The Suitability of SWAT Model in Sediment Yield Modeling for Ungauged Catchments . A case of Simiyu Sub-catchment, Tanzania

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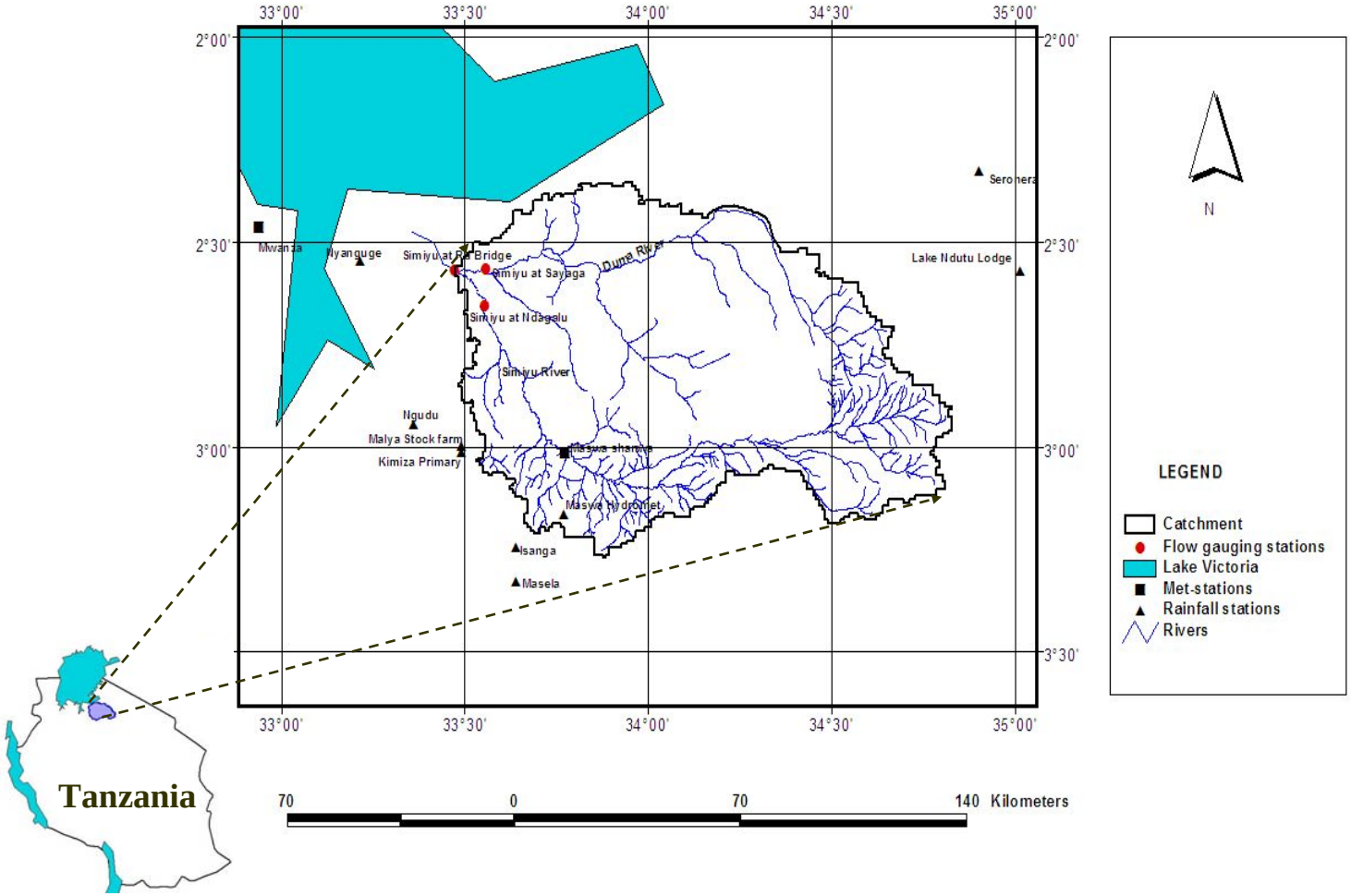
A location map of Simiyu River Basin



Long: 33.46°E – 34.84°E and Lat: 2.36°S – 3.27°S;

Area: 10,659 km²

Presentation Outline

- PROBLEM DEFINITION
- STUDY OBJECTIVES
- LITERATURE REVIEW
- DATA AND DATA ANALYSIS
- PROBLEM SCHEMATIZATION
- CALIBRATION
- VALIDATION
- DISCUSSIONS OF RESULTS
- RECOMMENDATIONS
- CONCLUSIONS

PROBLEM DEFINITION

Sedimentation problems in Tanzania is severe as reported by different studies (Christianson,1981; Temple,1973; Lyamuya et al.1994; Little, 1963; Mtalo and Ndomba, 2001).

Not only there is inadequate data to simulate the sediment transport in the basin but also the lack of compelling sediment yield modelling tool for tropical regions complicates the matter.

Consequently, no one could successfully study, understand and quantify the impacts of various types of modifications caused by human activities and nature on the hydrologic regime; both on water quantity and quality.

STUDY OBJECTIVES

The long-term objective is to develop a Sediment yield model for tropical regions. The specific objectives of this study are as follows:

- **Review the Watershed sediment yield models**
- **Assessing the suitability of SWAT model in modelling sediment yield to ungauged catchment**

Literature review

- Background of erosion problem in Tanzania
- Modelling experience in Tanzania
- Reviewed sediment yield models
- Model choice

