water yield in the catchment, possibility of flooding in the basin.

Rapid increases in nutrient loadings observed in the basin, which indicates increased human and polluting activities in the catchment both of which threaten water quality integrity.

Murchison Bay Watershed

Over the last 20 years the watershed has undergone several land use/land cover changes particularly with built-up land increasing, which explains increasing stream flows and flooding.

Increasing population in the catchment is the leading driver of wetland loss, increased sediment yield, and deteriorating water quality in the catchment.

Vegetative filter strips (2 m) and retention ponds (20 cubic meters) could substantially reduce sediment yield and surface runoff, respectively. The interventions are leading to increased groundwater recharge, indicating the need to resettle people living in low-lying areas.

Overall: *Data policies must be updated to improve curation and access among relevant agencies to ensure that data is accessible for informing water resources management decisions.*

2. Modeling Approach

LOCATIONS	**Pilot Study Areas** • Sasumua River Watershed, Kenya • Simiyu River Watershed, Tanzania • Murchison Bay Watershed, Uganda • Represent a variety of landscapes and threats to water security
MODEL	**Soil and Water Assessment Tool, SWAT** • Build on previous work in the study watersheds • Provide additional information and deeper insights • Variety of water quantity and quality outputs • SWAT 2012/SWAT+
BUILD AND TEST	**Model Inputs and Parameters** • Measured values to the extent possible • Sensitivity Analysis, Calibration, Validation • Literature-based values
APPLY	**Scenario Evaluations** • Effects of Future Climate • Land Use/Land Cover Change Impacts • Effects of Conservation Measures

3. Case Study 1: Sasumua River Watershed, Kenya

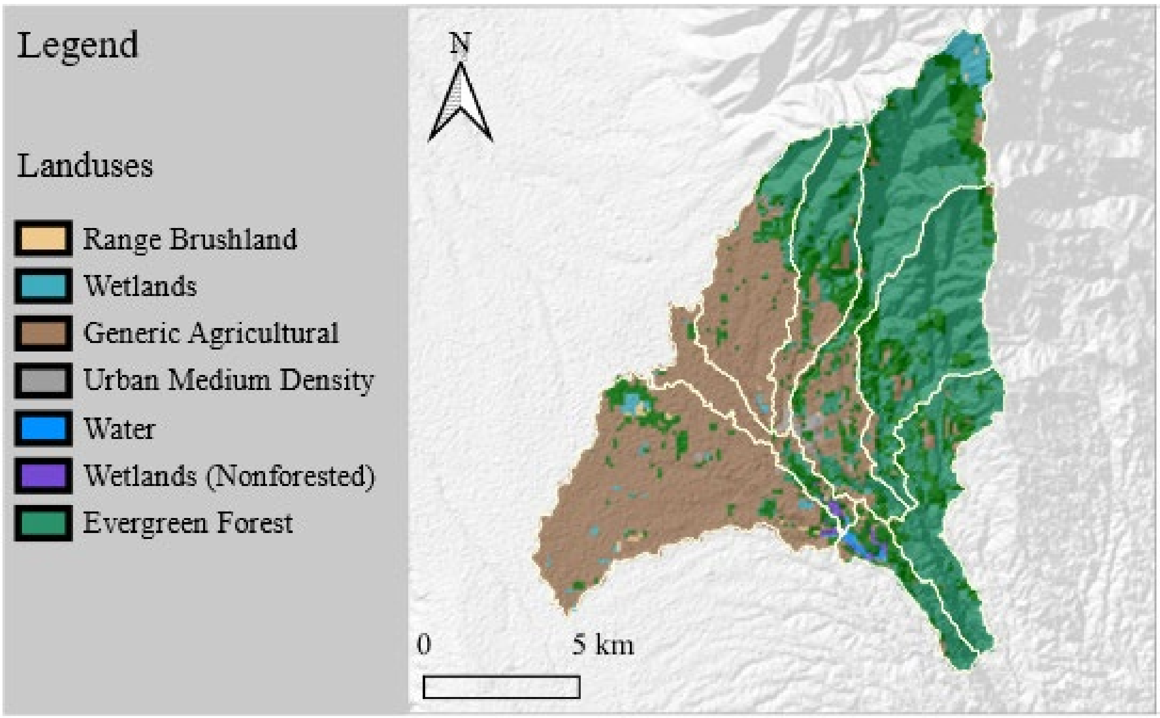


Figure 3-1: Sasumua River Watershed land use.

- Located within the Tana River Basin.
- Size: ~136 square kilometers.
- Primary landcover transitions from agriculture to forest as elevation increases.
- Aqueduct connects Chania River to Sasumua River 5 kilometers upstream of dam, and water is diverted from Kiburu River to reservoir.

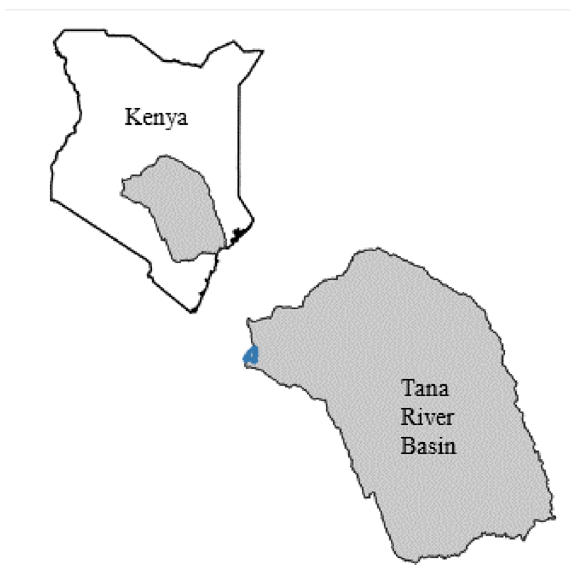


Figure 3-2: Sasumua River Watershed location.

3.1. Sasumua Case Study Details

THE ISSUES

Challenges and Threats

- Sasumua is a headwaters watershed which provides a substantial amount of fresh water to the city of Nairobi. Keeping water quality high is important to downstream interests.
- Land fragmentation with intensive agriculture and use of inputs are potential threats to water resources.
- Agricultural land is slowly beginning to encroach on forested areas of the watershed.
- Urban centers which sprang up after the Sasumua dam was built are rapidly growing with threat of pollution of water resources.
- Water abstraction for Nairobi is occurring amid shortages for watershed residents (mostly shortage of irrigation water).
- There is little information on what impacts the changing climate will have on the Sasumua River Watershed.
- Paucity of measured data makes it difficult to conduct standard model calibration and validation.

GOALS

Case Study Goals and Objectives

Goal

Demonstrate challenges and opportunities for data-driven decision-making with respect to water resources management in the region.

Specific Objectives

- Establish the current and potential future states of water resources in the watershed.
- Predict the effects of implementing a variety of management practices on sediment and nutrient losses.
- Evaluate how projected changes in climate will affect the watershed in the near-, mid-, and far-future.

Table 3-1: Sasumua Calibration and Validation.

Item	ET	Surface Runoff	Sediment
Target	75%	14%	< 10 tons/ha
Calibration	43%	15%	0.04 tons/ha
Validation	37%	20%	0.07 tons/ha

- *Archer, D. (1996) Suspended sediment yields in the Nairobi area of Kenya and environmental controls. In Erosion and sediment Yield: global and regional perspectives. Proceedings of the Exeter Symposium, July 1996, Eds. Walling, D.E. & Webb, B.W. Vol. 236, 37–48.*
- *Hunink, J. E., & Droogers, P. (2011). Physiographical baseline survey for the Upper Tana catchment: erosion and sediment yield assessment. Future Water Report, 112, 31. https://futurewater.nl/wp-content/uploads/2013/01/2011_TanaSed_FW-1121.pdf Accessed 7 Jan 2022.*
- *Mwangi et al.(2015) in Journal of Soil and Water Conservation, 70(2):75–90. https://doi.org/10.2489/jswc.70.2.75*

Table 3-2: Sasumua SWAT+ Model Parameters.

Description	Symbol	Range	Default Value	Final Value*
Curve number for moisture condition II	CN2	35-95	Varies	-12 (abs change)
Soil evaporation compensation factor	ESCO	0.01-1.0	0.95	0.68
Plant uptake compensation factor	EPCO	0.01-1.0	1	1
Baseflow alpha factor (1/days)	ABF_LTE	0.1-1.0	0.048	0.49
Groundwater delay time (days)	GW_Delay	---	---	---
Available water capacity (layer, mm/mm soil)	AWC	0.01-1.0	Varies	
Saturated hydraulic conductivity (mm/hr)	KSAT/K	0.0001-2000	Varies	
Surface runoff lag coefficient (days)	SURLAG/surq_lag	0.5-24	4	
K of lowest layer	PETCO	0.00161-0.00299	~0.00230	-16.17 (% change)
Soil water factor for cn3	CN3_SWF	0-1	0.95	1
Plant ET curve number coefficient	LATQ_CO	0-1	0.01	0.48
Minimum aquifer storage to allow return flow	FLO_MIN	0-10	3	8.1
Average slope length (m)	SLPSUBBSN/slp_len	Maximum ≈ 90	50	
Peak rate adjustment factor	APM/adj_pkrt	0.5-2	1	
Minimum value of USLE C factor	USLE_C / _min	---	Varies	
Biological mixing efficiency	BIOMIX /bio_mix	0-1	0.2	
Mixing efficiency of tillage operation	EFFMIX /mix_eff	0-1	Varies	
Phosphorus soil partitioning coefficient (m^3 /Mg)	PHOSKD/p_soil	100-200	175	
Phosphorus availability index	PSP/p_avail	0.01-0.7	0.4	

**Variation Procedures: Sensitivity Analysis and Calibration. A global sensitivity analysis (n=500, N=5000) was first performed over a wide range of variable values. A parameter set was pinpointed and varied over the closer range for calibration of the most sensitive parameters. Where blank, default values were used. See Companion Resources for additional information and downloadable files.*

Table 3-3: Sasumua Baseline (2011-2020) Model Outputs.

