# Modelling of Fincha watershed dynamics - Report on SWAT

The Soil and Water Assessment Tool (SWAT) is a widely used, physically-based, river basin-scale model developed by the U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS). It is designed to simulate the impacts of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds. The model was initially developed in the 1990s by Arnold et al. (1995) and has evolved over the years to include more advanced features, enabling its application to a wide range of environmental and hydrological research. SWAT is unique in its ability to simulate long-term processes at both small and large spatial scales. It incorporates data on climate, soils, land use, and management practices to model the hydrological cycle, sediment transport, nutrient cycling, and water quality dynamics. SWAT is capable of integrating these processes in a comprehensive manner, making it particularly useful for assessing the effects of various land use practices, conservation strategies, and climate change on water resources.

The primary purpose of SWAT is to provide tools for the sustainable management of water resources by simulating the effects of land management practices on water quality, water quantity, and other environmental processes over extended periods of time. The model can be applied to a wide range of watershed scales and is commonly used for simulating the hydrological cycle, including surface runoff, groundwater flow, and water storage in a watershed. It also models water quality by simulating sediment transport, nutrient cycling, and the movement of pollutants such as pesticides and fertilizers. SWAT is used to evaluate the impacts of different agricultural practices (e.g., irrigation, tillage, crop rotations) on runoff, sediment erosion, and nutrient loading to water bodies. It helps evaluate how changes in temperature, precipitation patterns, and extreme weather events affect watersheds and water resources. Additionally, SWAT is instrumental in testing and evaluating the effectiveness of various best management practices aimed at improving water quality and reducing soil erosion, such as riparian buffer strips, crop residue management, and conservation tillage.

SWAT has several strengths that make it a powerful tool for environmental modeling and watershed management. These include its comprehensive and flexible framework, which allows for the integration of various hydrological, ecological, and water quality processes. It accounts for physical, chemical, and biological processes in the landscape and water bodies. The model is flexible in terms of spatial and temporal scales and can be applied to watersheds ranging from small catchments to large river basins. One of the key advantages of SWAT is its ability to simulate long-term processes (decades to centuries), making it an ideal tool for studying the cumulative impacts of land management practices and climate change. SWAT can incorporate data from a variety of sources, including field measurements, remote sensing, and weather stations, which is critical for building a realistic representation of the watershed. The model can also integrate outputs from climate models and hydrological data, allowing for future scenarios and decision-making. SWAT has well-established procedures for model calibration and validation, which help improve the accuracy of simulations. Parameters such as curve number, soil properties, and Manning's n are adjusted during the calibration process to match observed hydrological and water quality data (Dibaba et al., 2021; Leta et al., 2023). Due to its flexibility and robust data processing capabilities, SWAT has been successfully applied in various regions worldwide for watershed management, flood risk assessments, water quality monitoring, and agricultural policy development.

Despite its many advantages, SWAT has certain limitations that can impact its performance and application in specific contexts. One limitation is its high data requirements: in fact, SWAT requires a wide range of (detailed) spatial and temporal data, including meteorological, hydrological, soil, and land use data, to build an accurate model. The availability and quality of these data can be a limitation, especially in regions where monitoring networks are sparse or unreliable. The model's accuracy can be compromised if data is not representative of local conditions or if spatial and temporal scales are mismatched. Calibration and validation of SWAT models can also be complex due to the large number of parameters that need to be adjusted. Adequate observed data is often difficult to obtain, particularly for water quality and sediment data, and the accuracy of SWAT predictions heavily depends on the quality of the input data and the calibration process. While SWAT is comprehensive, certain processes are modeled in a simplified manner. For example, the simulation of groundwater flow and subsurface hydrology is often less detailed than surface water modeling, which can limit the model's accuracy in regions with significant groundwater interactions or complex aquifer systems. Furthermore, while SWAT uses physical processes for simulating hydrology, certain processes, such as nutrient cycling, erosion, and vegetation growth are modeled using empirical relationships. These empirical equations are often region-specific and may not capture the true variability of these processes in different environmental conditions, potentially reducing the model's ability to predict outcomes accurately in novel settings or extreme scenarios. Additionally, for large-scale watersheds, running SWAT simulations over long periods can be computationally demanding. The model requires significant processing power and time, especially when multiple scenarios or extensive sensitivity analyses are being conducted. As with any environmental model, SWAT predictions carry inherent uncertainties, particularly when future scenarios, such as climate change, are involved. These uncertainties arise from limitations in input data, model parameterization, and the simplified representation of some physical processes. Therefore, results need to be interpreted with caution, and sensitivity analysis is essential to understand the range of possible outcomes.

