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Evaluation of the impacts of land use land cover change on hydrology. A case study of Nashe watershed

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Introduction

The LULC change influences hydrological responses of the water balance leading in spatial and temporal changes (Marhaento et al., 2017)

So, It will lead to water problems such as water pollution, water redundancy and shortage.

The historical, present and the potential future impacts of LULC change needs to be evaluated to manage effectively water resources in a catchment (Leta et al., 2021)

In Sub-Saharan African Countries, Ethiopia is one of the abundant water resources, available for agriculture, domestic, and hydropower generation.

Introduction

Similarly, the country has significant problems related to water resources, such as flooding and droughts.

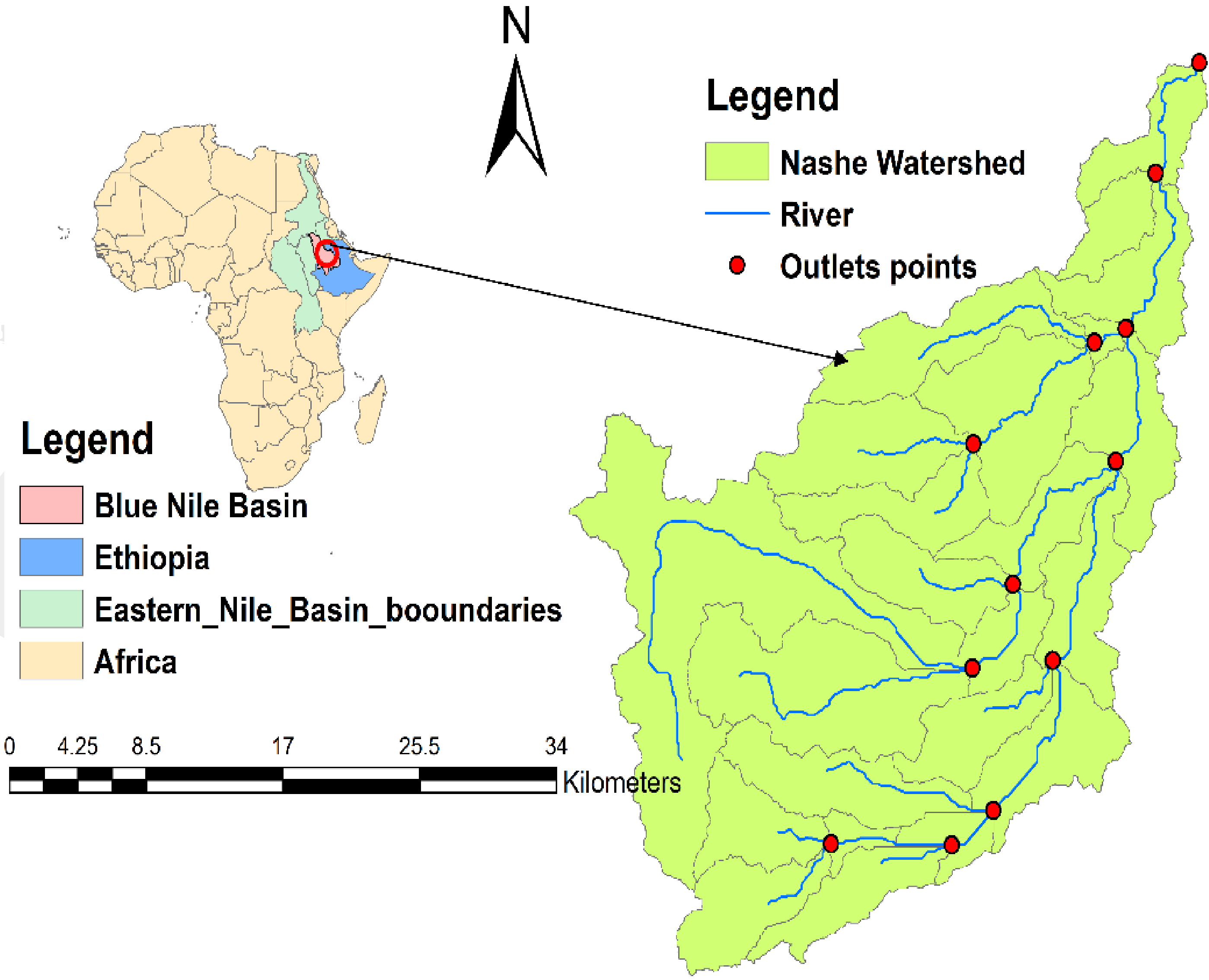
Furthermore, in the Nashe catchment, the agricultural land and urban expansion at the expense of range land, forest land, and grass land is the main problem and predictable to continue in the future (Leta et al., 2021)

Therefore, estimating the effect of LULC on hydrological response of the catchment by using different period LULC will contribute in identifying strategies of hydrological response of the watershed.