Components	Units	Value
ET	mm	613
Surface Runoff	mm	290
Subsurface Flow	mm	523
Deep Aquifer Recharge	mm	18
Sediment Yield	ton/ha	0.055
Nitrates	kg/ha	0.116
Organic Nitrogen	kg/ha	0.033
Organic Phosphorous	kg/ha	0.002

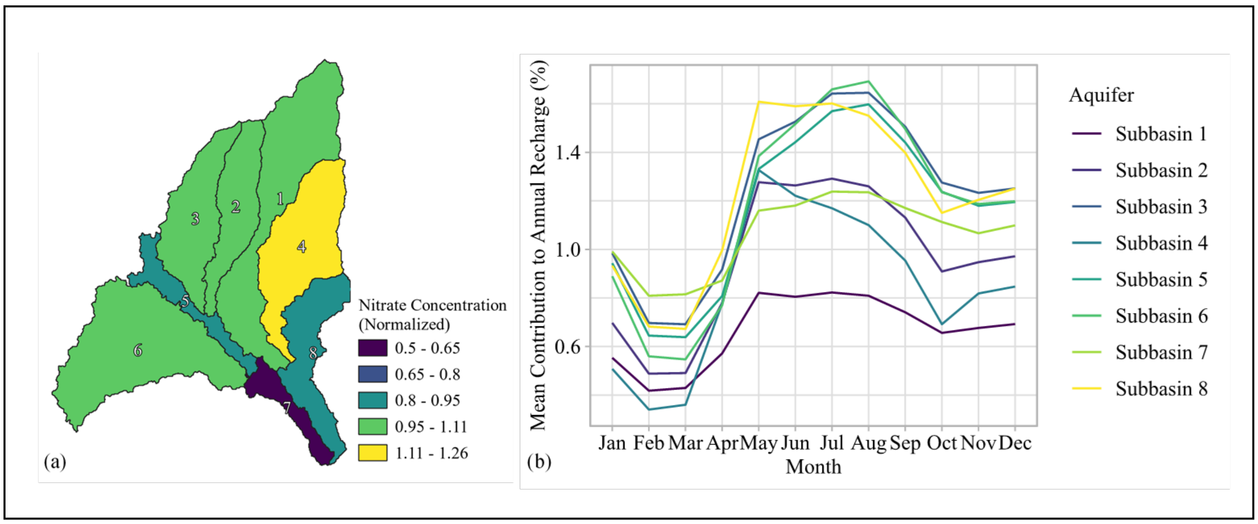


Figure 3-3: (a) Nitrate concentrations and (b) mean monthly recharge for Subbasins 1-8 from 2011-2020 from the Baseline model.

3.2. Sasumua Watershed Scenario Evaluations

Example practice. Photo credit: Victoria Garibay, 2021

Figure 3-4(a): Effects of Management Practices (6 Scenarios).

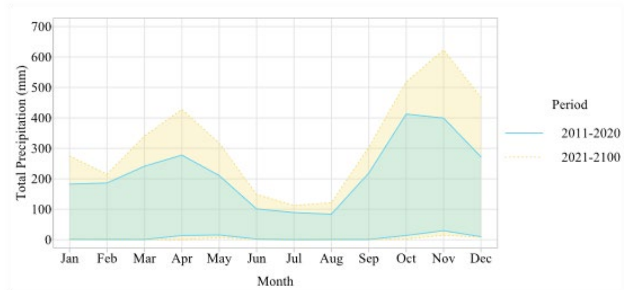


Figure 3-4(b): Effects of Future Climate (4 Scenarios).

Table 3-4: Management Scenario Descriptions

Management Scenario	Scenario Descriptions
Baseline	Cross slope tillage implemented on agricultural land.
1 Riparian Buffers	Indiscriminate buffer of rangeland around the stream network.
2 Filter Strips	Field border filter strips.
3 Terracing	Contoured terraces on 3-8% slopes with sod outlets implemented on agricultural land.
4 Field Diversions	Field diversion terraces at 40 m intervals on 3-8% slopes implemented on agricultural land.
5 Agricultural Water Harvesting Ponds	Addition of ponds on farms for irrigation modeled as equivalent subbasin pond.
6 Combined Application	Modifications for Scenarios 1, 2, 3, and 5 together.

3.3. Management Practice Effects

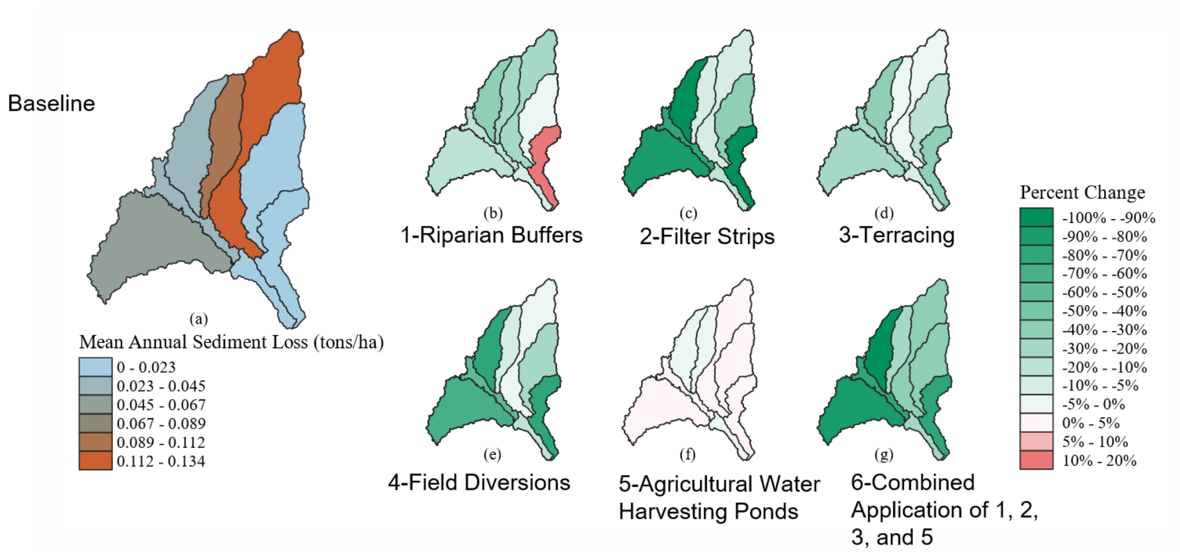


Figure 3-5: Scenario Evaluations. Combining management practices (Scenario 6) would produce the most substantial results; Scenario 2 (filter strips) would be the most effective among single practices.

3.4. Climate Change Impacts

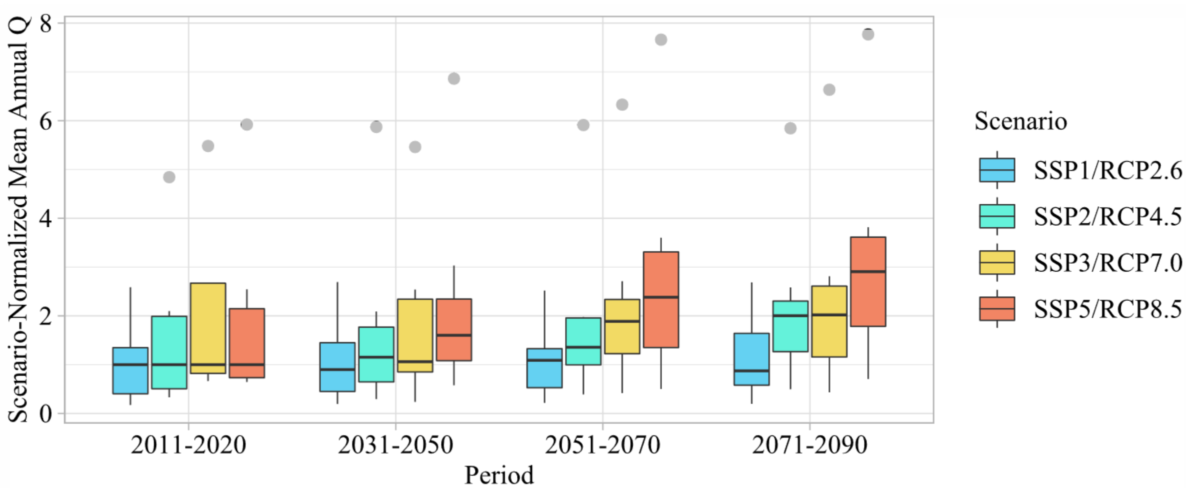


Figure 3-6: Stream flow (Q) comparisons. For three of four future scenarios (SSP2-SSP5), flows could be in excess of double the 2011-2020 values with increases continuing through the end of the century.

