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Assessment of the Impact of LULC Change on Water Resources: Tana sub-basin, Ethiopia

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Outlines

- ✓ Introduction
- ✓ Objectives
- ✓ Study area description
- ✓ Materials and Methods
- ✓ Result and discussion
- ✓ Conclusion

Introduction

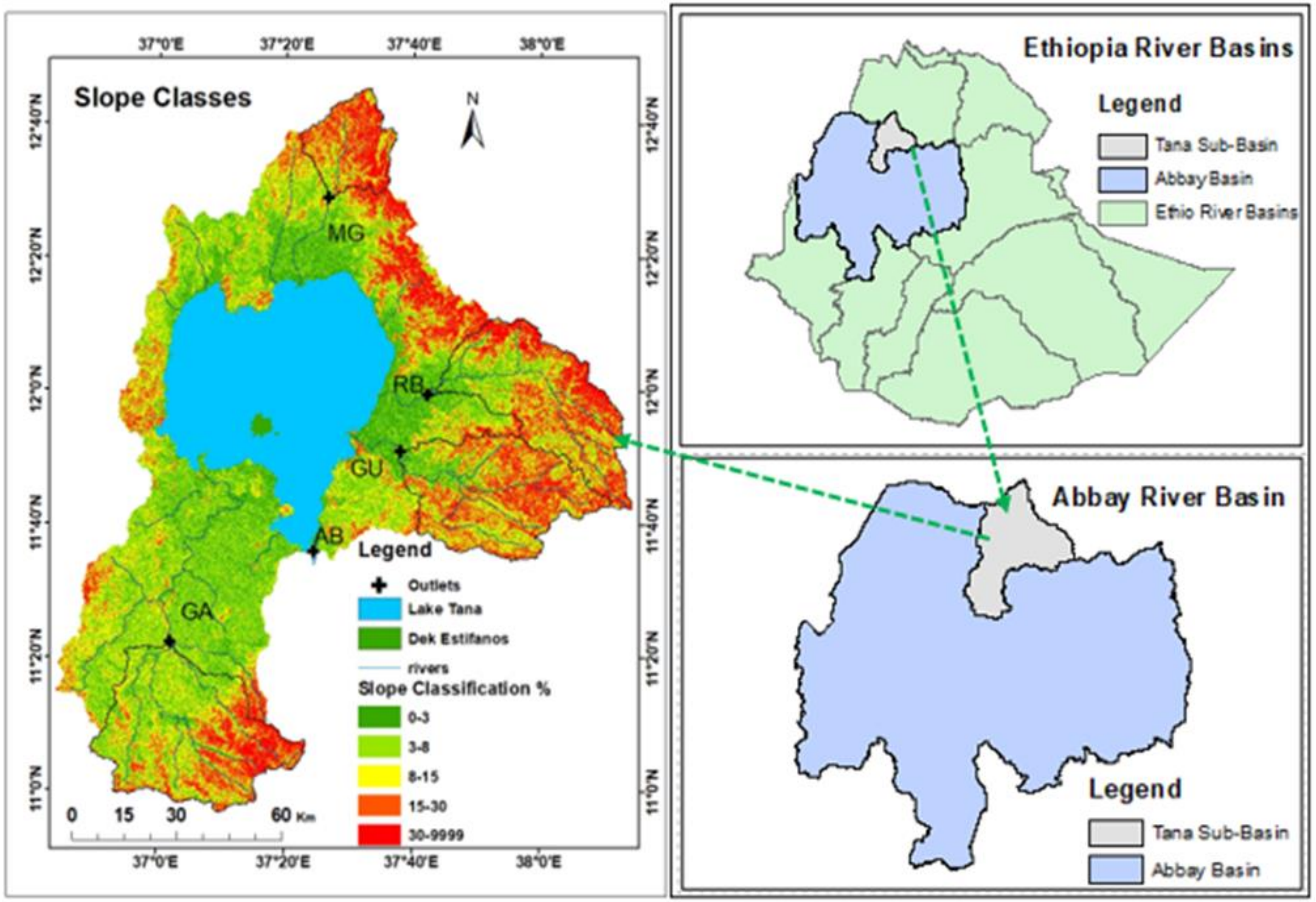
- ✓ Natural resources are critically under pressure because of increasing demand from water competing sectors, climate change, booming population, livelihood improvement, and economic crises.
- ✓ Land-use changes are altering the hydrologic system and have potentially large impacts on water resources (Wagner, 2014).
- ✓ The study area is one of the growth corridor of the country, Ethiopia (TaSBO, 2019).
- ✓ The land cover continuously changing and under the pressure of population growth, climate change and economic activities.
- ✓ These changes will have an impact on hydrological component of the study area.
- ✓ Tana sub-basin is thus under stress, the result being a disorganized distribution and utilization of natural resources

Objective

- ✓ The LULC of the study area was changed over time, which could impact water resources. Therefore, it is very crucial to assess and update the impact of land use and land cover change on the water resources in the Tana sub-basin.
- ✓ The study aimed to assess the impact of land use/land cover change on water resources in the Tana sub-basin using the Soil and Water Assessment Tool (SWAT).