Materials and Methods

Study area

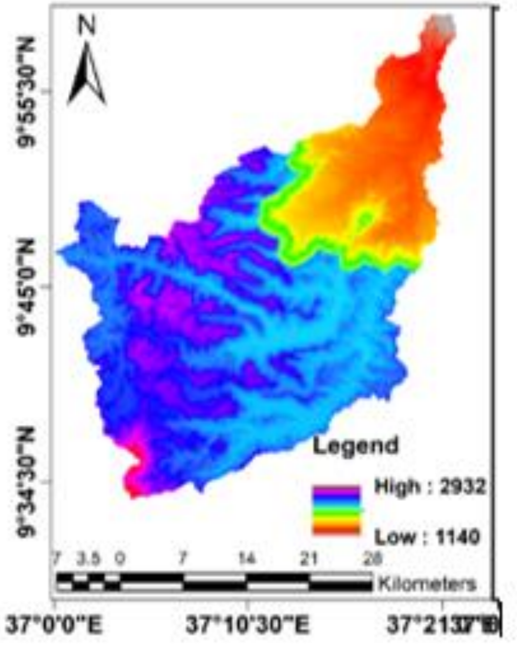
- North –West of Ethiopia
- Area 94578Ha of watershed
- $9^{0}35'$N and 9^{0} $52'$N latitudes
- $37^{0}00'$E and $37^{0}20'$E longitudes
- Average rainfall 1200mm to 1600mm
- Average annual temperature 22^{0}c



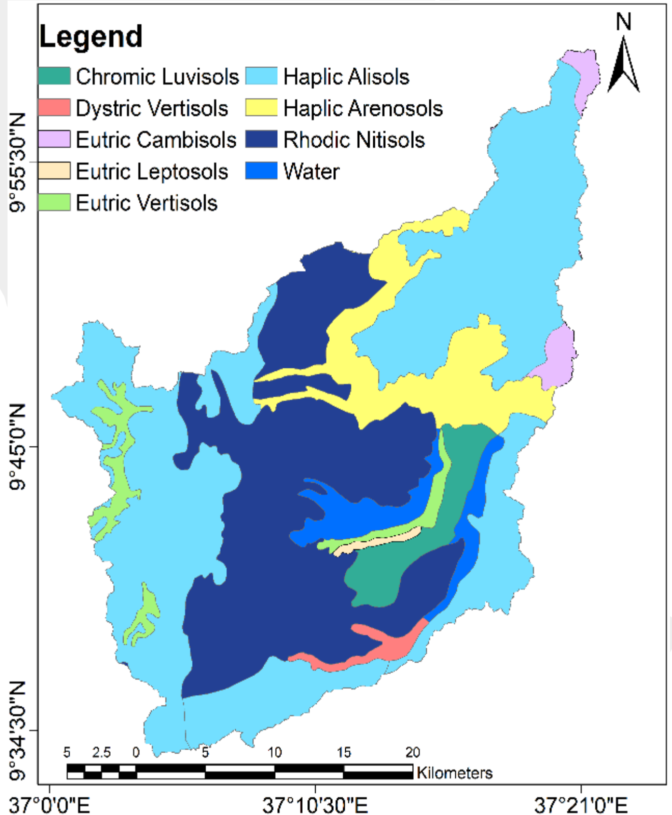
Materials and Methods

Input Data

DEM - A 30m spatial resolution.



Soil - Soil type map and soil physical property database. The soil type map was from the Ethiopian MoWIE.