**Case study**

The Fincha watershed is located in the Upper Blue Nile Basin, Horro Guduru Walaga Zone, Oromia Regional State, Ethiopia. It is located between latitudes 9°9′53″ N and 10°1′00″ N and longitudes 37°00′25″ E and 37°33′17″ E, at around 300 km from the capital Addis Ababa (Figure 1).

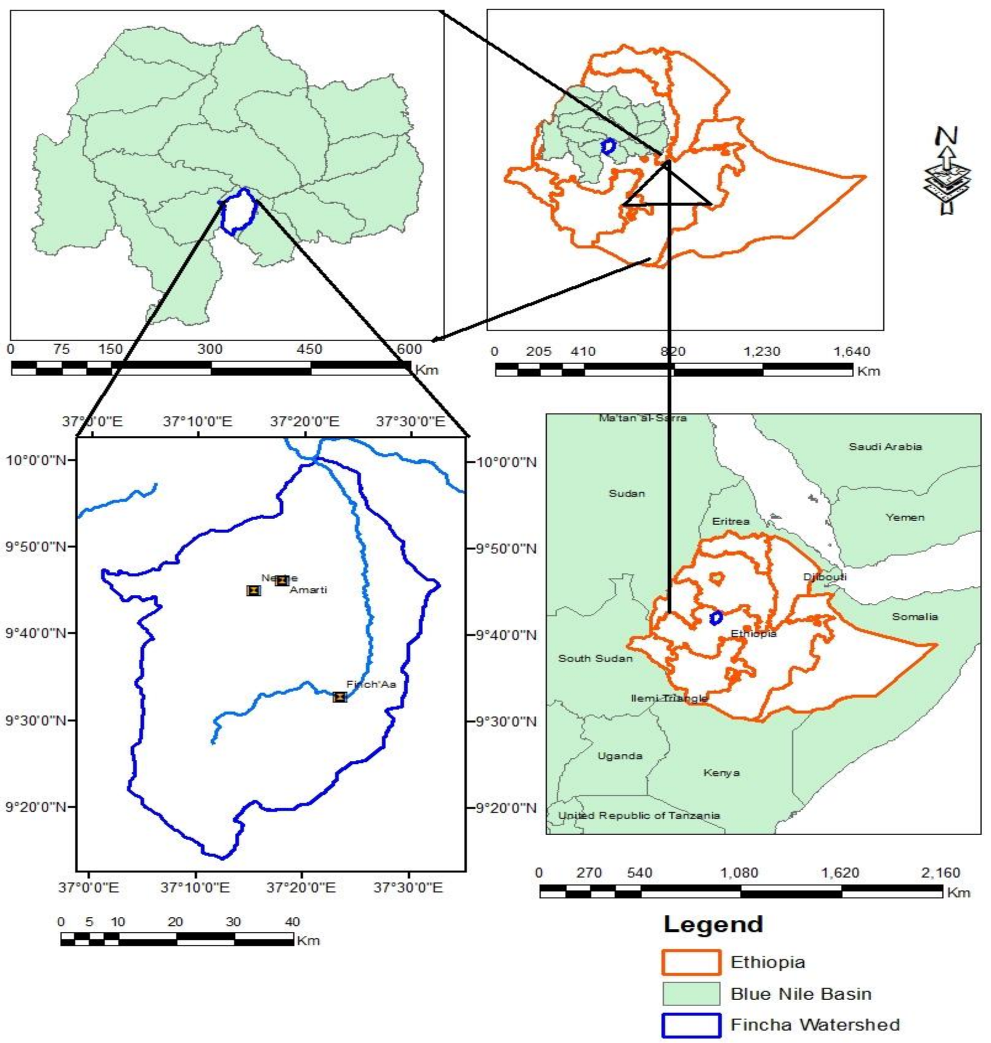


Figure 1. Location of the Fincha watershed, Oromia regional state, Ethiopia.

The region is characterized by four distinct seasons: Summer, from June to August, with heavy rains; Autumn, from September to November, is the harvest season; Winter, from December to February, the dry season characterized by morning frost; Spring, from March to May, very hot and with scattered rains. The annual rainfall ranges from 1367 to 1842 mm, with the Northern lowlands receiving the least rain and the Southern and Western highlands receiving more than 1500 mm per year (Regasa and Nones, 2022). The major rainy season lasts from June through September, with an average of 1604 mm of precipitation, with a maximum in July and August.

The Fincha watershed is of national and international relevance in hydro politics, because of its downstream connection to the Nile River basin and the local heavy agriculture. Natural resources such as the Fincha, Amerti, and Nashe lakes, not only contribute to the national economy by providing hydroelectric power, but are also used to irrigate extensive sugar cane fields (Leta et al., 2021; Regasa and Nones, 2022).

## Data used for the study

### Weather data

The study was conducted using daily weather data recorded over a period from 1986 to 2019. This dataset includes key meteorological variables such as precipitation, maximum and minimum temperatures, solar radiation, wind speed, and relative humidity. The data were collected from ten meteorological stations, namely Alibo, Fincha, Gebete, Hareto, Homi, Jermet, Kombolcha, Nashe, Shambu, and Wayyu. These datasets were provided by the Ethiopian Ministry of Water, Irrigation, and Energy (Regasa and Nones, 2023; Regasa and Nones, 2024).