Study area

- ✓ Area: 15,070.14 km2 and 20% of the sub-basin is the Lake Tana water body.
- ✓ $36^{0}45'$ - $38^{0}15'$ E long and $10^{0}57'$ - $12^{0}46'$ N lat
- ✓ Elevated region in Northern Ethiopia, situated in the headwaters of the Blue Nile Basin.
- ✓ Mean elevation is 2,026.54 m.a.s.l
- ✓ Highest elevations at 4,112 m.a.s.l. in the eastern part and Lowest elevation at the point of outflow into the Blue Nile at Bahir Dar is about 1,786 m.a.s.l



Study area

- ✓ Out of the total drainage area, 63.18% has a slope of 0-8%. The remaining 36.82% of the drainage area has a slope above 8%; out of which 15.65% has a slope of 8-15%

- ✓ Four major river watersheds:

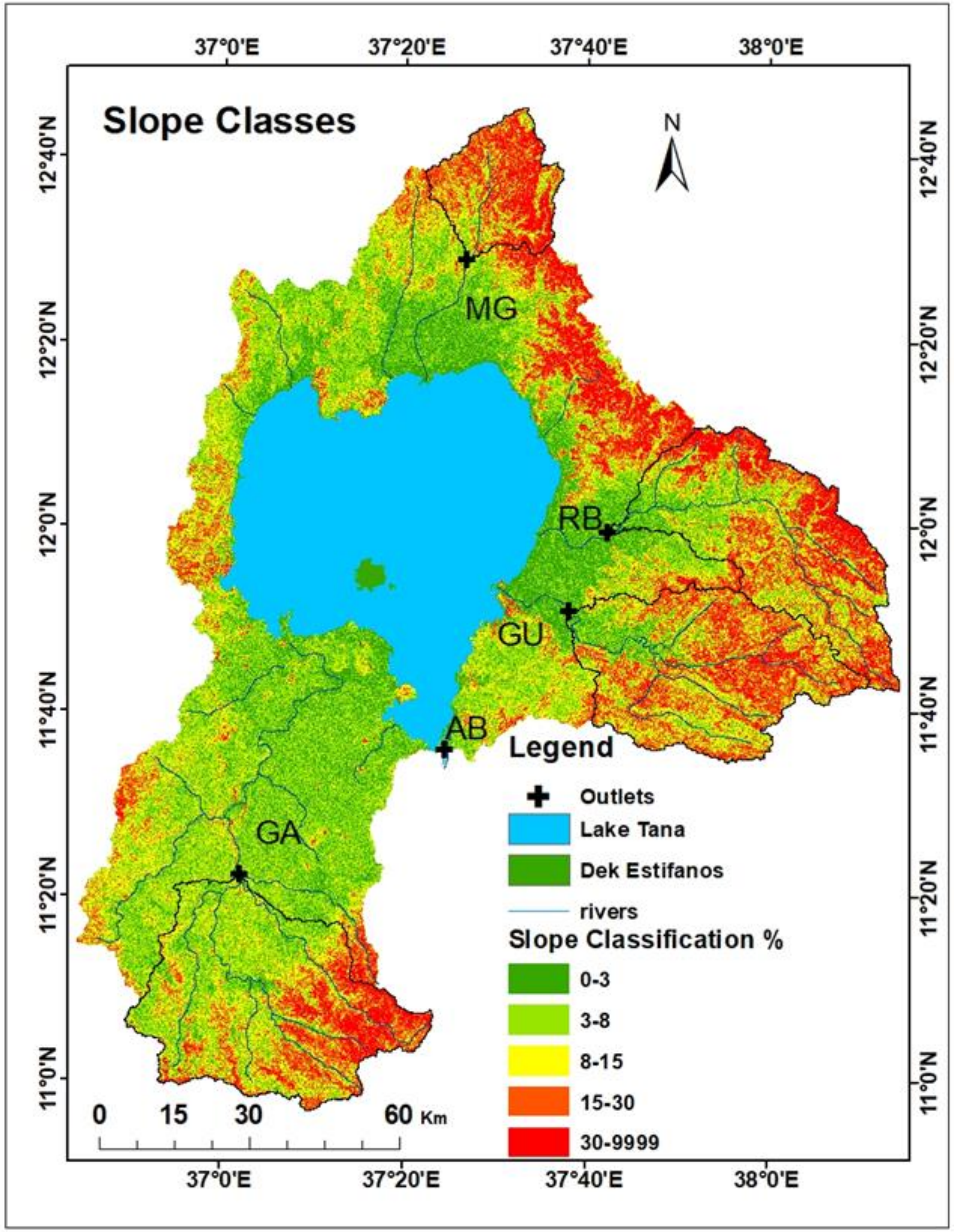
  Gilgel Abbay (1,656.35 km2),

  Ribb (1318.01 km2),

  Gumara (1,354.35 km2), and

  Megech (515.06 km2)

- ✓ More than 80% of the subbasin water resources generated from the four major watersheds