Climate Scenarios: Monthly and Seasonal Picture

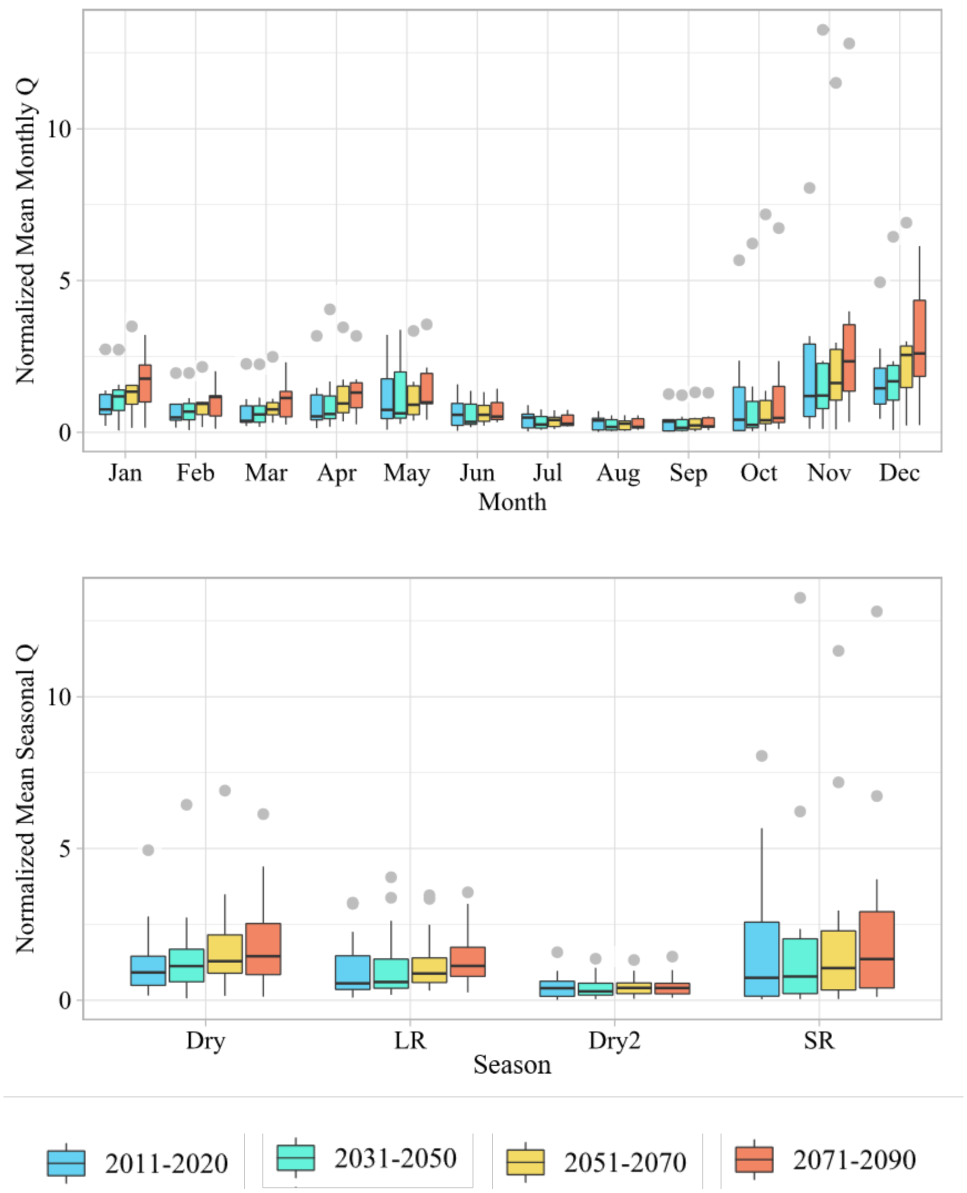


Figure 3-7: Monthly and seasonal comparisons. Stream flow (Q) increases for first dry (Dry) and short rains (SR) seasons (Nov/Dec/Jan) are projected in response to more precipitation during the short rains. LR (long rains).

3.5. Sasumua Watershed Recommendations

SUMMARY AND ACTIONS

Management Practices and Data for Decision-Making

- Proximity of farmlands and emerging urban centers to water sources threatens water quality and increases the cost of drinking water purification.
- Increase in rainfall will result in substantially higher flows into the Sasumua Reservoir, potentially doubling the modern value within 70 years.
- The catchment management intervention found to be most successful at reducing runoff and pollutant losses was a combination of several practices concurrently, while grass filter strips was the most effective among single practices.

Actions[1]:

- Upscale grass filter strips/contour grass buffer strips as practices that could be implemented singly.
- Invest in data collection and curation and commit to make the data freely available for research and decision-making.

[1] See also: *Mati, B.M. 2023. Addressing 21st Century Water Security Challenges in Kenya. Policy Brief. https://bit.ly/products-policybriefs*

4. Case Study 2: Simiyu River Watershed, Tanzania

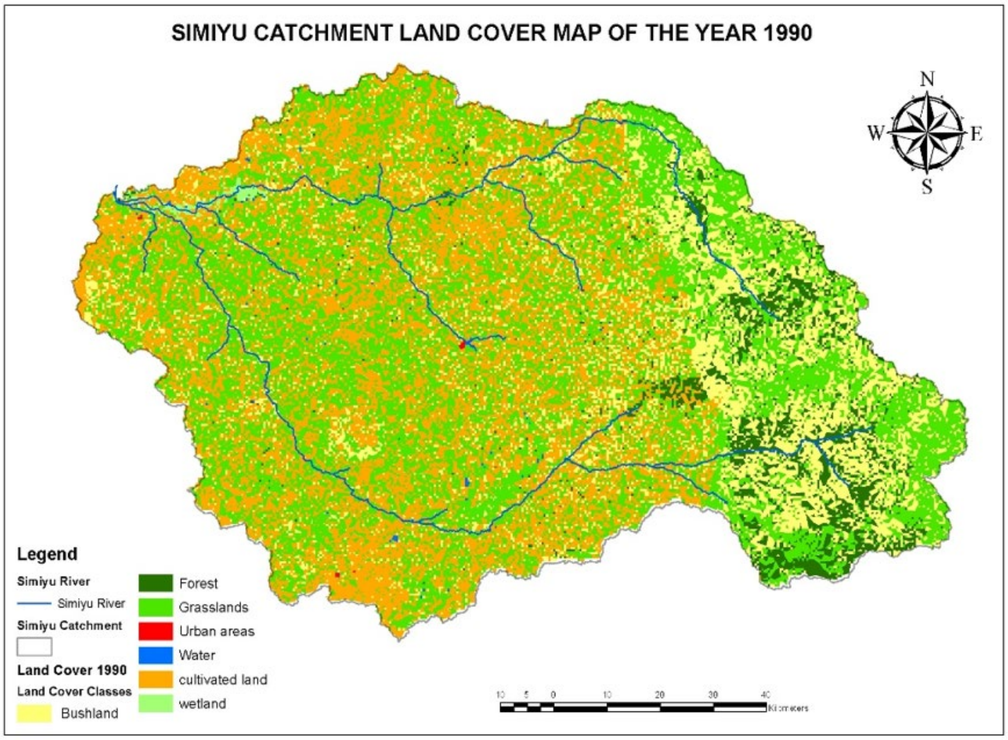


Figure 4-1: Simiyu River Watershed land use land cover.

- Drains into Lake Victoria.
- Size: ~10,659 square kilometers.
- River Simiyu is ephemeral and contains water only during and immediately after storm events.
- Simiyu water towers are Serengeti National Park and the Maswa Game Reserve.

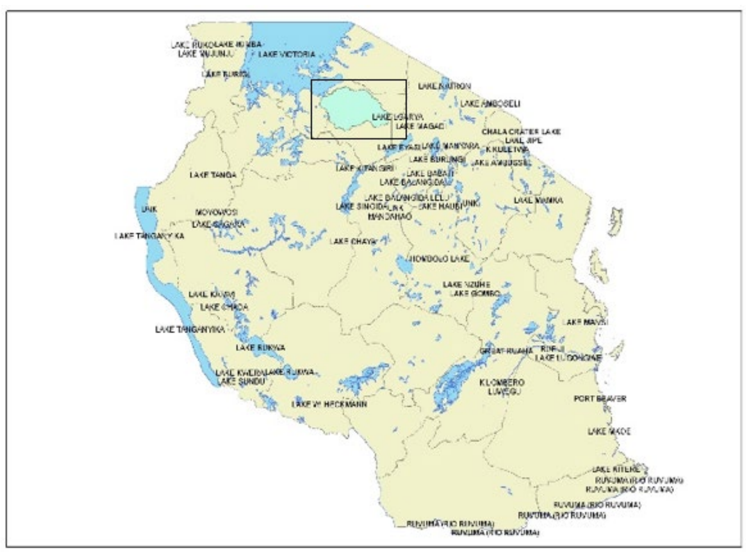


Figure 4-2: Simiyu River Watershed location.

4.1. Simiyu Case Study Details

THE ISSUES

Challenges and Threats

- Increased in Anthropogenic activities that have resulted in extensive land use changes.
- The Simiyu river is reported to yield high amounts of sediment, nitrogen, and phosphorus draining into Lake Victoria.
- High rainfall fluctuations between seasons and from one year to the other, affecting communities around wetlands whose socio-economic activities are heavily dependent on the rainfall and resulting in a reduction of agricultural and livestock production.
- Insufficient data on the impacts of land uses and climate on catchment hydrology.
- Poor understanding of the impacts of land use and climate changes on catchment hydrology.

GOALS

Case Study Goals and Objectives

Goal

Determine the current and potential future states of water resources in the Simiyu River Catchment.

Specific Objectives

- Analyze the climate data from 1980 to 2019 and projected scenario for 2030 - 2060 to identify periods of heavy rainfall, extended dry periods, and trends in climate data.
- Quantify land use and climate changes in the Simiyu Catchment from 1970 to 2019.
- Conduct hydrological modeling studies to assess the Impacts of land use and land cover changes on water budget components and sediments of the Simiyu Catchment.