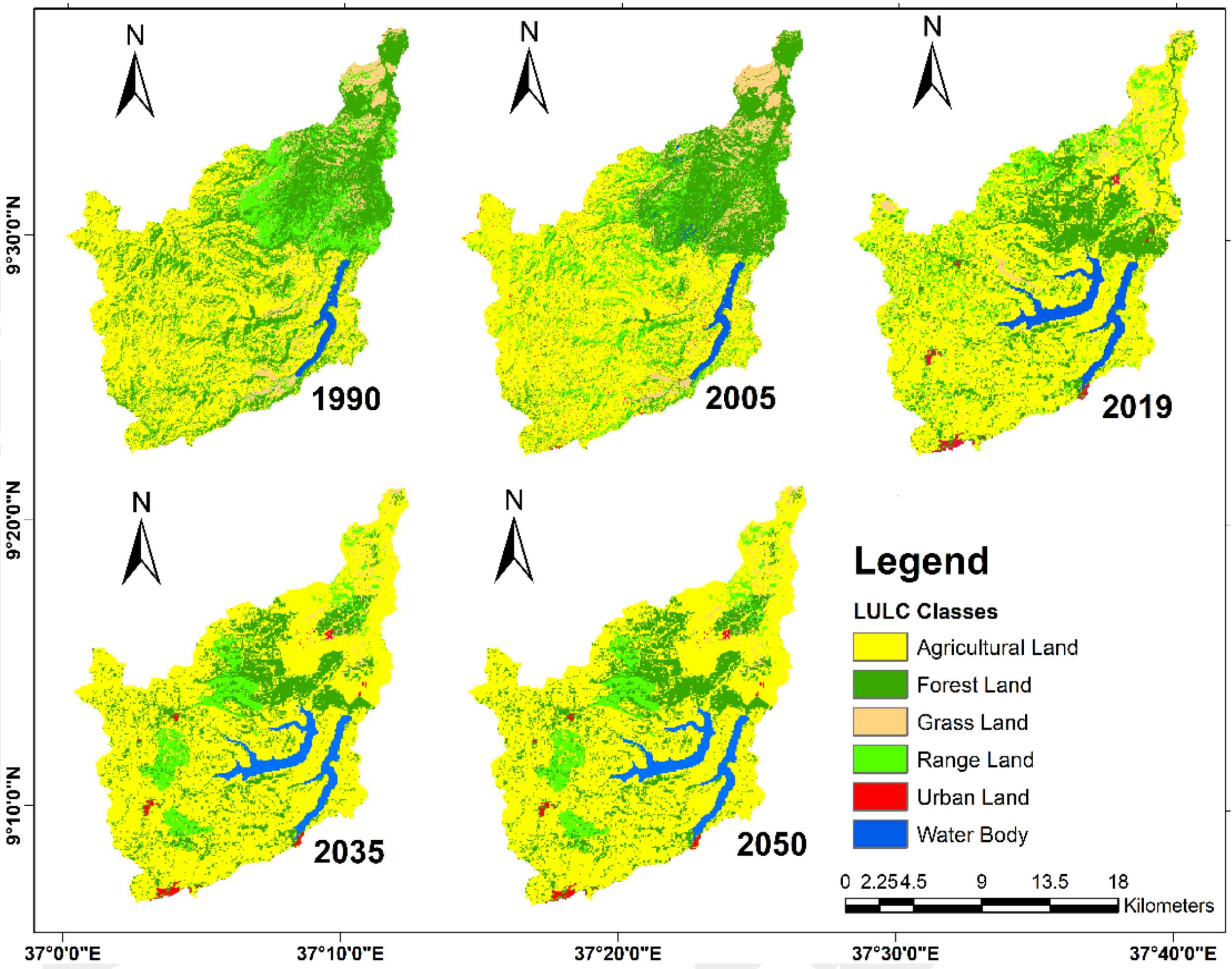
Materials and Methods

LULC - The classified LULC data (1990, 2005 and 2019) and the predicted LULC (2035 and 2050) was found from (Leta et al., 2021).

- Supervised classification method is applied to the satellite images.
- Land Change Modeler was applied to predict the future LULC.
- LULC was classified as: Agricultural land, Forest, Grassland, Urban Land, Water body, and Range land.

Weather Data - Daily weather data within and nearby stations of the watershed were collected from National Meteorological Agency.