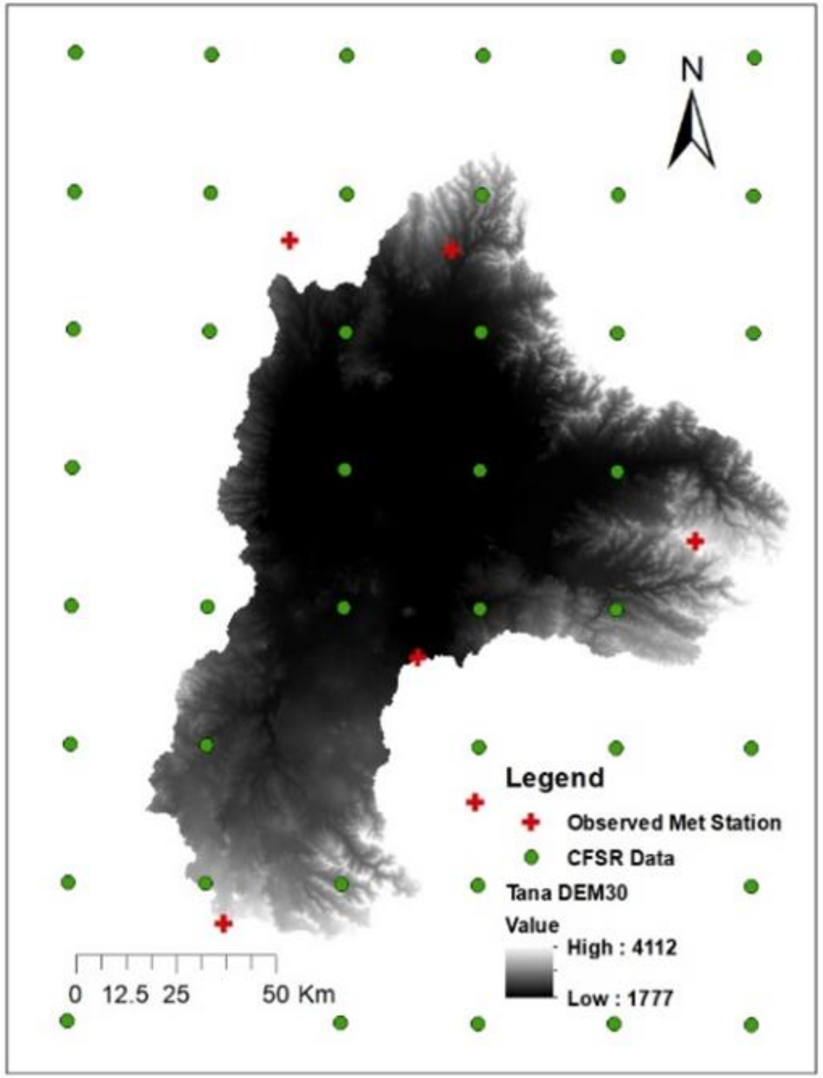


Important figures

- ✓ Slope classified into flat to very gently sloping (<3%), gently to sloppy sloping (3–8%), strongly sloping (8–15%), moderately steep (15–30%), and steep to extremely steep (>30%).
- ✓ Land cover was categorized into eight: Cultivation land, Forest, Shrub/Bushland, Water bodies, Afroalpine, Grassland, and Settlement/Built-up area.
- ✓ 69 sub-basins were delineated.
- ✓ About 942, 886, and 869 HRUs were then created for 1986, 2000, and 2014 LULC respectively and 10% thresholds were used for LULC, soil, and slope.
- ✓ Simulation covered 27 years (from 1987-2013) where the first three years (1987-1989) were used as model warm-up periods, 16 years (1990-2005) for calibration, and the last 8 years (2006-2013) for validation.

Data source and used

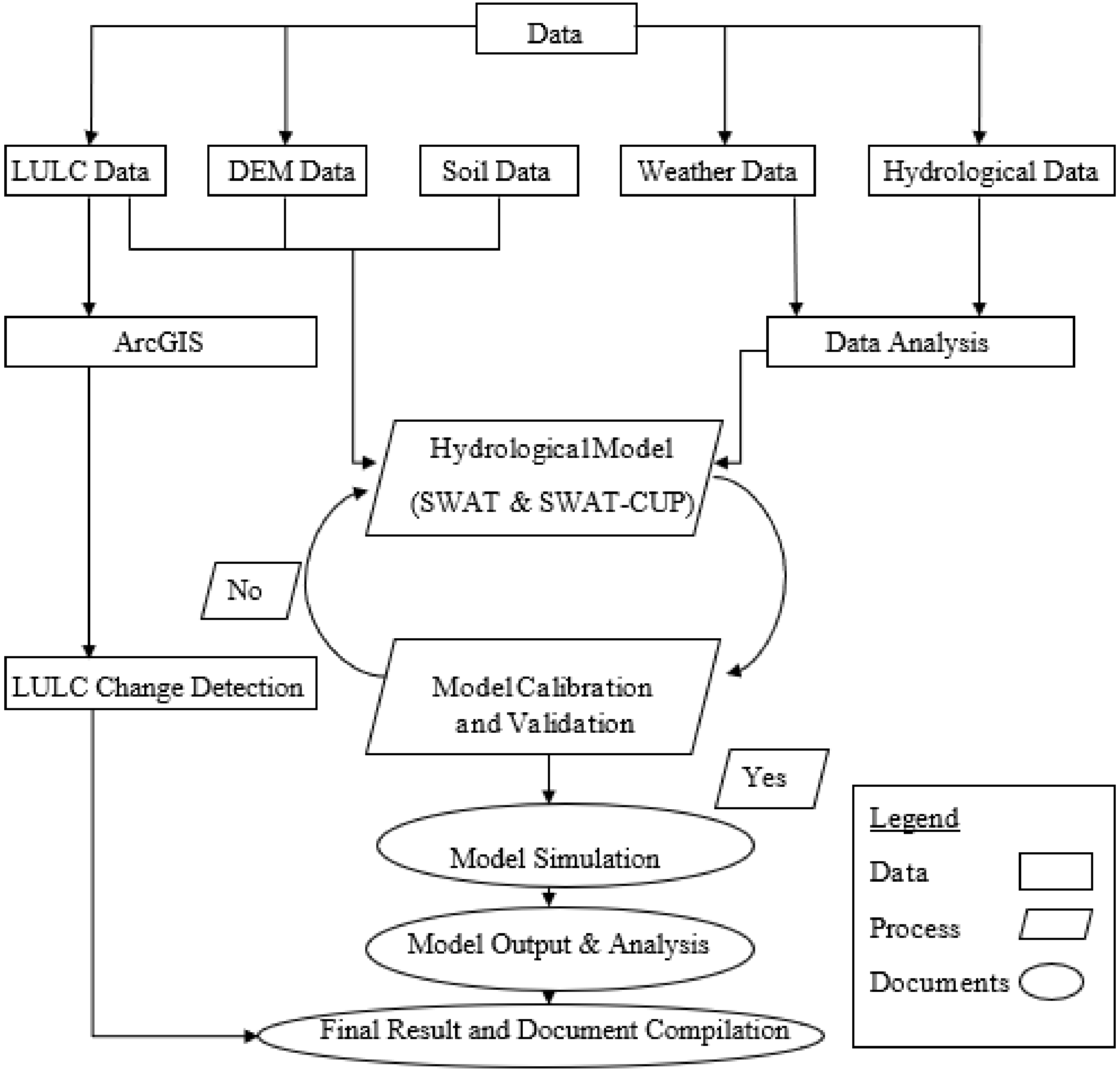
Variable	Source	Spatial and tempora resolution
DEM	NASA's	30m*30m SRTM
Soil Data (Map)	Ministry of Water, Irrigation and Energy, Ethiopia	90m*90m
Land use land cover	Amhara Design and Supervision Work Enterprise, Ethiopia	30m*30m 1986, 2000 and 201
Measured weather data (six variables)	National Meteorology Agency, Ethiopia	1987-2013
Rainfall (CFSR) for 42 stations	National Centers for Environmental Prediction (NCEP)	1987-2013
Flow data (4 stations)	Abbay Basin Development Office , Ethiopia	1987-2013