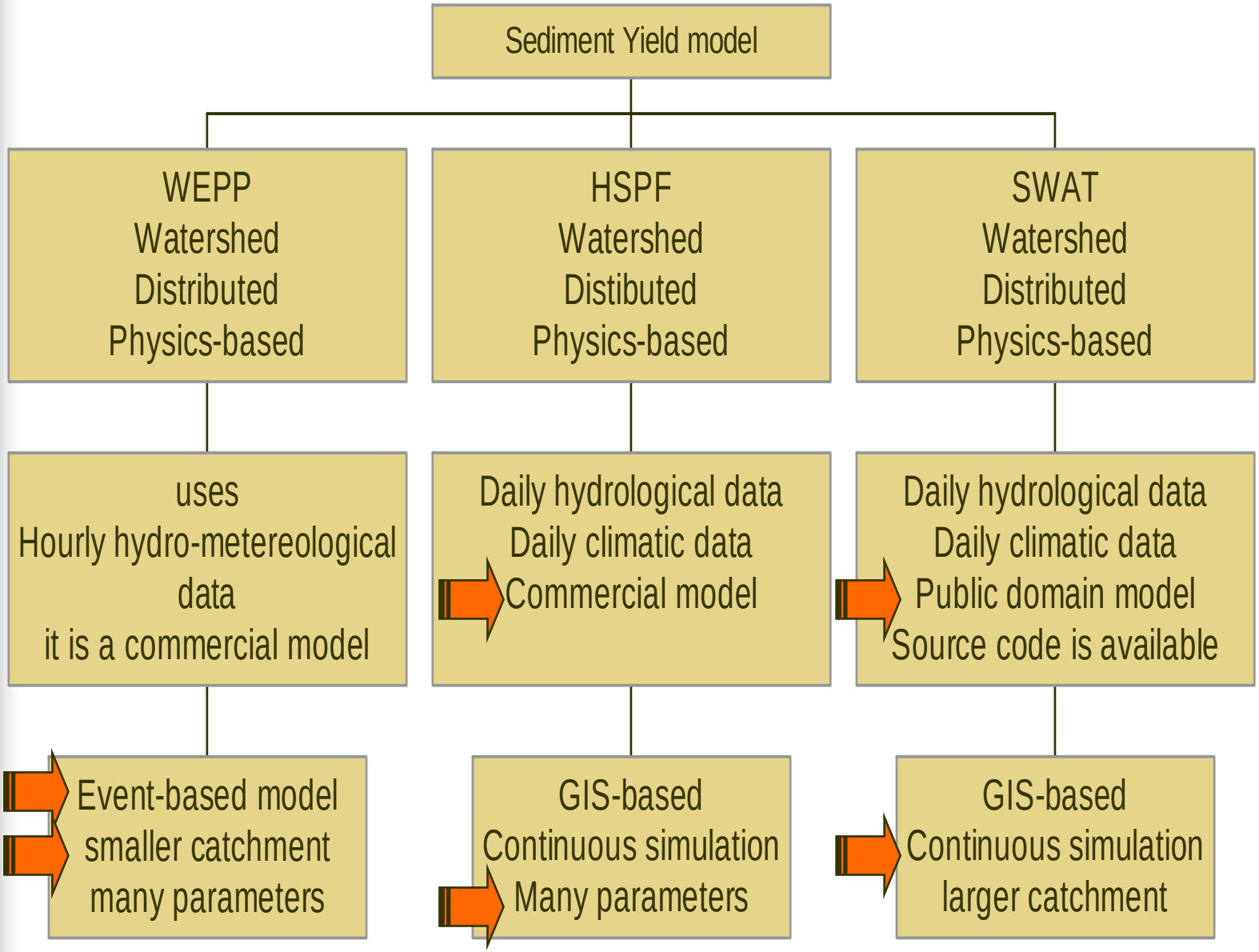
Background of erosion problem in Tanzania

- Erosion problems in Tanzania date back as early as 19th century in the era of East African caravan trade Christianson, (1981)
- Growing gullies in the foot slopes of mount Meru in Arusha region, Semu (1992);
- High Upland erosion rates, Mtalo and Ndomba (2001)
- Siltation of reservoirs, Christiansson (1981)
- Severe soil erosion in Uluguru Mountains, Little(1963)

Sediment yield modeling experience

- The USLE (developed in the U.S.A) and widely used throughout the world has in most cases been found to be inapplicable in the tropics (Mulengera, 1999).
- The Equation's soil erodibility nomograph commonly gives unrealistic values for tropical soils.
- Table values developed in the U.S.A. for estimating the crop and soil management factor of the equation are not applicable for farming practices and conditions found in the tropics.
- Mulengera,(1999) proposed a table and soil erodibility equation that uses only soil particle distribution.
- Mtalo and Ndomba (2001) used USLE Equation to estimate soil loss in the watershed. The results were compared with reservoir sedimentation survey information. About half of sediments finds its way to the outlet.
- The methods that require experimentation are demanding, in terms of resources and its transferability (i.e. scale) (Yanda, 1995).

Reviewed sediment yield models



Model choice

SWAT

(Watershed sediment yield model)

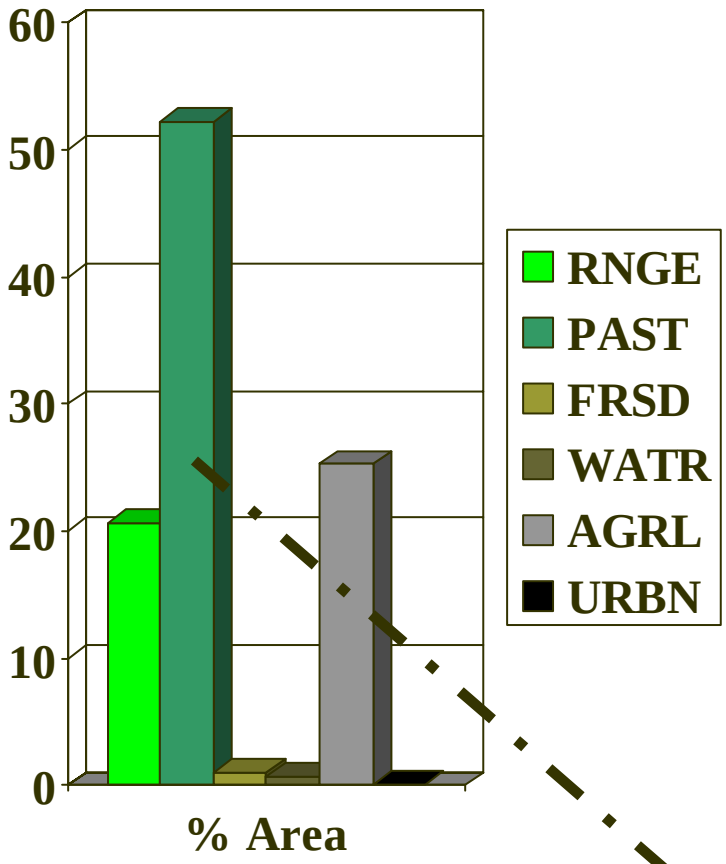
- Physics-based model
- GIS based and hence can support distributed phenomena
- Supports Long-time simulation
- Public domain model
- Source code is available
- Uses readily available daily hydro-climatic data
- Runs in a PC and window environment
- Simulates water resources in ungauged catchment with reasonable accuracy
- Technical support is available
- Long modelling experience