In instances where data were missing, the statistical software XLSTAT was employed to fill in the gaps and ensure the completeness of the dataset for analysis.

### Soil data

Soil data were pre-processed following the established guidelines and criteria set forth by the Food and Agriculture Organization (FAO) to ensure consistency and reliability in the analysis. The Fincha watershed, located in Ethiopia, is composed of ten distinct soil types, each of which has unique properties that influence both soil erosion rates and hydrological processes within the region. These soil types include Dystric Vertisols, Eutric Cambisols, Eutric Leptosols, Eutric Vertisols, Haplic Alisols, Haplic Arenosols, Haplic Phaeozems, Rhodic Nitisols, Chromic Luvisols, as well as areas classified as Water and Marsh. However, the majority of the watershed is dominated by Haplic Alisols and Eutric Cambisols, which cover the largest areas.

The type and characteristics of soil play a crucial role in both the rate of soil erosion and the hydrological processes in the watershed. Soils with high clay content, such as Vertisols, tend to have higher erosion resistance due to their cohesive nature when wet, though they can be prone to cracking and surface runoff during dry periods. On the other hand, soils like Haplic Alisols and Eutric Cambisols are more susceptible to erosion when exposed to heavy rainfall due to their structure and lower cohesion, leading to greater runoff and soil loss. The permeability of the soil, which determines the infiltration rate and drainage capacity, also influences hydrological processes. Soils with high permeability allow for better water infiltration, reducing surface runoff and, consequently, soil erosion. Conversely, less permeable soils lead to greater surface runoff, increasing the risk of erosion.