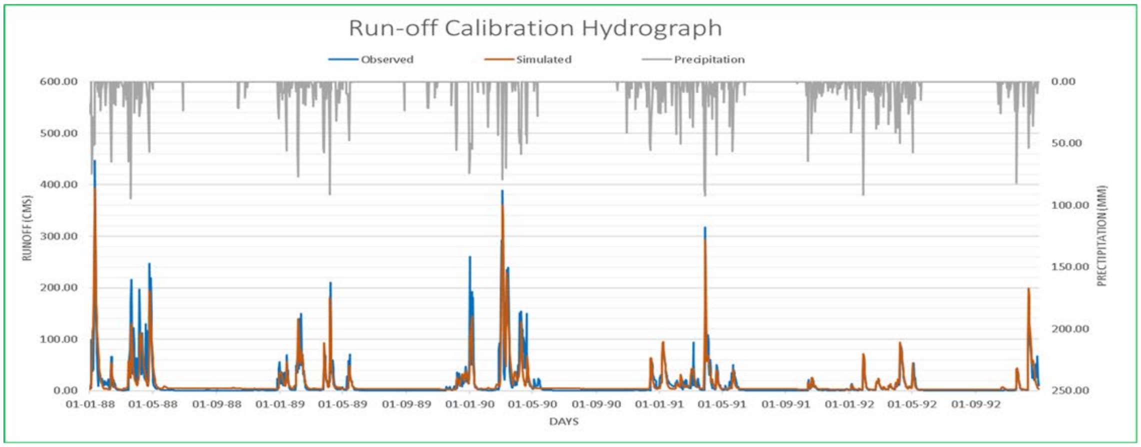
Table 4-1: Simiyu Calibration and Validation.

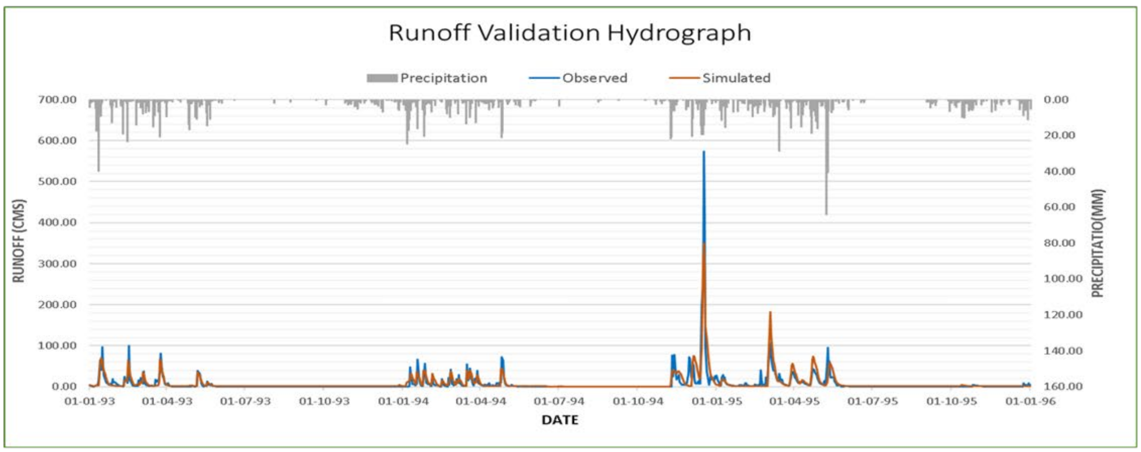
	Performance Statistics (Runoff)			
Period	R^2	NSE	RSR	PBIAS
Calibration (1978-1992)	0.78	0.78	0.47	-5.1
Validation (1993-1996)	0.75	0.75	0.5	-13.9

Table 4-2: Simiyu SWAT Model Parameters.

Description	Symbol	Range	Default Value	Final Value*
Curve number for moisture condition II	CN2	35-95	Varies	-12.7 (% change)
Soil evaporation compensation factor	ESCO	0.01-1.0	0.95	0.368
Plant uptake compensation factor	EPCO	0.01-1.0	1	0.789
Baseflow alpha factor (1/days)	ALPHA_BF	0.1-1.0	0.05	0.641
Groundwater delay time (days)	GW_Delay	---	---	413.6
Available water capacity (layer, mm/mm soil)	AWC	0.01-1.0	Varies	-0.116 (abs change)
Saturated hydraulic conductivity (mm/hr)	KSAT/K	0.0001-2000	Varies	
Surface runoff lag coefficient (days)	SURLAG	0.5-24	4	8.94
K of lowest layer	K_LO	0.00161-0.00299	~0.00230	
Soil water factor for cn3	CN3_SWF	0-1	0.95	
Plant ET curve number coefficient	CNCOEF	0-1	0.01	
Minimum aquifer storage to allow return flow	GWQMN	0-5000	0	1080
Average slope length (m)	SLPSUBBSN	Maximum ≈ 90	50	
Peak rate adjustment factor	APM	0.5-2	1	
Minimum value of USLE C factor	USLE_C	---	Varies	
Biological mixing efficiency	BIOMIX	0-1	0.2	
Mixing efficiency of tillage operation	EFFMIX	0-1	Varies	
Phosphorus soil partitioning coefficient (m^3 /Mg)	PHOSKD	100-200	175	
Phosphorus availability index	PSP	0.01-0.7	0.4	

**Variation Procedures: Standard SWAT-CUP calibration. Where blank, default values were used. See Companion Resources for additional information and downloadable files.*





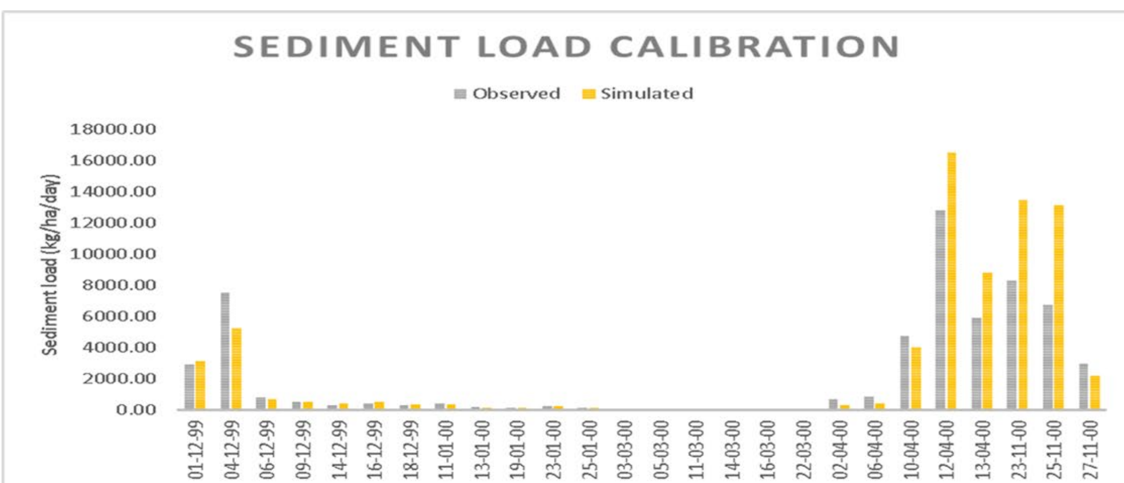
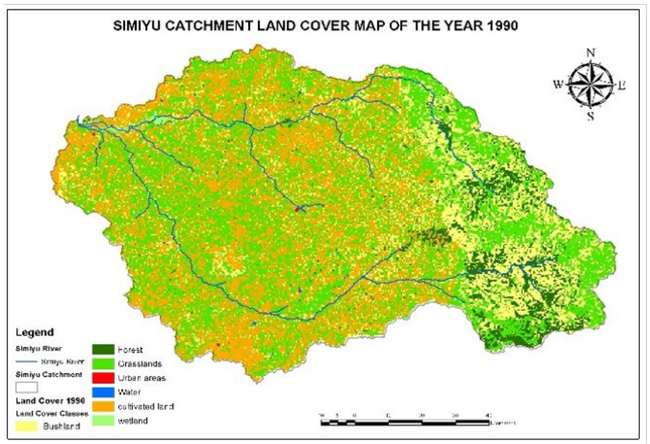
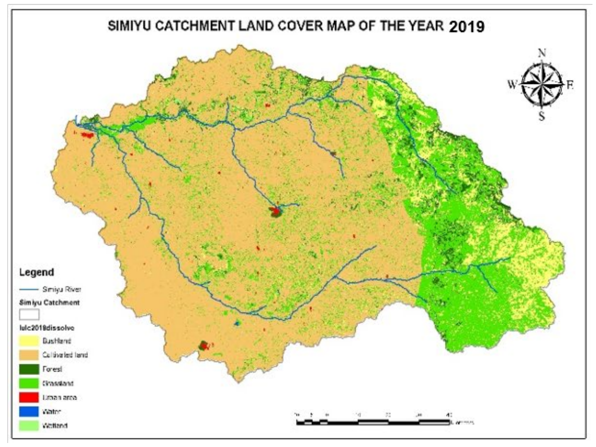


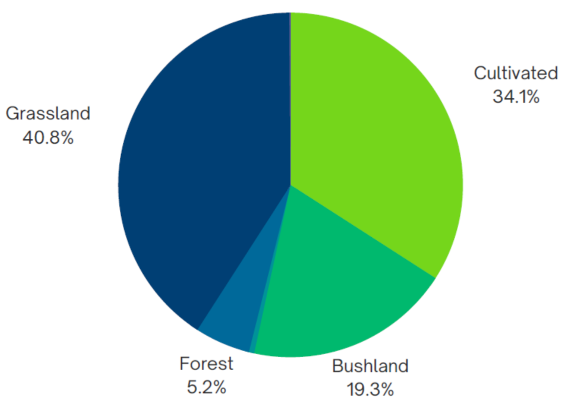
Figure 4-3: Calibration and validation charts. Overall errors obtained for flow calibration and validation periods were 5% and 13%, respectively. An overall error of 22% was obtained for sediments and nutrients.