DATA AND DATA ANALYSIS

Used and available data

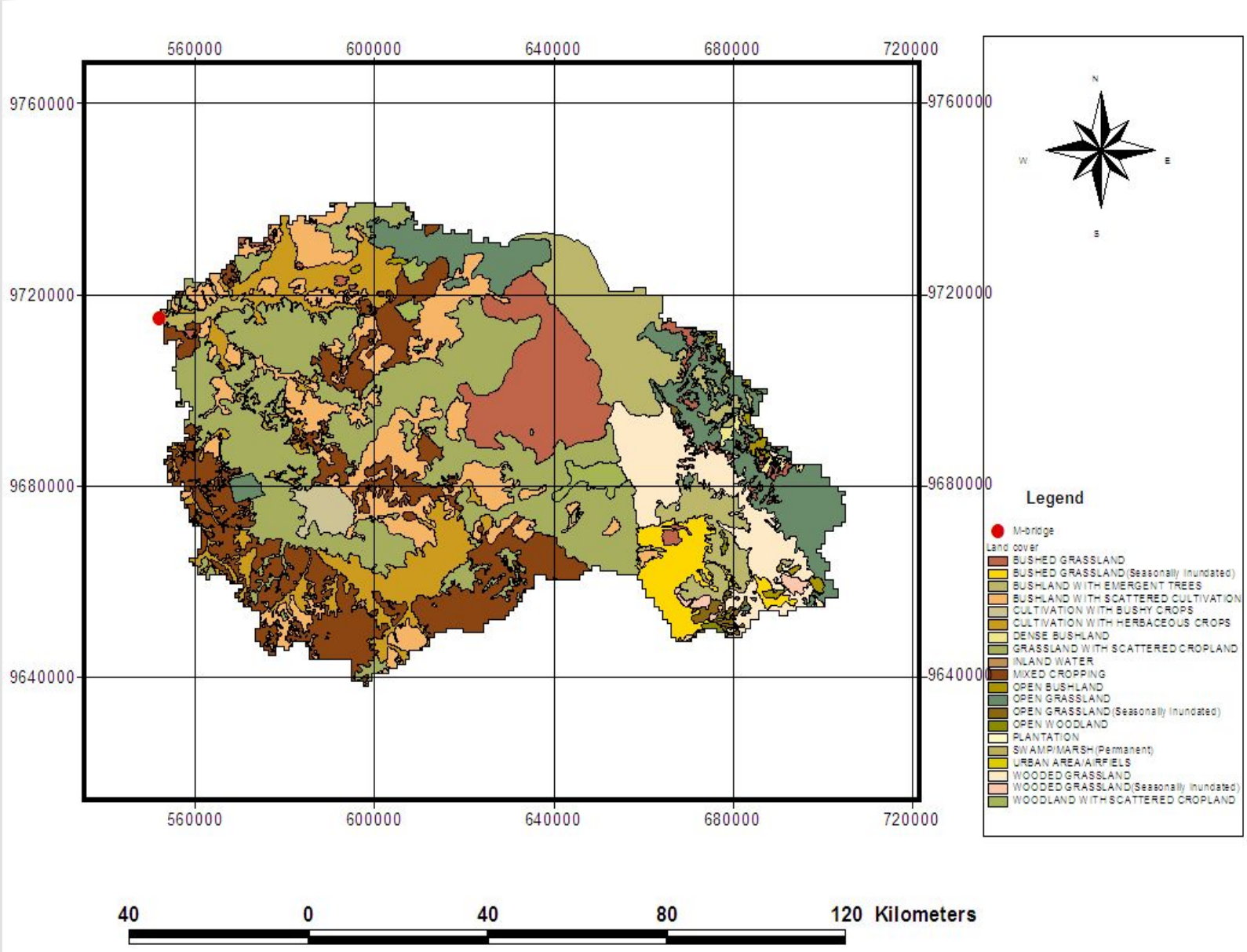
- Landuse maps
- Soil type maps
- Digital Elevation model (DEM)
- River flows data
- Rainfall data
- Climatic data
- Sediment flow data
- other Watershed maps