In the Fincha watershed, the dominance of Haplic Alisols and Eutric Cambisols means that hydrological dynamics, such as water retention, infiltration, and runoff, are significantly impacted by the physical properties of these soils. The interaction between soil texture, structure, and moisture retention capacity directly affects the water cycle, influencing both the rate of soil erosion and the overall hydrological behavior in the region. Understanding these soil characteristics is critical for managing erosion control measures and optimizing land use in the watershed.

**Land Use Land Cover**

Land use and land cover (LULC) play a significant role in influencing surface runoff, evapotranspiration, soil erosion, nutrient cycling, and pesticide accumulation within a watershed. Changes in land use directly impact the hydrological processes and the rate of soil erosion, as different types of land cover affect water flow, soil stability, and vegetation cover. For this study, Landsat satellite images were used to create a detailed LULC map for the years of 1989, 2004 and 2019, and the watershed was into six land use categories, carefully selected based on prior research, field data, and input from local farmers and specialists. The six classes included in the map were: water bodies, grasslands/swamps, built-up areas, agricultural land, woodlands, and shrub land.

These six land use classes were not only used for the 2019 mapping but also applied to analyze and compare land use conditions from earlier years (1989 and 2004) as well as future projections for the years 2030, 2040, and 2050. This approach allowed for the generation of multiple scenarios to study the effects of land use changes on hydrological and erosion processes over time.

To ensure compatibility with the Soil and Water Assessment Tool (SWAT), a widely used hydrological model, the original LULC classes were reclassified into standard categories recognized by the model. These categories include: water body (WATR), wetland/grassland (WETL), urban areas (URBN), agricultural land (AGRL), forested areas (FRST), and shrub land (FRSE) as indicated in Figure 2 below. This reclassification was necessary because SWAT requires specific designations for accurate modeling of hydrological processes and soil erosion rates.

Land use changes have a direct impact on soil erosion rates and hydrological processes in several ways. For example, agricultural lands often have high erosion rates due to the removal of natural vegetation, which leaves the soil more vulnerable to runoff and loss. In contrast, forests and shrubs provide protective cover that stabilizes the soil and reduces the impact of rainfall on the surface. Built-up areas and urbanization typically increase surface runoff due to the expansion of impervious surfaces such as roads and buildings, which prevent water from infiltrating the soil and exacerbate erosion downstream.

The presence of grasslands and wetlands can play a moderating role by enhancing water retention and infiltration, which reduces surface runoff and mitigates soil erosion. Wetlands, in particular, can help trap sediments, reducing the amount of soil lost to erosion, while also influencing local hydrological cycles by increasing evapotranspiration.

By creating and analyzing these LULC maps for different time periods and future scenarios, the study aims to provide valuable insights into how changes in land use may affect soil erosion, water flow, and overall watershed management. This information is crucial for developing effective land management strategies and erosion control measures that consider both current and future land use trends.