4.2. Simiyu Watershed Scenario Evaluations

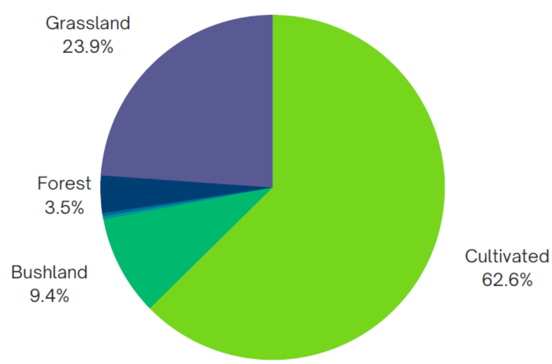
Summary of Scenarios: Effects of Changes in Land Use/Land Cover







1990 Land use/land cover. Urban (0.1%); Water/Wetlands (0.5%)



2019 Land use/land cover. Urban (0.3%); Water/Wetlands (0.3%)

Figure 4-4: Land use/land cover changes in the Simiyu River Watershed during the period 1990-2019: Marked increase in cultivated land has occurred, with considerable corresponding reductions in grassland, bushland, and forest. Increases in urban lands have also been observed.

Summary of Scenarios: Effects of Climate Change

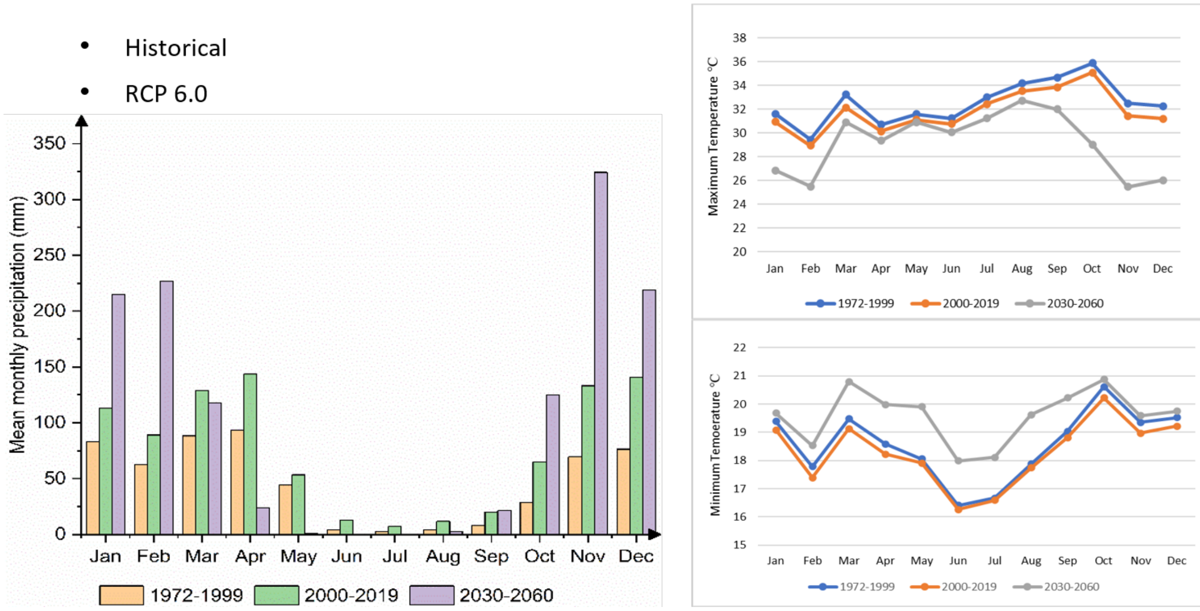


Figure 4-5: Simiyu climate changes—historical (1972-1999); current (2000-2019); future (2030-2060): Precipitation in the current period increased by 62% as compared to the historical baseline period. In the future period, precipitation shows an increasing trend of more than 100%. Temperature is increasing with a non-significant trend.

Table 4-3: Scenario Descriptions.

Management Scenario	Scenario Descriptions
Scenario 1	Average annual change in water balance parameters with the change in Land cover and land use in Simiyu watershed from 1990 to 2019
Scenario 2	Average annual change in water balance parameters with the change in climate from 1972/1988 - 2000/2019
Scenario 3	Projected average annual change in water balance parameter with the changing in climate condition from 1972/1988-2030-2060

4.3. Land Use Change Impacts

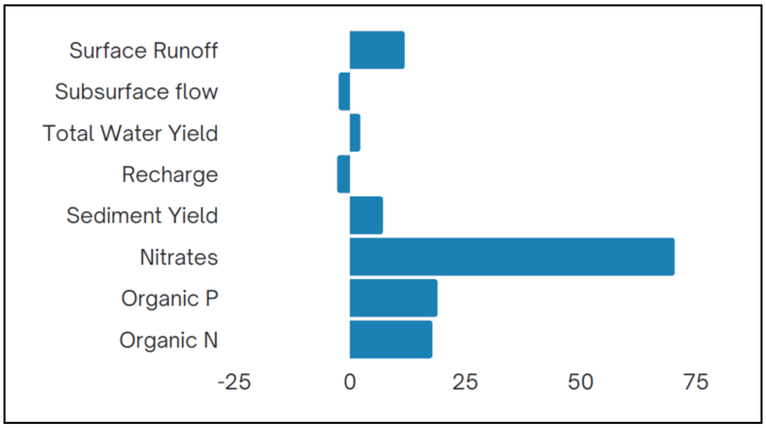


Figure 4-6: Average annual change in water balance and water quality components with change in land cover and land use in Simiyu watershed from 1990 to 2019. Changes in ET (-0.2%). Recharge: deep aquifer recharge.

CURRENT VALUES

Component	Value
ET, mm	831.5
Surface Runoff, mm	24.2
Subsurface Flow, mm	54.5
Deep Aquifer Recharge, mm	10.2
Sediment Yield, ton/ha	1.1
Nitrates, kg/ha	6.4
Organic Nitrogen, kg/ha	2.8
Organic Phosphorous, kg/ha	0.4

4.4. Climate Change Impacts

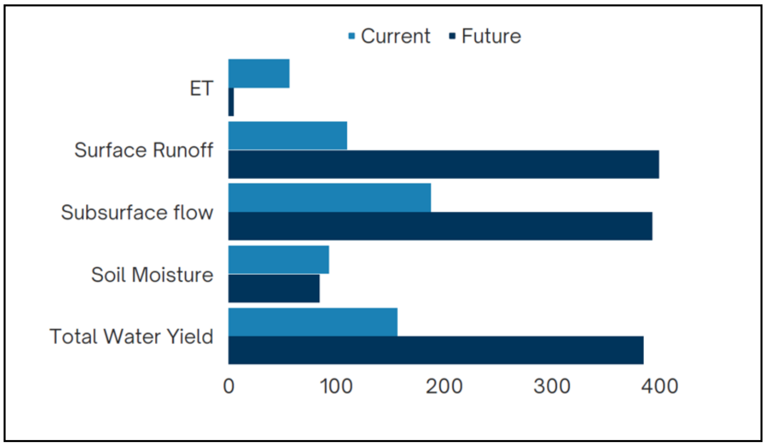


Figure 4-7: Current (2000-2019) and projected (2030-2060) average annual change in water balance components with change in climate expressed as a percentage of historical (1972-1988) values.

Overland flow shows increases in all the climate scenarios on average by more than 12 %; Increases in sediment loadings by more than 7% are attributable to changes in land use/land cover.

Figure 4-8: Climate change impacts on water flows in the Simiyu River Watershed.

4.5. Simiyu Watershed Recommendations

SUMMARY AND ACTIONS

Community Education and Policy Interventions

- Changes in land use as a result of increased anthropogenic activities in a changing climate, have jeopardized the integrity of the Simiyu Catchment resources.
- Increased point and non-point pollution from domestic, industrial, and agricultural activities is indeed contributing to siltation and degradation of the Simiyu River system.
- Climate projections in the catchment have indicated an increase in total annual precipitation and temperatures.
- Future flows and sediment loads in the Simiyu River will increase, especially during the wet months, with ongoing uncontrolled landcover and land use changes having a large influence in partitioning the hydrological cycle in the catchment.

Action[2]:

- Create progressive and dedicated awareness on sustainable land use and conservation practices with deliberate interventions on policy guidelines and strategic investments in catchment restoration.