Catchment characteristics

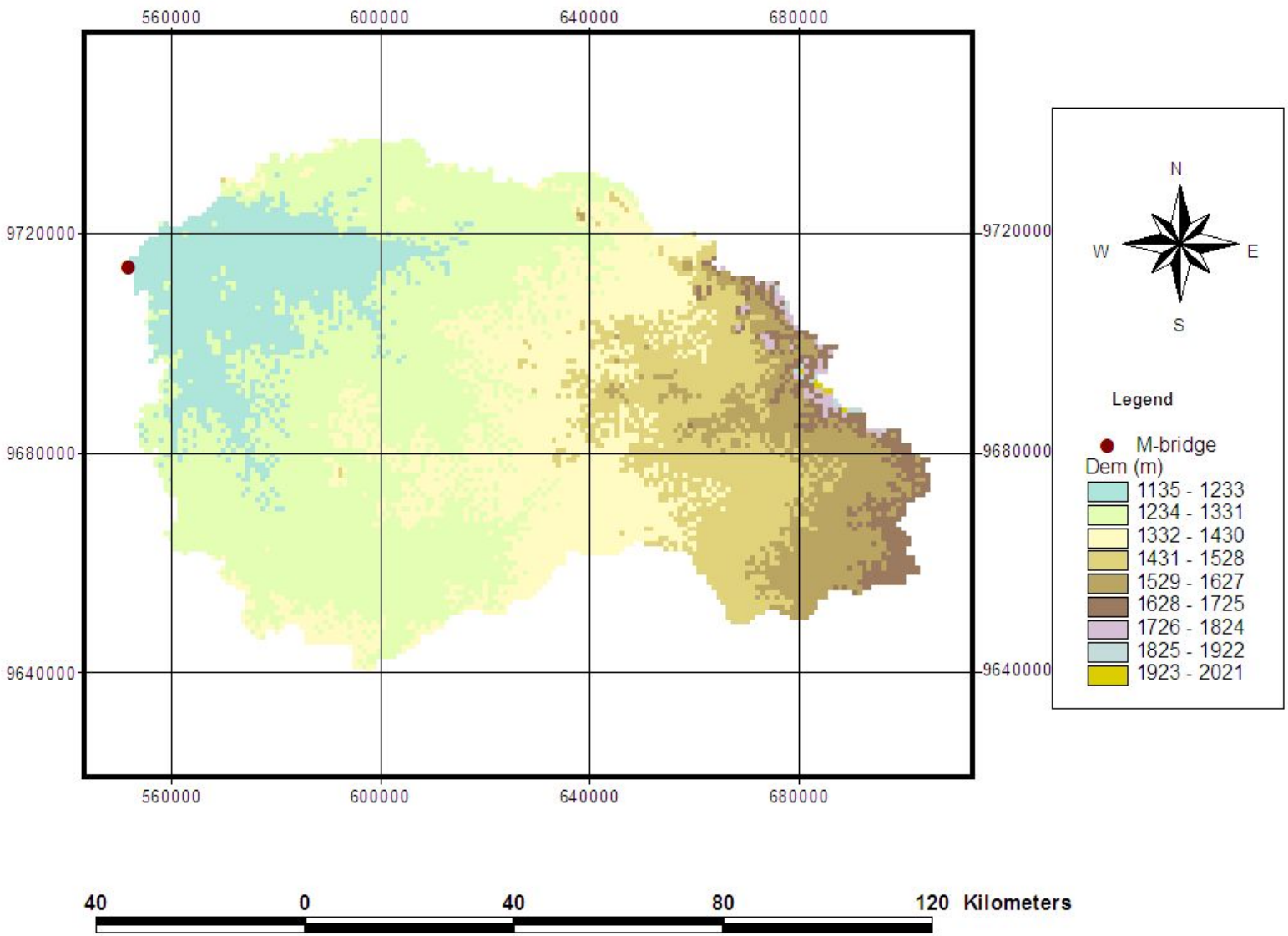


- Area = 10,659 km^2
- Highest elevation = 2021 m.a.s.l
- Lowest elevation = 1135 m.a.s.l
- Longest flow path = 222 km
- Slope= 0.3%
- Tributaries are simiyu and Duma
- Soil = Deep Sandy
- Landcover=PAST

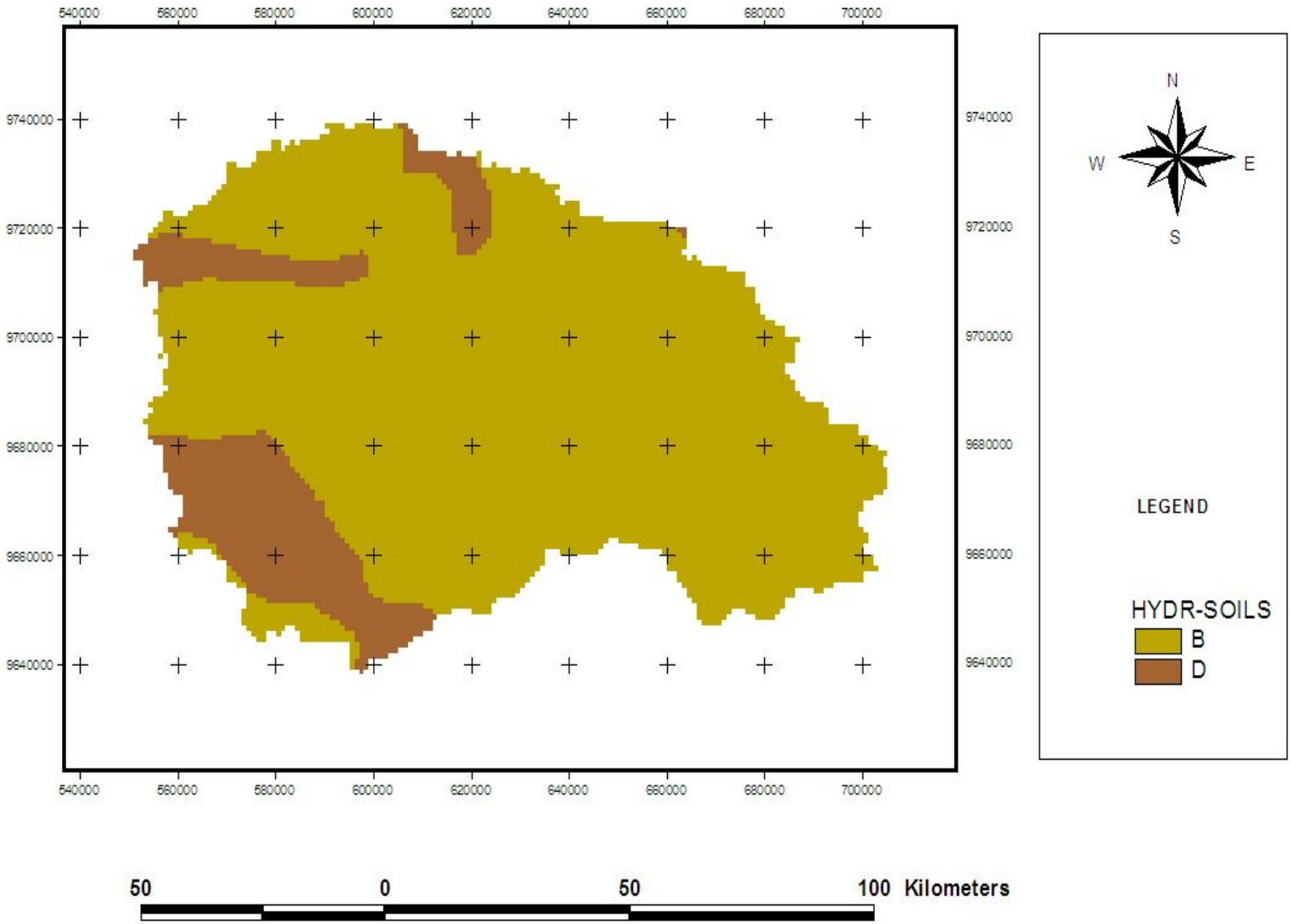
Land use map


560000
600000
640000
680000
720000
9760000
9720000
9680000
9640000
N
W
E
S
Legend
M-bridge
Land cover
BUSHED GRASSLAND
BUSHED GRASSLAND(Seasonally Inundated)
BUSHLAND WITH EMERGENT TREES
BUSHLAND WITH SCATTERED CULTIVATION
CULTIVATION WITH BUSHY CROPS
CULTIVATION WITH HERBACEOUS CROPS
DENSE BUSHLAND
GRASSLAND WITH SCATTERED CROPLAND
INLAND WATER
MIXED CROPPING
OPEN BUSHLAND
OPEN GRASSLAND
OPEN GRASSLAND(Seasonally Inundated)
OPEN WOODLAND
PLANTATION
SWAMP/MARSH(Permanent)
URBAN AREA/AIRFIELS
WOODED GRASSLAND
WOODED GRASSLAND(Seasonally Inundated)
WOODLAND WITH SCATTERED CROPLAND
40
0
40
80
120 Kilometers