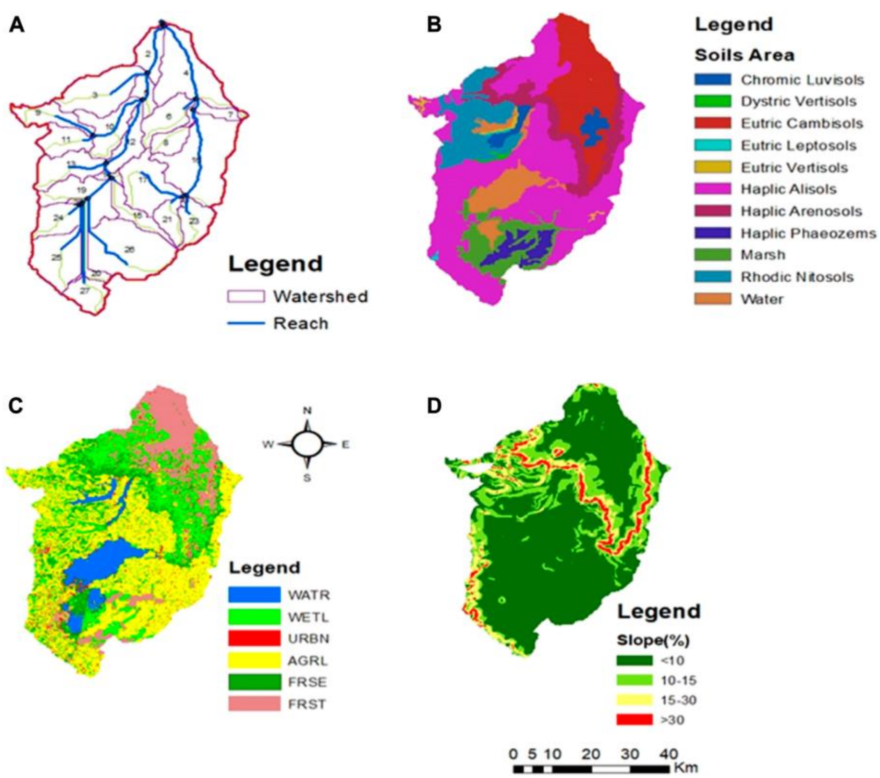


Figure 2: Main characteristics of the study area: (A) river system and sub-watersheds; (B) soil types; (C) Land UseLandCoverof2019; (D) terrain slope (Regasa and Nones, 2023).

**Slope**

Using a 30m x 30m DEM of the Fincha watershed and the Arc-GIS spatial analysis tool, four slope categories were selected: <10%, 15%, 25%, and>30%.These categories are considered representative of the Fincha watershed's topography following the previous studies conducted in the region.

**Key Methods and Equation**

From the SWAT website (swat.tamu.edu), the version of Arc-SWAT 2012.104.19 was downloaded, and its interface was then linked to ArcGIS 10.3.1 for the modeling process. This integration procedure involved setting up a SWAT project and defining the spatial extent of the analysis, which included identifying the watershed, sub-watersheds, and Hydrological Response Units (HRUs) (Arnold et al., 2012; Gassman et al., 2007). Additionally, the process entailed writing and editing the SWAT input files and running the simulations. After collecting all the necessary data, the input data were prepared for use in the model. The watershed was delineated, HRUs were defined, and various classification data, such as land use, soil types, and slope characteristics, were incorporated into the model to provide accurate environmental representations for the simulations.

Through the integration of the water balance equation and the MUSLE (Modified Universal Soil Loss Equation) for estimating soil erosion, SWAT offers a comprehensive framework for managing water and soil resources. The water balance equation forms the basis of hydrological simulations, ensuring accurate predictions of water movement within a watershed (Dibaba et al., 2021; Leta et al., 2023).

The water balance equation used in the study is expressed as:

$$SW_t = SW_o + \sum_{i=1}^{t}(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw})$$

In this equation:

- $SW_t$ represents the final soil water content (millimeters) after the time period ttt,

- $SW_o$ represents the initial soil water content on day iii (millimeters),
- t is the time (in days),
- $R_{day}$ is the amount of precipitation on day iii (in millimeters),
- $Q_{surf}$ represents the surface runoff on day iii (in millimeters),
- $E_a$ is the amount of evapotranspiration on day iii (in millimeters),
- $W_{seep}$ is the amount of water entering the vadose zone (the unsaturated zone of the soil profile) on day iii (in millimeters),
- $Q_{gw}$ is the return flow from groundwater on day iii (in millimeters).

This equation serves as the foundation for simulating the hydrological processes, and it enables the estimation of how water is stored, transported, and used across the landscape. It provides a detailed mechanism for calculating soil moisture, runoff, and other components of the water cycle.