Hydrological data - The measured hydrological data at the gauging station was collected from hydrology department of Ethiopian MoWIE.



Modeling

The major model components include DEM, weather, hydrology, soil properties, and land management.

In the SWAT model, the water balance is the base and driving force for all hydrological processes.

$$SWt = SWo + \sum_{i=1}^{n} (Rday - QSurf - Ea - Wseep - Qgw)$$

where: SWt is the final soil water content(mm), SWo is the initial water content (mm), t is the time (days), Rday is the amount of precipitation on day i (mm), Qsurf is the amount of surface runoff on day i (mm), Ea is the amount of evapotranspiration on day i (mm), Wseep is the amount of water entering the vadose zone from the soil profile on day i (mm) and Qgw is the amount of return flow on day i (mm).

Materials and Methods

Sensitivity analysis: is a method of identifying the most significant parameters for calibration and validation (Arnold et al., 2012).

Calibration and Validation

Calibration -The process of adjusting input model parameters to ensure that simulations match with observations.

Validation -The confirmation of the calibrated parameters by testing the calibrated parameters with an independent set of data without further adjusting model parameters.

Model Performance Evaluation

The model performance was conducted to determine the consistency of simulation compared to the measured data during the calibration and validation periods.

Results and Discussions

The top three most sensitive parameters are CN.mgt, GW_DELAY.gw, and SOL_K(..).Sol. The parameters include those governing sub-surface and surface hydrological processes and stream routing.

Parameters Name	Description	Sensitivity		
		t-Stat	P-Value	Rank
r__CN2.mgt	SCS runoff curve number	13.13	0.00	1
v__GW_DELAY.gw	Ground water Delay from soil to channels(days)	-8.21	0.00	2
r__SOL_K (..).sol	Saturated hydraulic conductivity (mm/hour)	7.23	0.00	3
v__ALPHA_BF.gw	Base flow alpha factor for bank storage	2.68	0.00	4
v__CH_N2.rte	Manning's roughness coefficient for the main channel	1.96	0.00	5
v__GWQMN.gw	Threshold depth of water in shallow aquifer required for return flow(mm)	-1.17	0.01	6
r__SOL_AWC (..).sol	Soil available water capacity (mm H20/ mm soil)	-0.96	0.03	7
r__SLSUBBSN.hru	Average slope length (m)	-0.83	0.03	8
r__RCHRG_DP.gw	Deep aquifer percolation fraction	-0.54	0.04	9