Digital Elevation Model



Soil type map



Hydrological data

FLOW DATA								
Station code	Catchment	Station place	Area (km2)	Lat	Long	Record period		% Miss data
						From	To	
112012	Simiyu-Ndagalu	Ndagalu	5918	-2.639	33.568	Jan-50	1-Jan	47
112022	Simyu	Bridge	10659	-2.575	33.462	Jan-69	Dec-00	22
112032	*Duma-Sayaga*	Sayaga	5320	*-2.586*	*33.497*	*Jan-70*	*Dec-78*	*0*

Ndagalu (112012) discharge data

No.	Statistic	1st series	2nd series	Whole series
1.	Minimum	0.00	0.00	0.00
2.	Maximum	331.00	645.50	645.50
3.	# of zeros	511	599	1110
4.	Mean	11.32	11.67	11.49
5.	Variance	1156.35	1993.07	1574.25
6.	Std dev.	34.01	44.64	39.68
7.	C. Variation	3.01	3.83	3.45

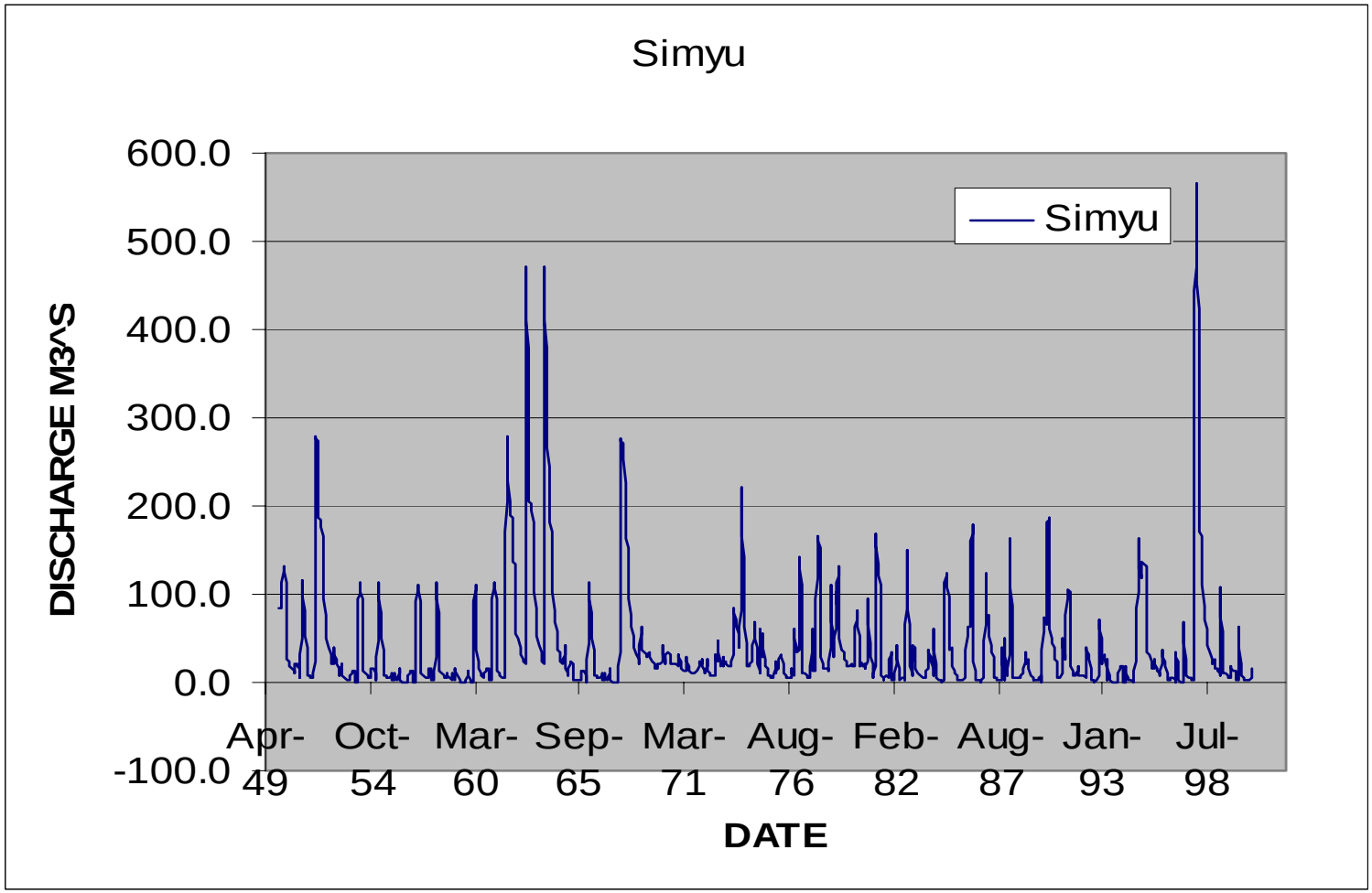
Sayaga (112032) discharge data

No.	Statistic	1st series	2nd series	Whole series
1.	Minimum	0.00	0.00	0.00
2.	Maximum	236.00	236.00	236.00
3.	# of zeros	549	709	1258
4.	Mean	14.58	12.08	13.33
5.	Variance	1304.51	1213.46	1260.15
6.	Std dev.	36.12	34.83	35.50
7.	C. Variation	2.48	2.88	2.66

Road-bridge (112022) discharge data

No.	Statistic	1st series	2nd series	Whole series
1.	Minimum	0.00	0.00	0.00
2.	Maximum	278.80	221.90	278.80
3.	# of zeros	90	0	90
4.	Mean	28.13	26.57	27.35
5.	Variance	1401.49	1699.16	1550.45
6.	Std dev.	37.44	41.22	39.38
7.	C. Variation	1.33	1.55	1.44

Hydrograph at Simiyu outlet-Main bridge



Rainfall data

RainfalL data							
Hydromet ID	Station Name	Longitude	Latitude	Altitude (masl)	Period	Missing %	File
9233005	NGUDU	33.35	-2.95	1219	29-95	6	1
9233031	NYANGUGE	33.2	-2.55		70-90	15	1
9234005	SERONERA	34.92	-2.33	1540	61-95	17	1
9235009	LODGE	35.217	-2.583		79-94	32	1
9333005	HYDROMET	33.767	-3.167	1341	28-93	9	1
9333015	FARM	33.483	-3	1251	50-95	5	1
9333040	KIMIZA PRIMARY	33.483	-3.017		72-94	11	1
9333051	MASELA	33.633	-3.333		73-93	2	1
9333053	ISANGA	33.633	-3.25		73-93	12	1