Material/tools used

Tools	Input variables	Purpose
Dew02.exe	Min and Max daily T and average daily humidity	used to compute daily dewpoint
WGNmaker and PCP stat	RF, Max and Min T, one-hour RF, solar radiation, wind speed and dew point temperature	used to compute statistical parameters for precipitation
ArcGIS10.3	LULC, Soil data, DEM, river and watershed shapefile	used for preparation an input for SWAT model and result visualization of model, and used to analyze the land use land cover change
SWAT-CUP	SWAT model output (simulated), flow data,	Used for calibration, validation, and uncertainty analysis of the SWAT model, and were also used to optimize the SWAT model parameters (monthly time)
SWAT2012	LULC, Soil data, DEM, Weather data,	used to assess the impact of LULC change on water resources in the study area

Methodological framework



$$NSE = 1.0 - \frac{\sum_{i=1}^{n}(Qm,i - Qs,i)^2}{\sum_{i=1}^{n}(Qm,i - \bar{Q}m)^2}$$

$$R2 = \left[\frac{\sum_{i=1}^{n}(Qm,i - \bar{Q}m)(Qs,i - \bar{Q}s)}{\sqrt{\sum_{i=1}^{n}(Qm,i - \bar{Q}m)^2}\sqrt{\sum_{i=1}^{n}(Qs,i - \bar{Q}s)^2}}\right]^2$$

$$PBIAS = 100 * \frac{\sum_{i=1}^{n}(Qm,i - Qs,i)}{\sum_{i=1}^{n}Qm,i}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Qs,i - Qm,i)^2}$$

$$RSR = \frac{RMSE}{STDV}$$

Result and Discussion

Sensitivity analysis

- ✓ Sensitivity analysis was undertaken and performed using the data period 1990-2013 for stream flow of 4 rivers for Tana subbasins (more than 80% of water resources generated)
- ✓ List of the most ten sensitive parameters for streamflow simulation was used out of twenty-four hydrological parameters based on their t-stat and p-value
- ✓ In most of the watersheds, the most sensitive four parameters are

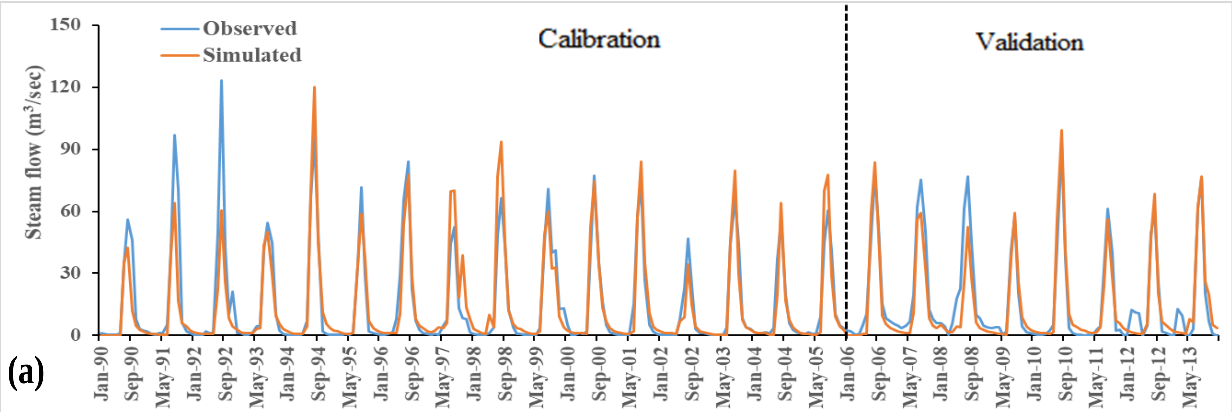
Sensitivity	**Gumara River**	**Rib River**	**Megech River**	**Gilgel Abbay River**
1	A_GW_DELAY	V_GW_REVAP	R_CN2	R__CN2
2	R_CN2	V_ALPHA_BF	A_GW_DELAY	R__SOL_Z
3	A_GWQMN	V_RCHRG_DP	A_GWQMN	A__GWQMN
4	V_GW_REVAP	A_GW_DELAY	V_GW_REVAP	R__SOL_ALB