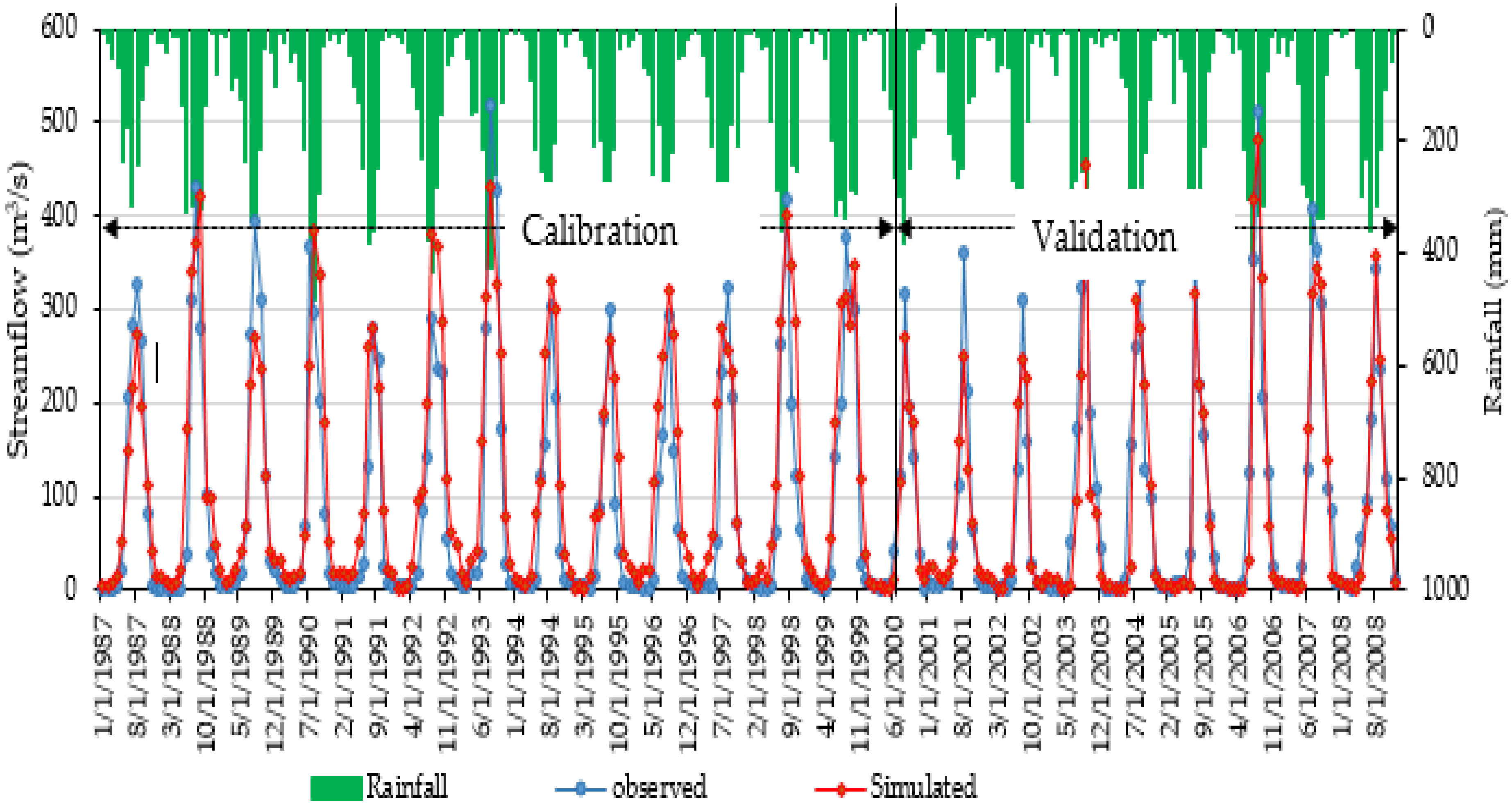
Results and Discussions

Calibration (1987-1999)

$R^2 = 0.80$
NSE = 0.76
PBIAS = 3.03
P-factor = 0.83
R-factor = 0.74

Validation (2000-2008)

$R^2 = 0.85$
NSE = 0.80
PBIAS = 1.28
P-factor = 0.80
R-factor = 0.69



Results and Discussions

The findings revealed that above 80% and 40% of the surface runoff and ground water happens throughout the wet season, whereas less than 10% of the surface runoff happens in the dry and short rainy season.

The surface runoff in the wet season was increased by 2.15% from 2019 to 2035 LULC change.

The extraction of forest land, range land, grass land, and agricultural area and urban area expansion highly influence surface runoff, peak flow, and base flow following rainfall events.

The surface runoff will decrease by 1.41% from 2035 to 2050 due to the gradual increase of grass land and range land starting from the year 2035.

Results and Discussions

The reduction in forest land decreases infiltration and evapotranspiration rates, resulting in a decrease of base flow and an increase in impervious surface covers.

The average annual lateral flow of the watershed declined by 2.27%, 5.55%, and 18.24% in 2019, 2035, and 2050 with the baseline scenario (1990).

The monthly peak flows happened in July and August and the maximum monthly discharges occurred in 2050, while the minimum flow occurred in 1990.

Generally, the increase of surface runoff in wet seasons may result in flooding and a decline in the dry season may affect water scheme practices.

Conclusion

The SWAT hydrological model was used to simulate historical and future continuous fluctuations in stream flow through time.

The relation of LULC categories and hydrological components revealed that the surface runoff was highly attributed to change in the agricultural land with a higher correlation coefficient.

The increment of surface runoff and decline of ground water observed during the rainy season may lead to increasing extreme weather events, sedimentation, runoff, siltation, and water shortages may happen during the dry season and obstruct socio-economic development in Ethiopia.

The suitable management policy should be prepared depending on the usually LULC change of the watershed. Additionally, appropriate conservation measures of water and soil are extremely essential and should be flexible and adaptable to changing insights on the impacts.

Thank you for your attention!