Climatic data

Climate data								
Hydromet ID	Station Name	Latitude	Longitude	Altitude (masl)	Period	Missing data	Data	File
9232009	Mwanza	-2.467	32.917	1140	70-74	<1	3	1
9333029	*Maswa Shanwa*	*-3.017*	*33.767*	*1341*	*70-84*	*<1*	*1*	*1,2,3*

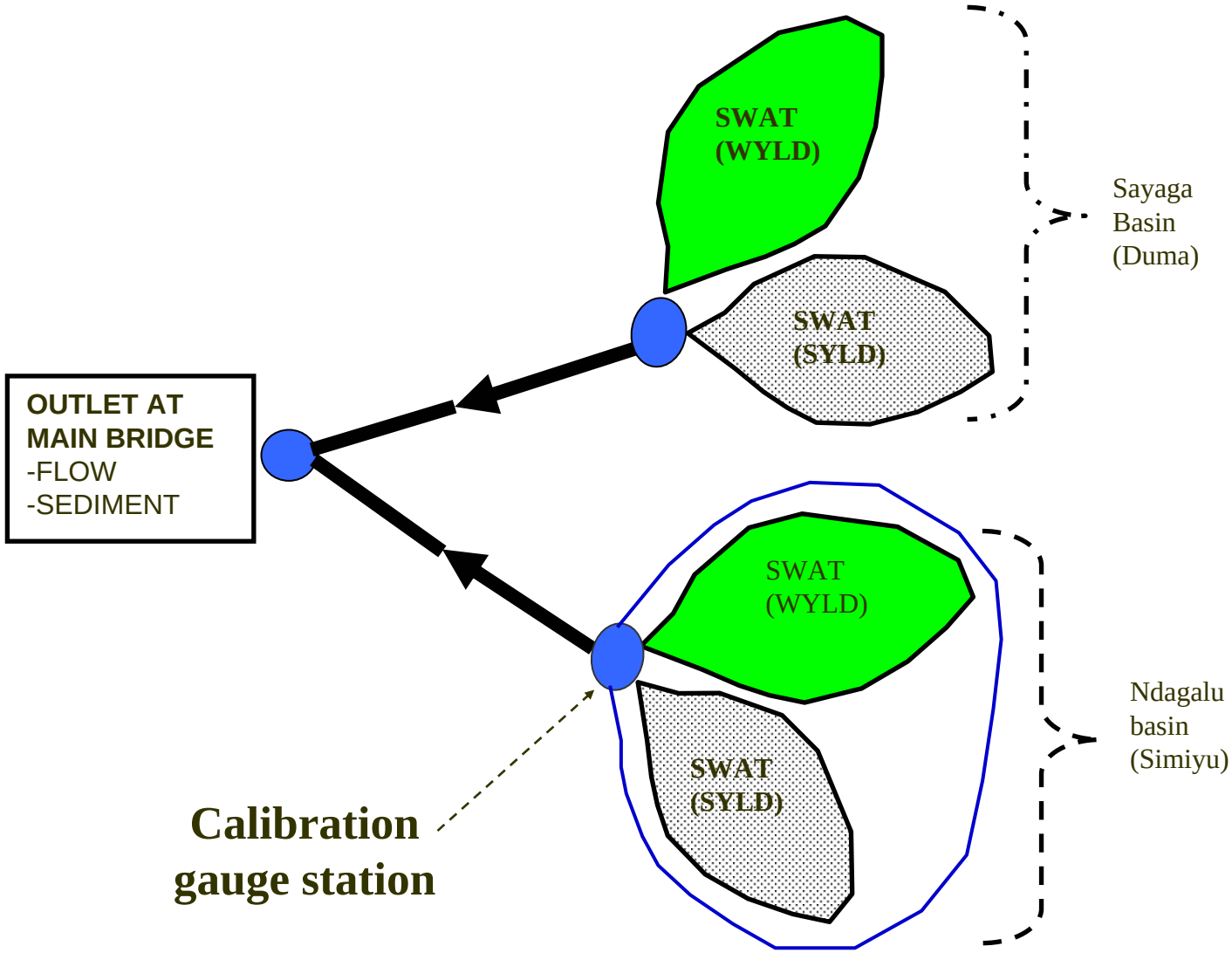
Sediment flow data

Date	Discharge, Q (m3/s)	Total suspended Solids (TSS) (tonnes/day)	Remarks
7/12/2000	152.71	5,673.48	Secondary data
8/12/2000	122.775	3,871.83	Secondary data
9/12/2000	71.23	1,323.17	Secondary data
10/12/2000	97.04	3,605.23	Secondary data
11/12/2000	134.52	10,750.84	Secondary data
12/12/2000	139.4	11,020.41	Secondary data
13/12/2000	91.02	1,966.03	Secondary data