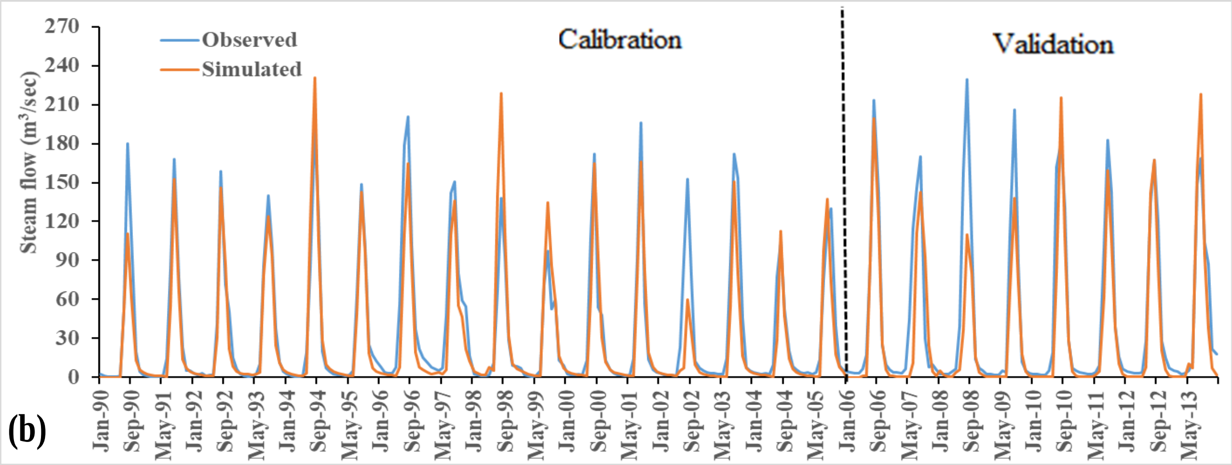
Result and Discussion

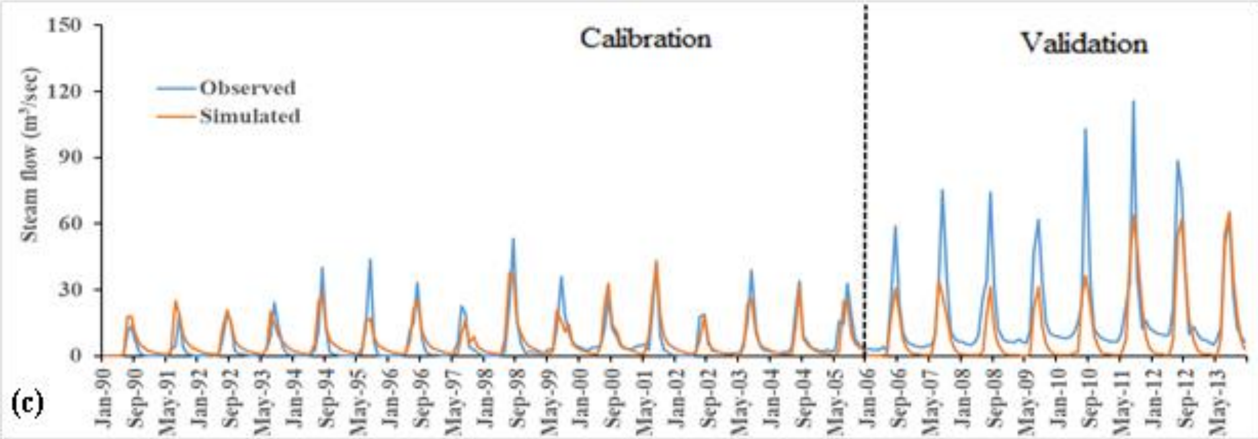
Model Calibration and Validation

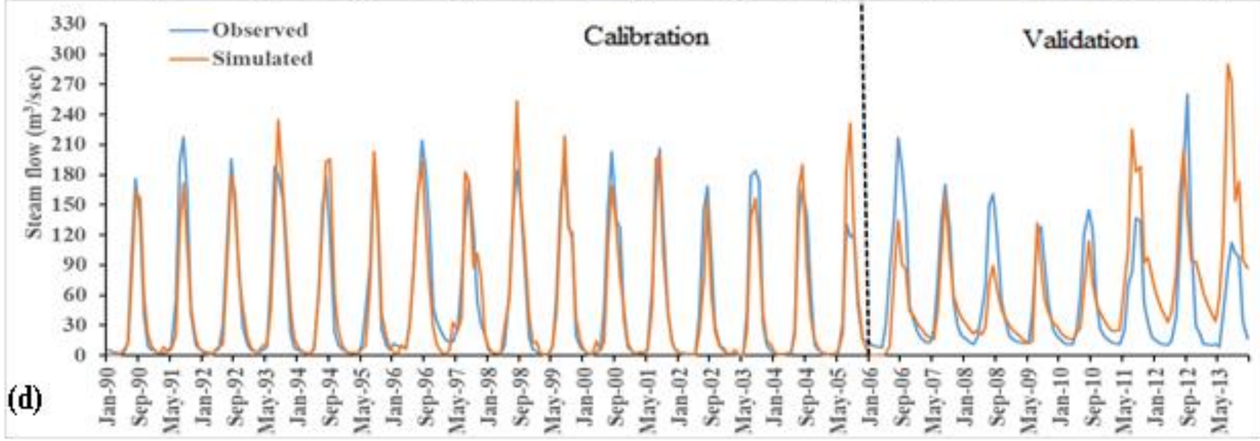
SWAT model performed well in all watersheds for the calibration and validation periods

Sub-basin	Major watershed	Calibration				Validation			
		R2	NS	PBIAS	RSR	R2	NS	PBIAS	RSR
Tana	Gumara (b)	0.84	0.83	16.20	0.41	0.83	0.80	24.60	0.45
	Megech (c)	0.72	0.72	-9.4	0.53	0.74	0.57	44.1	0.65
	Gilgel Abbay	0.88	0.88	2.90	0.35	0.71	0.65	-4.3	0.93
	Rib (a)	0.83	0.82	4.10	0.42	0.90	0.89	11.60	0.33