[2] See also: Kongo, V., F. Anderson, C. Kibugu, S. Munishi. 2023. Data for Decision (D4D): Enhancing Water Security in Tanzania. Policy Brief. *https://bit.ly/products-policybriefs*

5. Case Study 3: Murchison Bay Watershed, Uganda

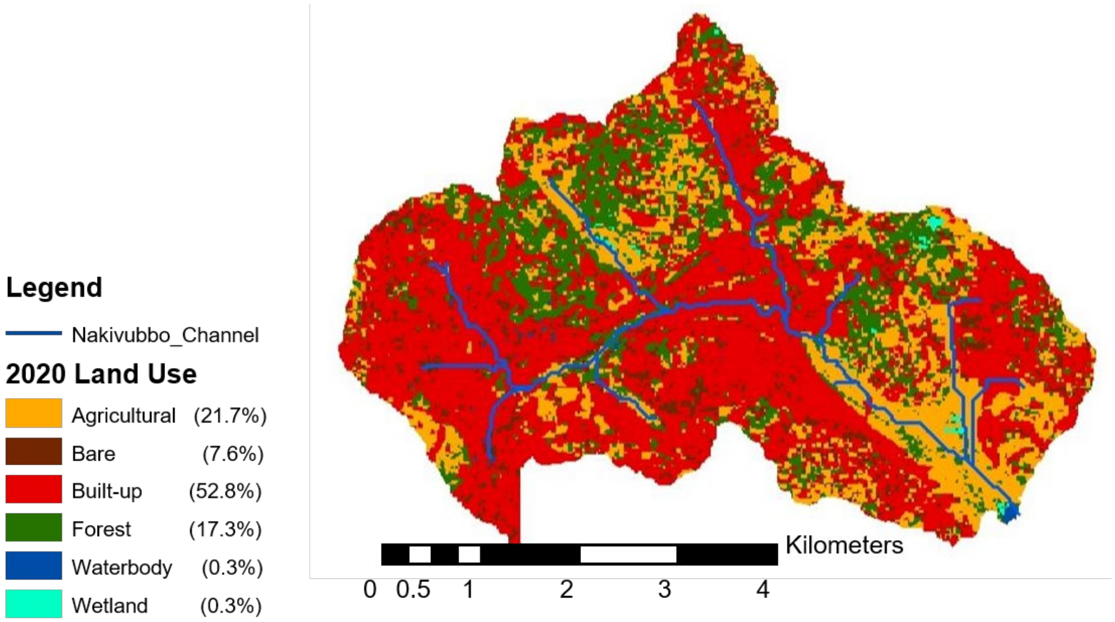


Figure 5-1: Murchison Bay Watershed land use.

- Drains into Lake Victoria.
- Size: ~140 square kilometers.
- The catchment delivers water from Kampala city through Nakivubbo channel to Lake Victoria.

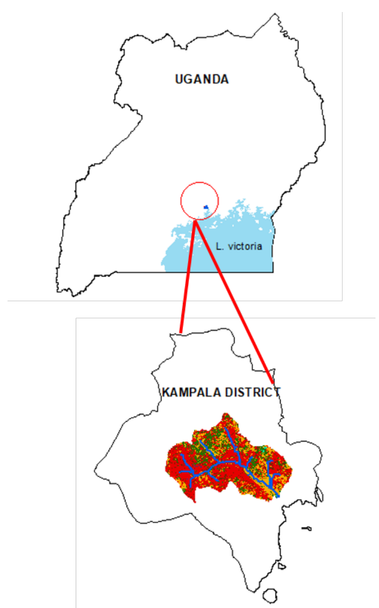


Figure 5-2: Murchison Bay Watershed location.

5.1. Murchison Case Study Details

THE ISSUES

Challenges and Threats

- The Murchison Bay catchment has undergone several human induced natural resources degradation and unregulated land use land cover changes (LULCC) over the last decade.
- The current and future impacts of such changes on water quality and quantities are poorly understood and have not been predicted.
- Hence a study of the impacts of LULCC on catchment hydrology for better water resource management in the catchment.

GOALS

Case Study Goals and Objectives

Goal

To assess the effects of land use land cover change (LULCC) on water quantity and quality in the Murchison Bay catchment of Uganda.

Specific Objectives

- Assess the spatial and temporal nature of land use land cover changes in the Murchison Bay catchment in Uganda.
- Calibrate and validate a SWAT model for the simulation of discharge and sediment yield for the Murchison Bay catchment.
- Predict the future impacts of land use land cover changes on water quantity and quality in the catchment.

Table 5-1: Murchison Bay Calibration and Validation.

	Performance Statistics (Flow)			
Period	**R^2**	**NSE**	**RSR**	**PBIAS**
Calibration (2000-2002)	0.74	0.72	0.43	-0.05
Validation (2004-2007)	0.68	0.75	0.55	2.35

Table 5-2: Murchison Bay SWAT Model Parameters.

Description	Symbol	Range	Default Value	Final Value*
Curve number for moisture condition II	CN2	35-95	Varies	49.4
Soil evaporation compensation factor	ESCO	0.01-1.0	0.95	1
Plant uptake compensation factor	EPCO	0.01-1.0	1	
Baseflow alpha factor (1/days)	ALPHA_BF	0.1-1.0	0.05	0.827
Groundwater delay time (days)	GW_Delay	---	---	39.6
Available water capacity (layer, mm/mm soil)	AWC	0.01-1.0	Varies	0.28
Saturated hydraulic conductivity (mm/hr)	KSAT/K	0.0001-2000	Varies	0.281
Surface runoff lag coefficient (days)	SURLAG	0.5-24	4	
K of lowest layer	K_LO	0.00161-0.00299	~0.00230	
Soil water factor for cn3	CN3_SWF	0-1	0.95	
Plant ET curve number coefficient	CNCOEF	0-1	0.01	
Minimum aquifer storage to allow return flow	GWQMN	0-5000	0	2.73
Average slope length (m)	SLPSUBBSN	Maximum ≈ 90	50	
Peak rate adjustment factor	APM	0.5-2	1	
Minimum value of USLE C factor	USLE_C	---	Varies	
Biological mixing efficiency	BIOMIX	0-1	0.2	
Mixing efficiency of tillage operation	EFFMIX	0-1	Varies	
Phosphorus soil partitioning coefficient (m^3 /Mg)	PHOSKD	100-200	175	
Phosphorus availability index	PSP	0.01-0.7	0.4	

**Variation Procedures: Standard calibration. Where blank, default values were used. See Companion Resources for additional information and downloadable files.*

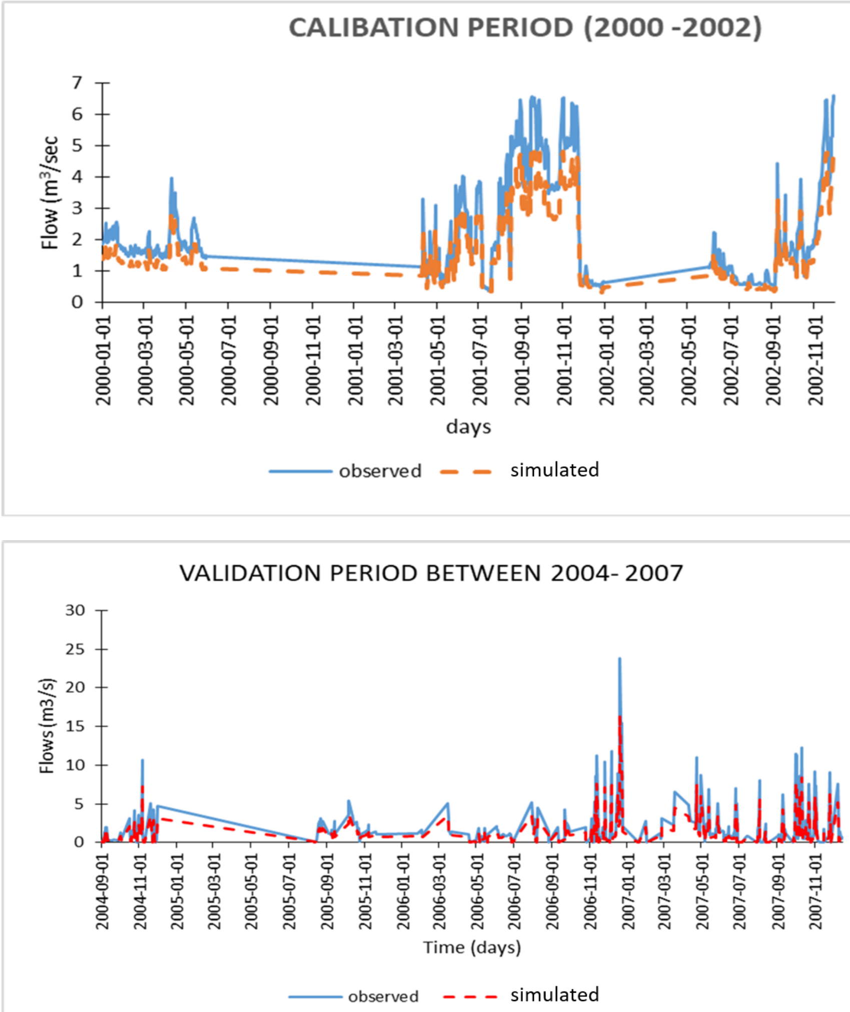


Figure 5-3: Model calibration and validation charts.