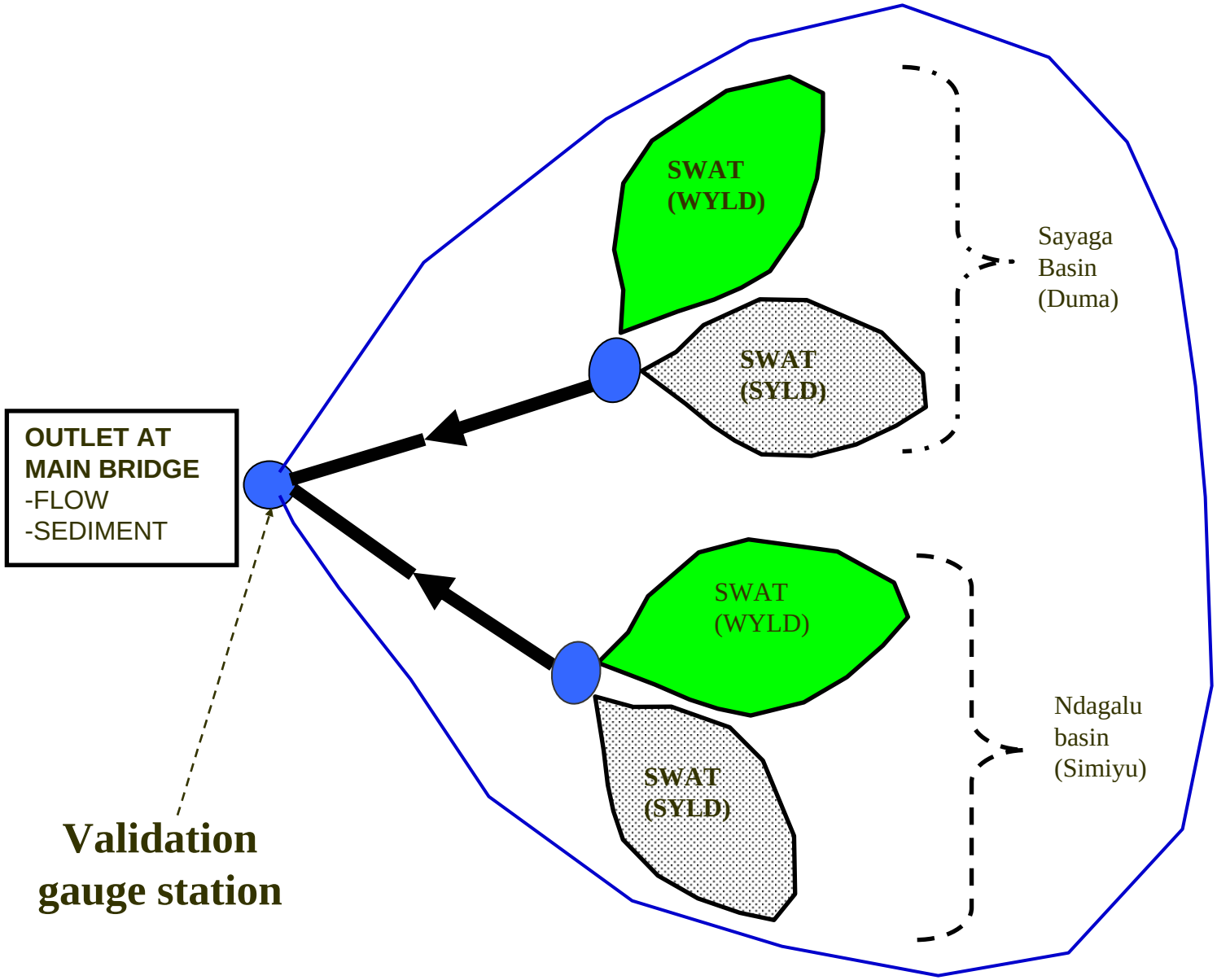
METHODS

- ✓ Literature review
- ✓ Model selection
- ✓ Data analysis
- ● Problem schematization
- ● Model calibration
- ● Model validation

Problem schematization



Problem schematization (contd.)