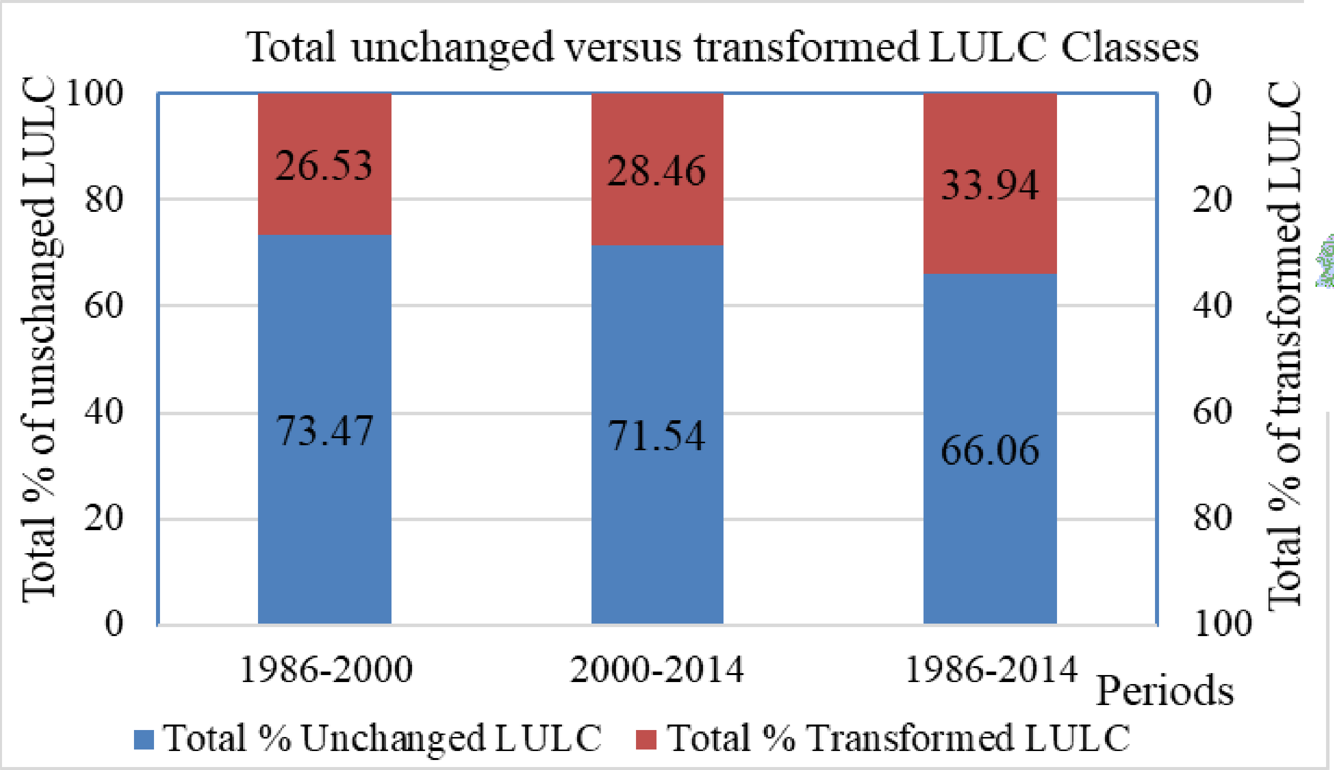


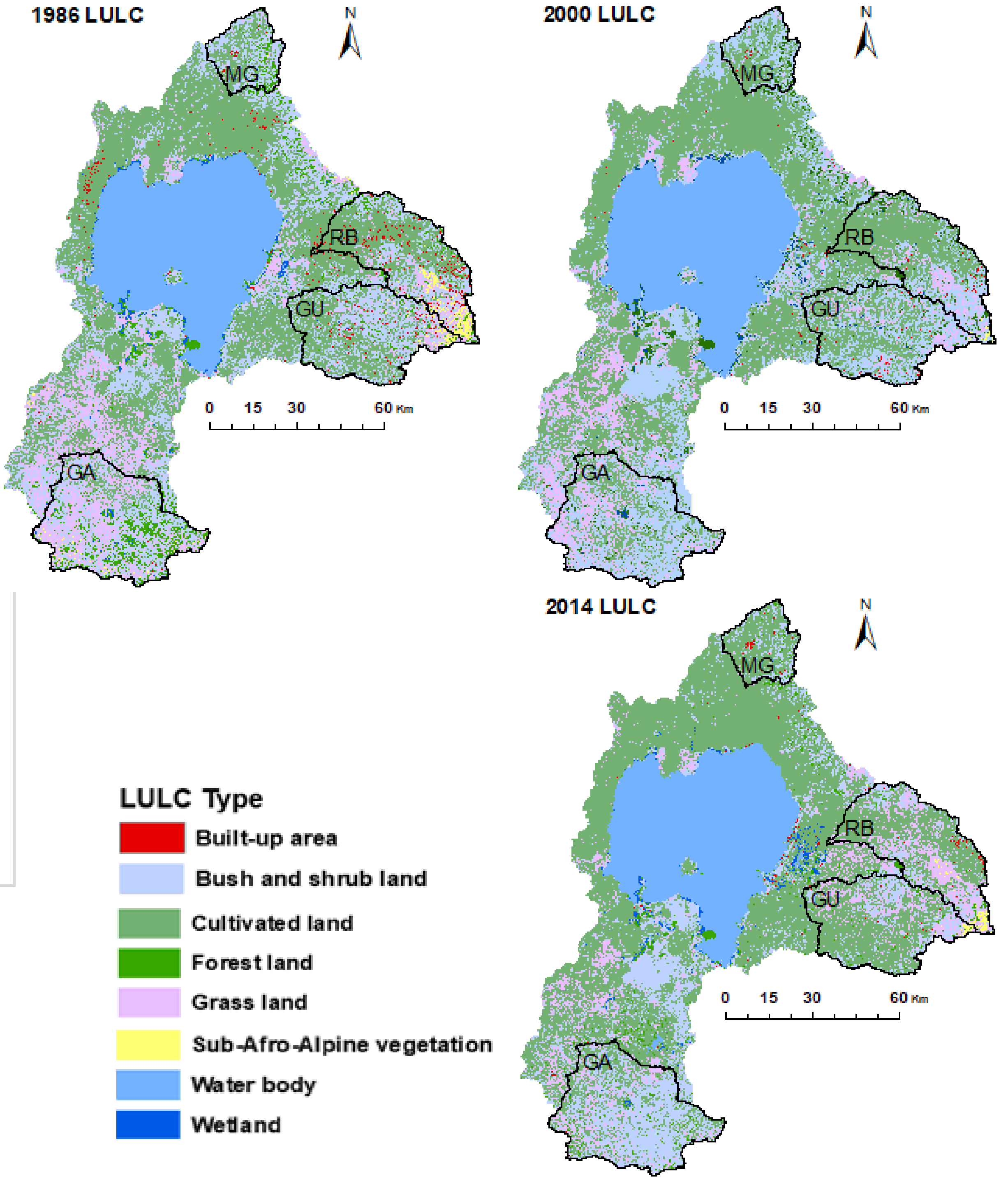




Result and Discussion

LULC changes: 1986, 2000, 2014





Result and Discussion

LULC changes: 1986, 2000, 2014

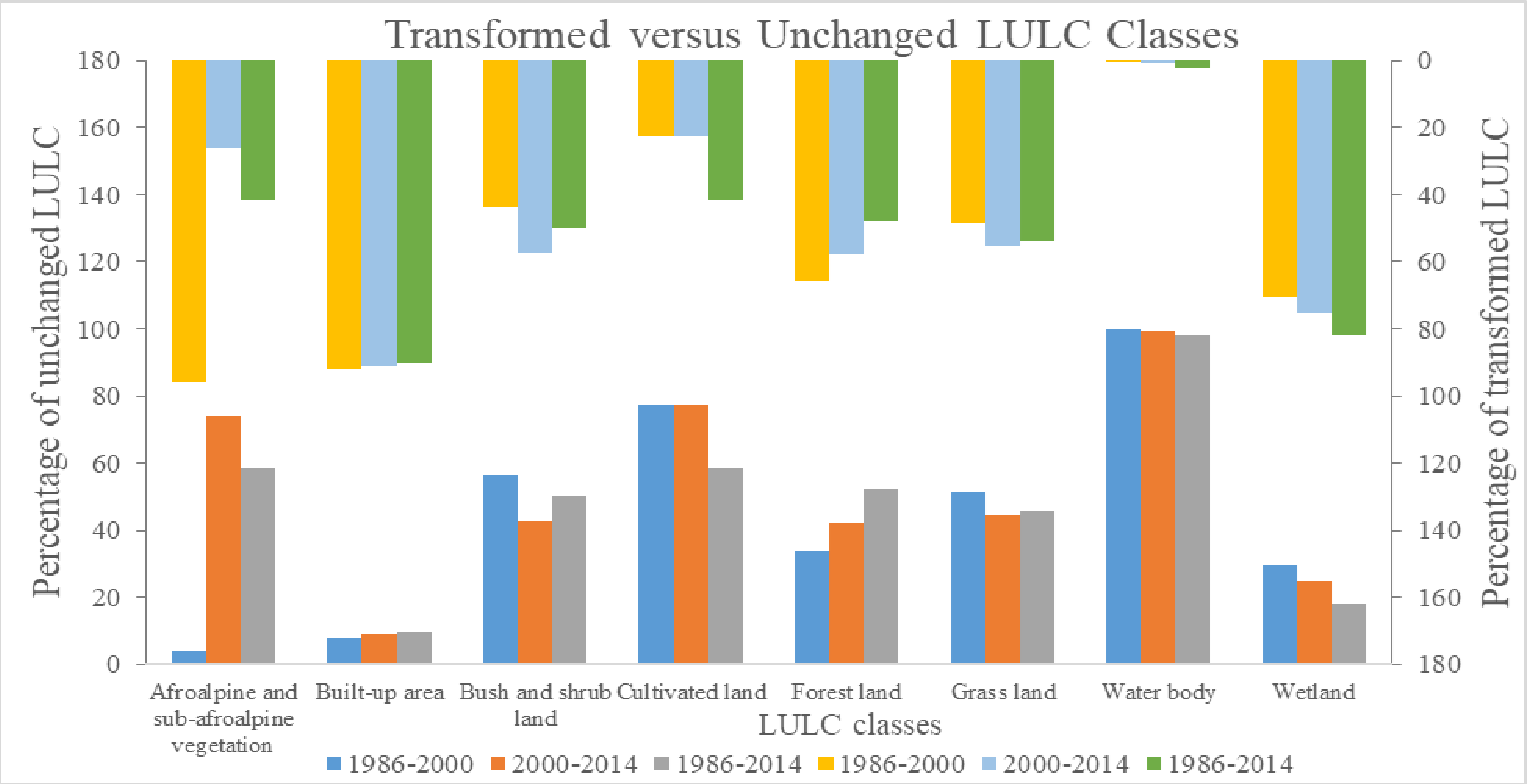
Forestland and grassland have decreased continuously in these years.

Sub-afro-alpine vegetation showed a dramatic decrease in the second period of assessment.

Bushes and shrubs recorded about a 1% increase in the total area and an unexpectedly fast decline in the second period.

Forest land showed a continuous reduction while water bodies and wetlands showed a small variation as compared to the other