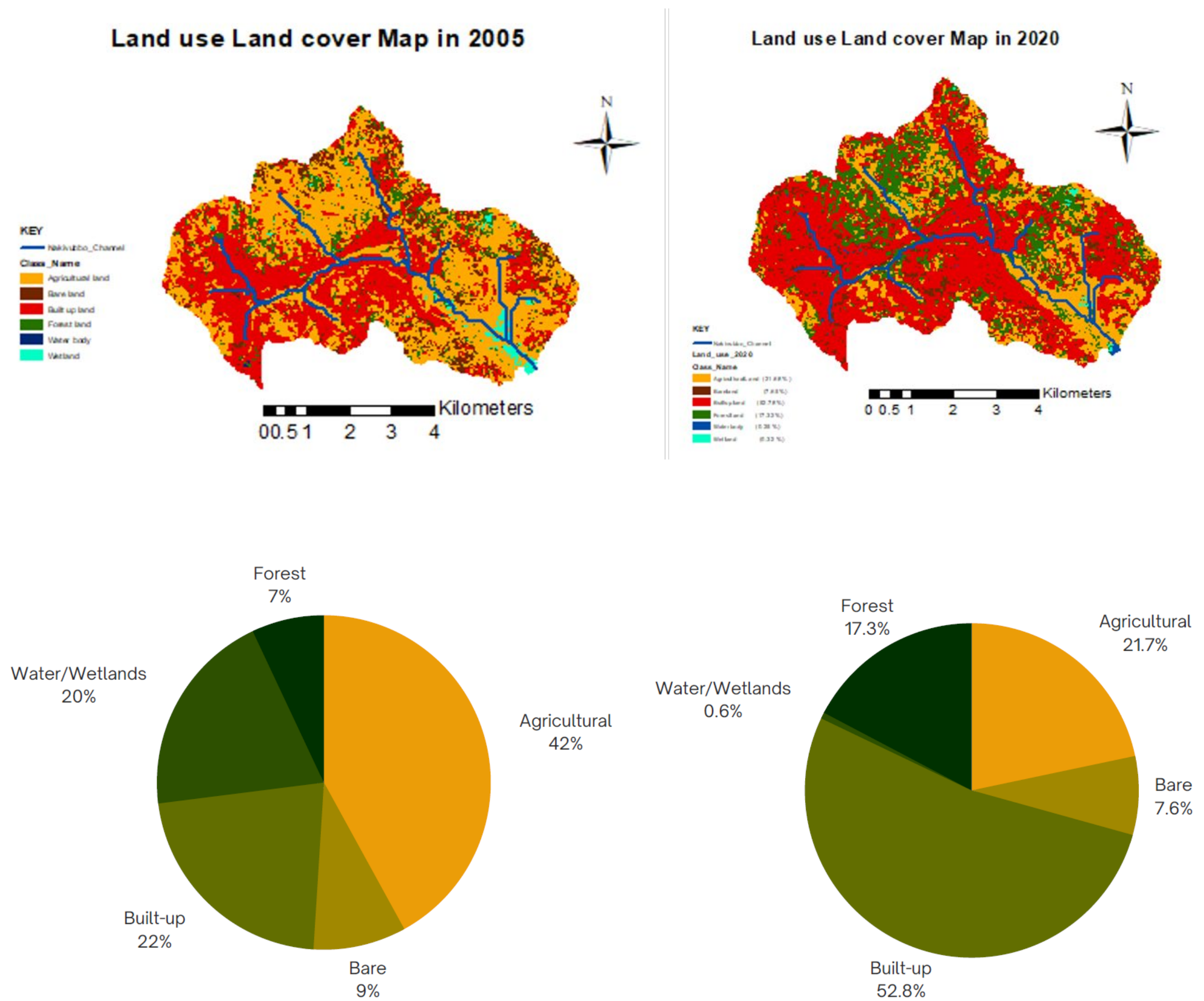
Table 5-3: Additional Validation.

Item	ET	Surface Runoff	Sediment
Target	80%	30%	< 7 tons/ha
Calibration	45%	18%	0.17 tons/haa
Validation	38%	24%	0.23 tons/ha

Overall model prediction performance was considered satisfactory.

5.2. Murchison Bay Watershed Scenario Evaluations

Summary of Scenarios: Effects of Changes in Land Use/Land Cover



2005 Land use/land cover　　　　2020 Land use/land cover

Figure 5-4: Land use/land cover changes for the period 2005-2020: Marked land use land cover changes occurred in the watershed over the past 15-20 years, with built up land increasing at faster rate. Increasing population in the catchment is the leading driver of wetland loss.

Table 5-4: Land Use Change Impacts.

Component	Variable	Units	Baseline (2000)	Predicted (2030)	Predicted (2040)
Water Quantity	ET	mm	581.0	588.0	589.2
	Surface Runoff	mm	268.6	298.3	309.7
	Subsurface Flow	mm	724.6	716.5	705.6
	Water Yield	mm	993.2	1014.8	1015.4
	Deep Aquifer Recharge	mm	38.3	36.5	35.9
Water Quality	Sediment Yield	ton/ha	13.4	11.6	11.7
	Total Nitrogen	kg/ha	149.6	164.4	171.4
	Nitrates	kg/ha	69.1	62.4	62.4
	Total Phosphorus	kg/ha	26.0	29.4	30.7
	Total Soluble Phosphorus	kg/ha	0.3	0.1	0.3
	Organic Nitrogen	kg/ha	16.5	11.6	10.9
	Organic Phosphorous	kg/ha	2.2	1.6	1.5

Table 5-5: Management Scenario Descriptions.

Management Scenario	Scenario Descriptions
1. Vegetative Filter Strips	Both backyard and compound strips instead of paved surfaces, and also garden borders.
2. Grassed Waterways	These were applied at the mean width (GWATW) 1 m, 2 m, 5 m at shorter length ranging between 0.5 km to 1 km, due to being in the city.
3. Surface Runoff Detention Ponds	At the backyard of every infrastructure and along highways (1 m, 2 m, 5 m and 10 m widths).

5.3. Management Practice Effects

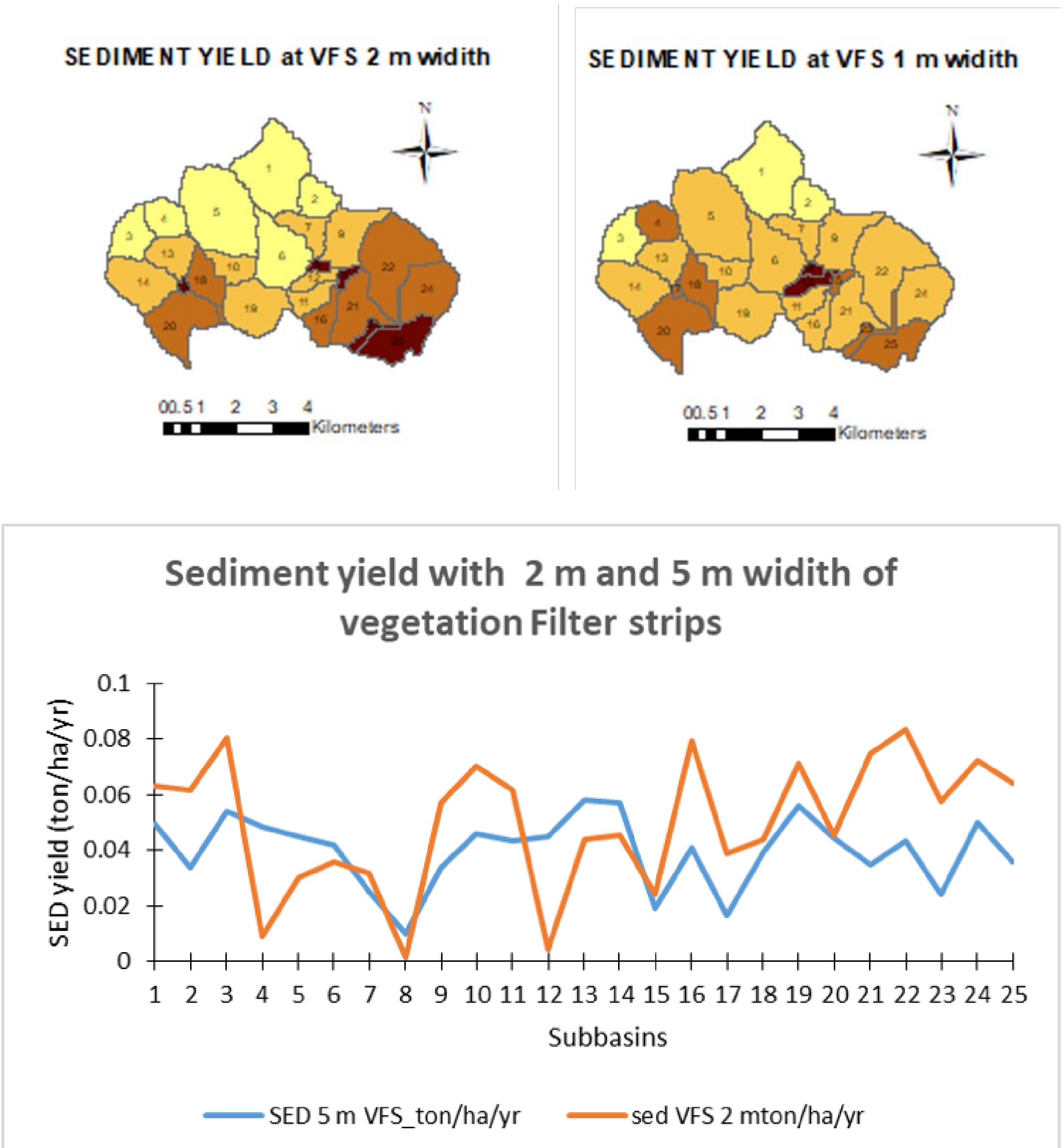


Figure 5-5: Effects of management practices. Vegetative filter strips at 2 m reduced sediment yield by 21 % and up to 42% in some subbasins (up to 70% for 5 m). Detention ponds of 20 cubic meters reduced surface runoff by 60%. Grassed waterways presented minimal impact.

5.4. Murchison Bay Watershed Recommendations

SUMMARY AND ACTIONS

Flood Management and Data for Decision-Making

- The watershed has experienced a dramatic increase in built-up land alongside decreases in bare land, agricultural land, and wetland cover.
- Surface runoff and sediment loading have increased, while groundwater replenishment has decreased.
- These changes can result in destructive flooding and flash-floods, posing severe socio-economic challenges to businesses and residents.