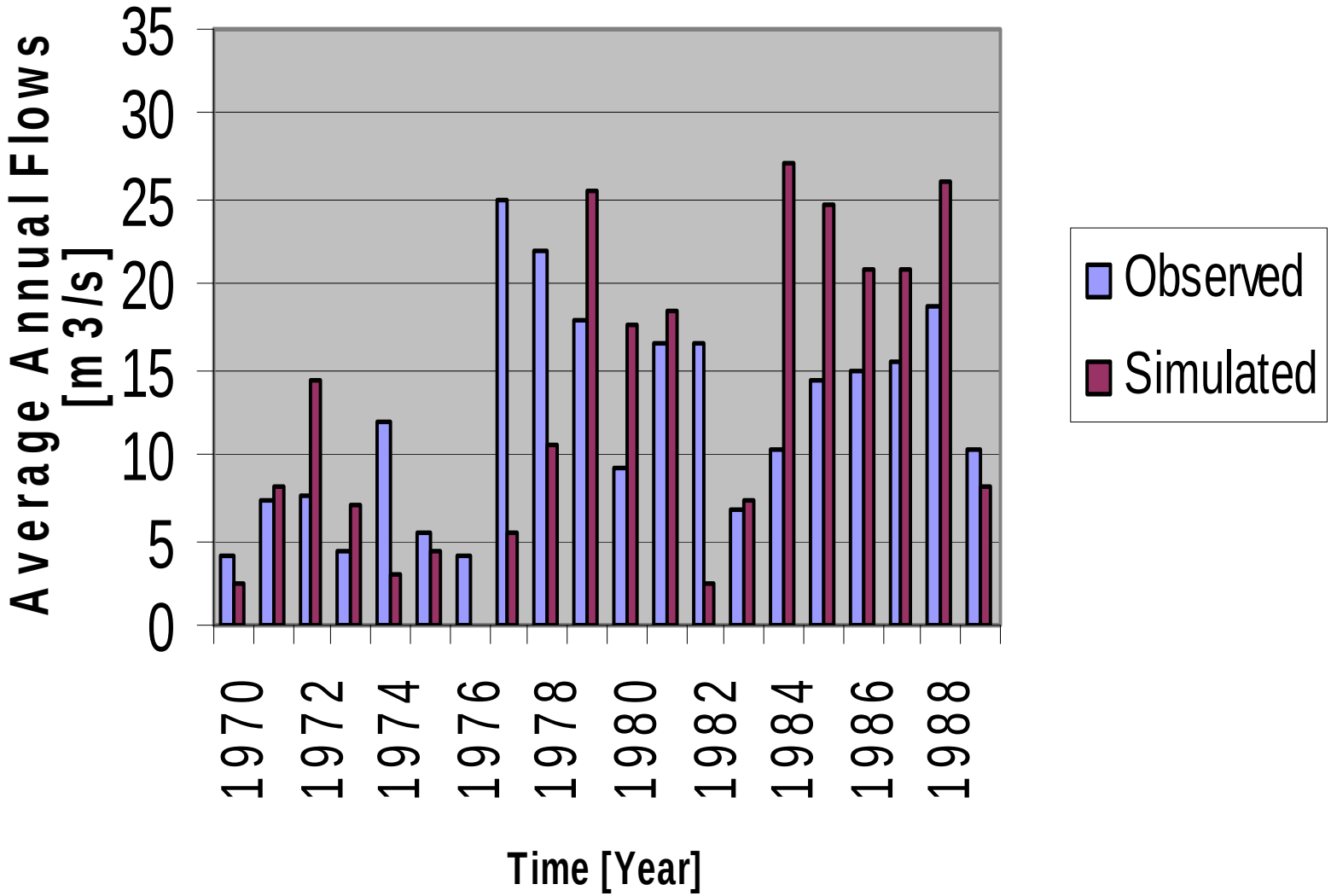


Model Calibration

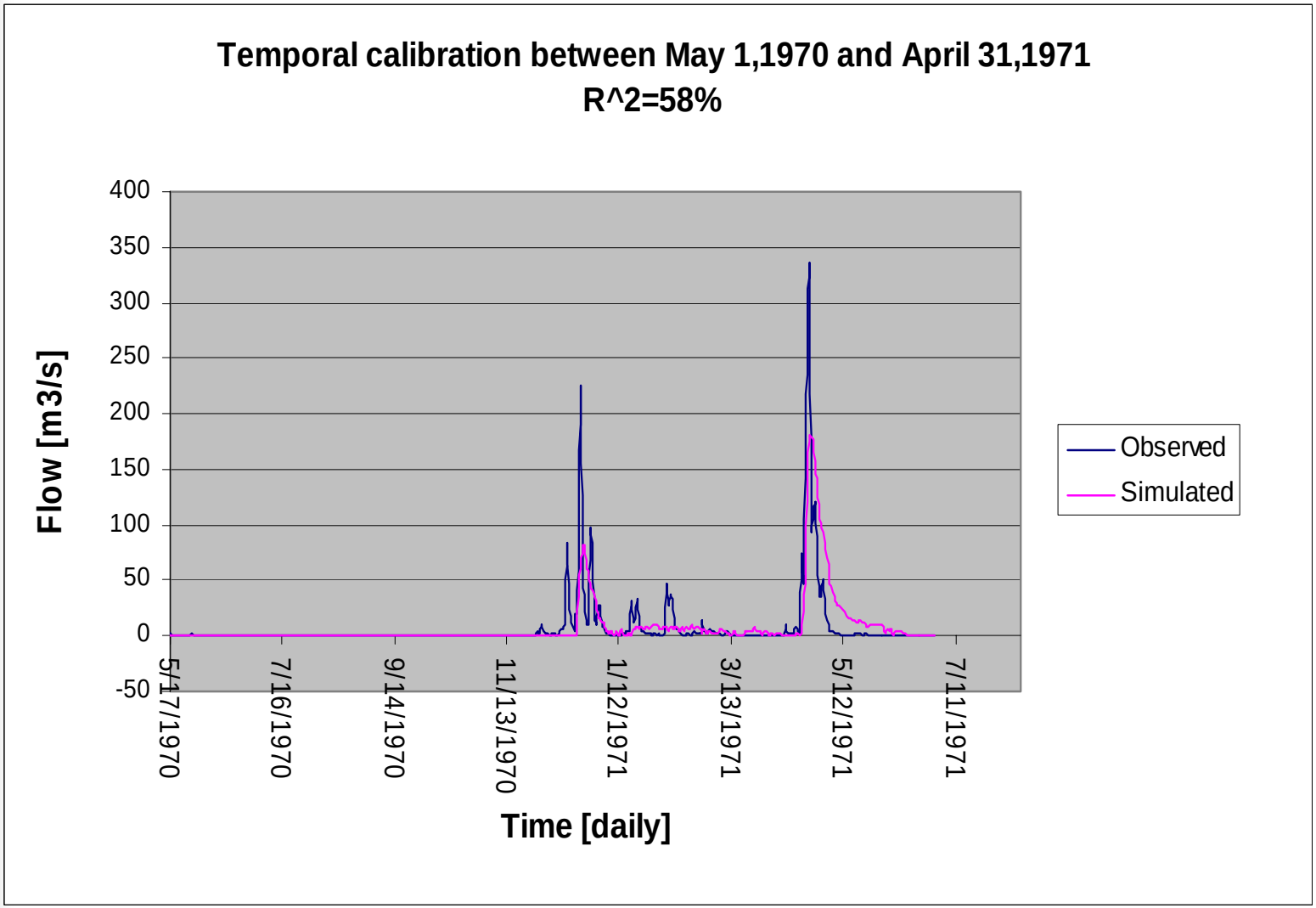
Average annual volumes

	Total Water Yield WYLD (mm)	Surface Flow SURF (mm)	Baseflow GWQ (mm)
OBSERVED	84.3	58.4	25.9
SIMULATED	77.64	52.41	25.15

Long-time Simulation Results



Simulated vs observed hydrograph



Model Validation/Application at Main outlet of Simiyu Catchment

Observed			Simulated			Remarks
Date (d/m/y)	Flow (m^3/s)	Sediment loads (ton/day)	Date (d/m/y)	Flow (m^3/s)	Sediment loads (ton/day)	
7/12/2000	152.7	5673.5	2/4/1975	151.2	4444.3	Rainy season
8/12/2000	122.8	3871.8	3/4/1975 22/2/1989	122.9 121.9	2924.8 **3350.0**	Rainy season
9/12/2000	71.2	1323.2	15/4/1974 26/4/1977	71.6 70.8	1853.2 1856.5	Rainy season
10/12/2000	97.0	3605.2	26/12/1982 29/1/1985 24/1/1987 26/12/1989	99.8 97.1 98.4 94.6	3658.2 **3762.8** 3084.6 2528.0	Rainy season
11/12/2000	134.5	10750.8	20/1/1987 16/3/1978	132.2 131.7	7117.0 6114.3	Rainy season
12/12/2000	139.1	11020.4	7/4/1978 30/12/1979	133.6 135.8	11815.0 9844.4	Rainy season
13/12/2000	91.0	1966.0	15/4/1978 30/12/1982 31/12/1988	91.4 90.0 89.5	**1953.9** 1401.2 1595.1	Rainy season

Discussion of Results

- The predictions by SWAT so far can be viewed as “natural” flow-abstractions or irrigation not considered
- Considered dominant source of sediment is from rill and inter-rill (sheet erosion)
- The simulated sediment loads are reasonable although no concurrent data sets were used
- Sediment loads were not calibrated due to a lack of measured sediment loads in the catchment
- Peaks of hydrograph were not well captured, probably because of poor resolution of soil type map.The available soil map shows that deep sandy soil occupies 86% of the area in the catchment.
- Simulation results are comparable to observations when measured climatic data are used.

Recommendations

- Detail sediment sampling data at Sayaga, Ndagalu and Main Bridge gauging stations is required.
- Detailed soil type and climatic data is required.
- Human interventions information such as irrigation data is required.
- For better understanding of the model performance in the ungauged catchment, it is proposed that follow-ups studies in sediment yield modelling should customize SWAT model

Conclusions

- Observed and simulated annual flows are comparable with means of 12.93m3/s and 12.67m3/s respectively.
- Temporal calibration of flows gave a modelling efficiency according to Nash and Suttcliffe criterion of R^2 =58%.
- Simulated long-term specific sediment yield of Simiyu catchment is 0.523t/ha/year
- The modelling result from Simiyu basin suggests that SWAT model is suitable for ungauged catchments
- Geo-spatial data sourced from internet have been useful in developing the SWAT model

Thanks!