Continuous increment in cultivated land



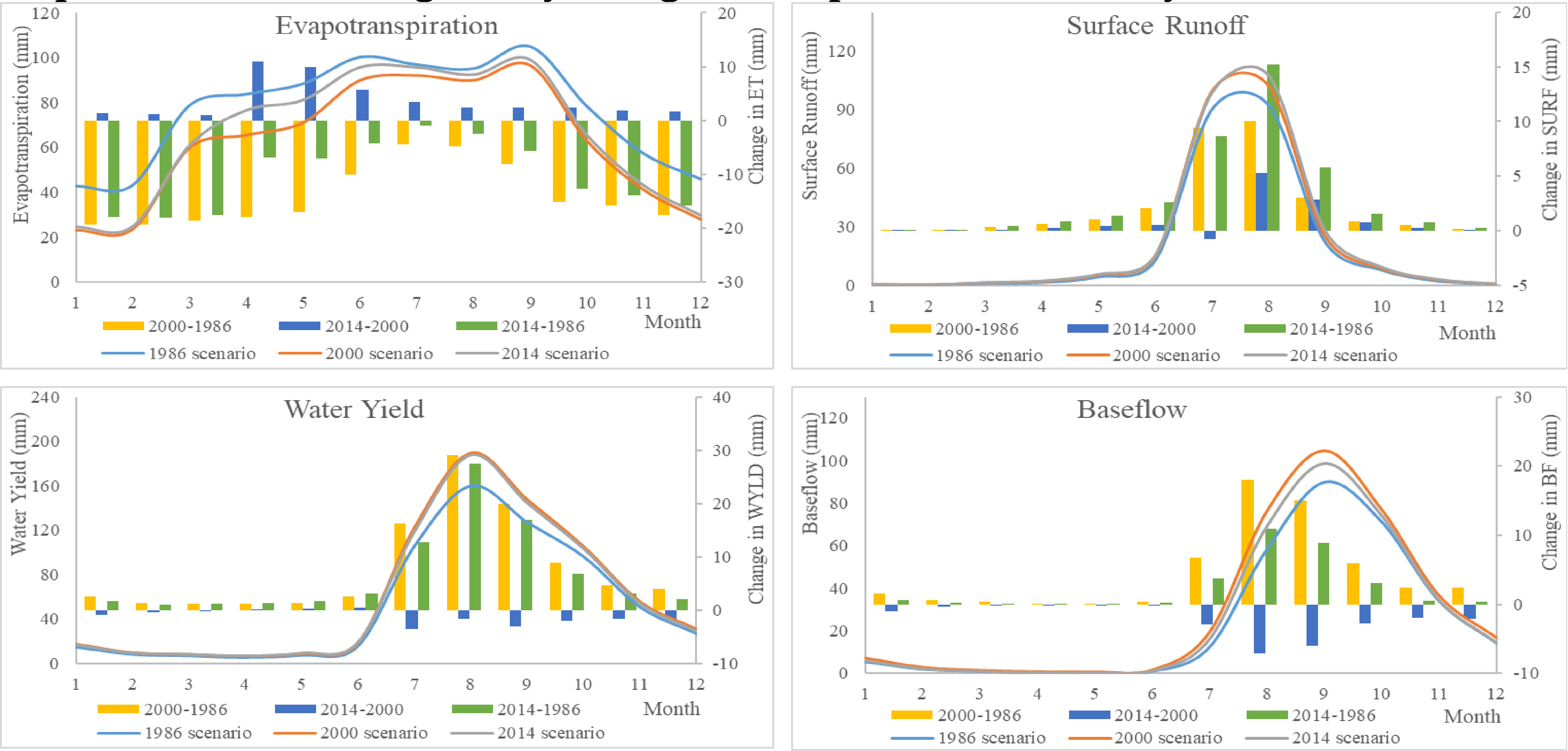
Result and Discussion

Impacts of LULC change on water resources

Period	LULC (%)								Water resources component (mm			
	Afroalpine and sub-Afroalpine vegetation	Built-up area	Bush and shrubland	Cultivated land	Forest land	Grass land	Water body	Wetland	ET	SURQ	WYLD	BF
1986	0.81	0.99	24.06	36.64	4.36	12.13	20.29	0.72	913.65	233.61	628.88	291.5
2000	0.07	0.28	25.09	40.71	2.33	10.49	20.37	0.67	745.62	261.65	722.45	345.1
2014	0.25	0.29	17.87	48.82	1.81	9.53	20.62	0.80	790.34	271.36	708.14	320.4
2000-1986	-0.74	-0.71	1.03	4.07	-2.03	-1.64	0.08	-0.06	-168.03	28.04	93.57	53.6
2014-2000	0.18	0.01	-7.22	8.12	-0.52	-0.96	0.25	0.13	44.72	9.71	-14.31	-24.7
2014-1986	-0.56	-0.70	-6.19	12.18	-2.55	-2.60	0.33	0.07	-123.31	37.75	79.26	28.9

Result and Discussion

Impact of LULC Change on hydrological components on monthly scale



Result and Discussion

- ✓ Land cover remained unchanged was 73.47% (1986-2000), 71.54% (2000-2014). The overall changes was 33.94% (1986-2014) which pushed the unchanged land cover down to 66.06%.
- ✓ Average annual water yield increased by 14.88% and 12.6%, baseflow increased by 18.4% and decreased by 7.16%, surface runoff increased by 12% and 16.16%, evapotranspiration decreased by 18.39% and 13.49%, for 2000 and 2014 respectively, compared to baseline 1986.
- ✓ Expansion of cultivation land and reduction of bush and shrubland, grassland and forest help increase surface runoff, and water yield, and reduce evapotranspiration and baseflow in this study
- ✓ Increase in surface runoff and water yield in the study area corresponds to sub-basins with a reduction in forest cover and shows an effect on evapotranspiration.

Result and Discussion

- ✓ High forest cover will respond to a high rate of transpiration, and this will increase the value of evapotranspiration.
- ✓ ET depends on forest and other cover than waterbodies bodies in the study area
- ✓ Cultivation land decreases soil infiltration rate/percolation/baseflow and increases surface runoff compared to grassland and shrubland.
- ✓ LULC change has significant impacts on infiltration rates, runoff production, total simulation flow, interflow, base flow, water yield, evapotranspiration, and water retention capacity of the soil or change in storage of the soil; hence, it affects the water balance of the study area.

Conclusion

- ✓ SWAT model applicable and performed well in the study area
- ✓ LULC change is one factor that has significant impacts on the hydrology component of the study area.
- ✓ This will continue to have consequences on natural resources management and development.
- ✓ Expected reduction of surface runoff during the dry season may affect agriculture/irrigation and water-oriented activities while its increments during the wet/rainy season may lead to flooding.

Conclusion

- ✓ The approach used in this study has accredited contributions of changes in LULCs to water resources, providing perceptible information that will allow stakeholders and decision-makers to make prominent choices regarding natural resource planning and management.
- ✓ Establishing land use policy, ensuring and enforcing land use plan
- ✓ Research methods used can serve as a guide for other similar studies and be applied to a variety of river basins to predict the consequences of LULC changes on water resources

☺ Thank you

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