Action[3]:

- Implement integrated flood management that incorporates surface runoff and sediment reduction into land use plans, and aims to restore natural drainage systems.
- Invest in research and data acquisition and commit to make the data freely available, to support evidence-based planning.

[3] See also: Kisekka, J.W., N. Kiggundu, and D. Mugenyi. 2023. Managing land use change will reduce flooding in the Greater Kampala Metropolitan Area. Policy Brief. *https://bit.ly/products-policybriefs*

6. Summary and Recommendations

SUMMARY AND ACTIONS

Sustainable Environmental Management and Data for Decision-Making

- Case studies have been conducted in three key watersheds—Murchison Bay Watershed (Uganda); Simiyu River Watershed (Tanzania); and, Sasumua River Watershed (Kenya), representing a variety of landscapes and threats to water security.
- Key recommendations revolve around the need for sustainable environmental management within the catchments, and improved access to data for decision-making.

Actions:

- **Reduce** flows, sediment, and nutrient loads using conservation practices such as grass filter strips.
- **Demarcate** buffer zones and enforce against encroachment.
- **Launch campaigns** to control excess roof and surface runoff water from urban areas, for example, promote rainwater harvesting.
- **Sensitize residents and agencies** concerned on the need to protect water resources including proper waste management.
- **Update water and data policies** to improve curation and access of data among relevant agencies and researchers to ensure that data is accessible for informing water resources management decisions.

PONDER

Points to Ponder

- What can be done to ensure data are available in ample quantities for use with modeling applications?
- How is the riparian buffer defined for policy and decision-making in the different countries?
- What are potential solutions to mitigate negative impacts of floods and drought in your catchment?
- What measures are being taken or can be taken in your catchment to reduce movement of pollutants into streams, rivers, and lakes, and improve their water quality?

7. Companion Resources

DOWNLOADABLE DATA AND VISUALIZATIONS

- Historical and Future Precipitation and Temperature Data, and Water Data for Select Stations and Watersheds in Kenya, Tanzania, and Uganda. Version 1.0 of November 30, 2022; Released Nov 30, 2022. DOI: 10.4231/DG18-V225 (https://purr.purdue.edu/publications/4170/1)
- Climate Scenario Exploration Dashboard: https://app.climate-dashboard.geddes.rcac.purdue.edu/
- Simiyu River Watershed: https://www.gwptz.org/projects/simiyu_river_catchment/

MODEL PARAMETERS IN CSV FORMAT

- SWAT+ and SWAT Model Parameters for: Sasumua River Watershed, Kenya; Simiyu River Watershed, Tanzania; and, Murchison Bay Watershed, Uganda. Purdue University Research Repository. doi:10.4231/CKJ4-8354

PUBLICATIONS

- Garibay, V.M., M.W. Gitau, V. Kongo, J. Kisekka, and D. Moriasi. 2022. Comparative Evaluation of Water Resource Data Policy Inventories Towards the Improvement of East African Climate and Water Data Infrastructure. Water Resources Management. DOI: https://doi.org/10.1007/s11269-022-03231-z
- Garibay, V.M., and M.W. Gitau. 2022. East Africa Water Security Project: Quick Reference Guide. https://bit.ly/products-quickreference
- Garibay, V., M.W. Gitau, N. Kiggundu, D. Moriasi, and F. Mishili. 2021. Evaluation of reanalysis precipitation data and potential bias correction methods for use in data-scarce areas. Water Resources Management. DOI: https://doi.org/10.1007/s11269-021-02804-8
- Gitau, M.W., V. Garibay, N. kiggundu, D. Moriasi, J. Kisekka, S. Munishi. 2022. East Africa Water Security Project: Workshop Report. https://bit.ly/products-WorkshopReport

LITERATURE-BASED VALUES (soft data)

- Sasumua River Watershed (pg 30)
- Simiyu River Watershed (pg 30)
- Murchison Bay Watershed (pg 31)
- Citations by watershed (pg 32)

Table 7-1: Literature-based Values: Sasumua River Watershed.

Component	Variable	Value(s)	Source
Water Quantity	ET	55% of precipitation; 973 mm (81% of precipitation), 65-90%	Kerandi, 2017 Mwangi, 2015
	Surface runoff	12-16% of precipitation	Kerandi, 2017 Mwangi, 2015
	Subsurface flow (baseflow)	470 mm (70% of streamflow)	Mwangi, 2015
Water Quality	Soil erosion	9 ton/ha-y; 0-10 ton/ha-y	Mwangi, 2015 Hunink 2013
	Sediment yield	40,924 ton/y < 0.2Mtons/y	Mwangi, 2015 Hunik, 2013

Table 7-2: Literature-based Values: Simiyu River Watershed.

Component	Variable	Value(s)	Source
Water Quantity	ET	776 mm (91.4% of the annual precipitation)	Rwetabula et al., 2007
	Surface runoff	17 mm (38.6% of the annual streamflow)	Rwetabula et al., 2007
	Subsurface flow (baseflow)	27 mm (61.4% of the annual streamflow)	Rwetabula et al., 2007
	Soil moisture	4 mm (0.5% of the annual precipitation)	Rwetabula et al., 2007
	Streamflow	44 mm (5.2 % of the annual precipitation)	Rwetabula et al., 2007
Water Quality	Sediment yield	98,467 tons/yr	Kimwaga et al., 2011
	Total nitrogen	0.112-0.237 kg/ha/yr to 1.003-1.339 kg/ha/yr in (1975 to 2006)	Kimwaga et al., 2012

Table 7-3: Literature-based Values: Murchison Bay Watershed.

Component	Variable	Value(s)	Source
Water Quantity	Surface runoff	123	Anaba et al,2017
Water Quality	Sediment yield	26.4 tons/ha/year	Anaba et al,2017
	Nitrates	0.037 mg/l	Akurut et al, 2017
	Total Nitrogen Orthophosphate Total Suspended Solids	1.1 - 42.5 mg/l 0.69 - 6.2 mg/l 108.5 - 266 mg/l	Kayima et al., 2008

Literature-based Values: Citations

Sasumua River Watershed

- Hunink, J.E., Niadas, I., Antonaropoulos, P., Droogers, P., de Vente, J. (2013). Targeting of intervention areas to reduce reservoir sedimentation in the Tana catchment (Kenya) using SWAT. Hydrological Sciences Journal, 58(3), 600–614. https://doi.org/10.1080/02626667.2013.774090
- Kerandi, N., Arnault, J., Laux, P., Wagner, S., Kitheka, J., Kunstmann, H. (2017). Joint atmospheric-terrestrial water balances for East Africa: a WRF-Hydro case study for the upper Tana River basin. Theoretical and Applied Climatology, 131(3-4):1337–1355. https://doi.org/10.1007/s00704-017-2050-8
- Mwangi, J., Shisanya, C. A., Gathenya, J. M., Namirembe, S., Moriasi, D. N. (2015). A modeling approach to evaluate the impact of conservation practices on water and sediment yield in Sasumua Watershed, Kenya. Journal of Soil and Water Conservation, 70(2):75–90. https://doi.org/10.2489/jswc.70.2.75

Simiyu River Waterhseds

- Rwetabula J., De Smedt F., Rebhun M. (2007). Prediction of runoff and discharge in theSimiyu River (tributary of Lake Victoria, Tanzania) using the WetSpa mod Hydrology and Earth System Sciences journal, 4, 881-908
- Kimwaga, R.J., Bukirwa, F., Banadda, N., Wali, U.G., Nhapi, I., and Mashauri, D.A. (2012). Modelling the Impact of Land Use Changes on Sediment Loading Into Lake Victoria Using SWAT Model: A Case of Simiyu Catchment Tanzania. The Open Environmental Engineering Journal, 5(1), 66–76. https://doi.org/10.2174/1874829501205010066
- Kimwaga, R.J., Mashauri, D.A., Bukirwa, F., Banadda, N., Wali, U.G., Nhapi, I., and Nansubuga, I. (2011). Modelling of Non-Point Source Pollution Around Lake Victoria Using SWAT Model: A Case of Simiyu Catchment Tanzania. The Open Environmental Engineering Journal, 4(1), 112–123. https://doi.org/10.2174/1874829501104010112

Murchison Bay Watershed

- Anaba, L.A., Banadda, N., Kiggundu, N., Wanyama, J., Engel, B., and Moriasi, D. (2017). Application of SWAT to assess the effects of land use change in the Murchison Bay catchment in Uganda. Computational Water, Energy, and Environmental Engineering, 2017(6):24-40.
- Akurut, M., Niwagaba, C.B., and Willems, P. (2017). Long-term variations of water quality in the Inner Murchison Bay, Lake Victoria. Environmental Monitoring and Assessment, 189(1):22, DOI: 10.1007/s10661-016-5730-4
- Kayima, J., Kyakula, M., Komakech, W., and Echimu, S. P. (2008). A study of the degree of Pollution in Nakivubo Channel, Kampala, Uganda. Journal of Applied Sciences and Environmental Management, 12(2). DOI: 10.4314/jasem.v12i2.55540

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Websites

https://resourceplan.co.ke/laser-pulse-east-africa-water-security-project/

https://www.gwptz.org/projects/simiyu_river_catchment/

https://web.ics.purdue.edu/~mgitau/projects-1.html

Background photo: Selander Bridge, Dar es Salaam, Tanzania. Photo credit: Margaret Gitau, 2022