The MUSLE, on the other hand, provides essential insights into the potential for soil erosion, helping to inform soil conservation strategies. Together, these equations enable the model to address environmental concerns and promote sustainable land use practices in diverse contexts, from agricultural settings to urban watersheds.

$$Sed = 11.8(Q_{surf} * q_{peak} * Area_{HRU})^{0.56} * K * C * P * LS * CFRG$$

where *Sed* is sediment yield in metric tons per day, $Q_{surf}$ is the surface runoff volume (mm), $q_{peak}$ is the peak run-off rate ($m^3$/s), $Area_{HRU}$ is the area of HRU (ha), *K* is the soil erodibility factor, *C* is the cover and management factor, *P* is the practice support factor, LS is topographic factor and *CFRG* is the course fragment factor.

**Sensitivity Analysis, Calibration and Validation in Hydrological Modeling**

A sensitivity analysis is a technique used to assess how different input parameters affect the output of a model. In the context of hydrological modeling (in this case, the SWAT model), sensitivity analysis is critical to understanding how well the model can predict real-world phenomena, such as water stream flow and sediment yield.

Water stream flow refers to the amount of water flowing through a river, stream, or watershed, typically measured in cubic meters per second ($m^3/s$) or liters per second (L/s).

Sediment yield refers to the amount of sediment (such as silt, sand, and clay) that is transported by water from the landscape into streams or rivers. This is usually expressed in tons per hectare per year (t/ha/yr).

The sensitivity analysis, therefore, helps in understanding how well the SWAT model can simulate these two important components water flow and sediment transport by varying input parameters and comparing the simulated results to actual observed data.

**SWAT Model and SWAT-CUP Interface**

SWAT relies on various parameters that need to be calibrated for accurate predictions.

To properly calibrate and validate the SWAT model, it's essential to perform a sensitivity analysis; this is where SWAT-CUP (SWAT Calibration and Uncertainty Procedures) comes in. SWAT-CUP is a software interface designed to assist with the calibration, uncertainty analysis, and sensitivity analysis of the SWAT model (Van Griensven et al., 2006; Van Griensven and Meixner, 2009). It helps identify which parameters have the most significant influence on the model's output and provides insights into how well the model's predictions align with observed data.

**SUFI-2 Approach**

To perform the sensitivity analysis, the SUFI-2 approach (Sequential Uncertainty Fitting version 2) was used. SUFI-2 is a method for uncertainty analysis that estimates the uncertainty in model outputs (such as streamflow or sediment yield) based on uncertain input parameters. This technique is used within SWAT-CUP to generate parameter sets that best match observed data while accounting for uncertainty in those parameters.

The SUFI-2 approach generates a range of model predictions by varying parameters within their uncertainty bounds. These predictions are then compared with observed data to see how well the model can match real-world measurements.

**Selection of Parameters for Sensitivity Analysis**

In this study, the sensitivity analysis focused on parameters connected to sediment processes and streamflow. According to the text, seven parameters related to sediment processes and nine parameters related to streamflow were chosen for calibration. These parameters influence how water flows through the landscape and how sediment is transported within the watershed.

Sediment-related parameters might include factors such as soil erodibility, sediment transport capacity, or the effectiveness of conservation measures in reducing erosion. In line with the following seven parameters were selected for sensitivity analysis. These are; Exponential factor for channel sediment routing (R_SPEXP.bsn), Sediment concentration in lateral and ground water flow (R_LAT_SED.hru), Channel cover factor (R_CH_COV2.rte), Linear factor for channel sediment routing (R_SPCON.bsn), Channel erodibility factor (R_CH_COV1.rte), Peak rate adjustment factor for sediment routing in the sub-basin (tributary channels) (R_PSP.bsn) and USLE support Practice factor (R_USLE_P.mgt).

Streamflow-related parameters might include rainfall, land use, soil infiltration capacity, or parameters related to river routing and storage.

The selection of these parameters was based on literature evidence, meaning they were chosen based on previous studies (e.g., Dibaba et al., 2021; Leta et al., 2023) that identified which parameters are most critical in simulating water flow and sediment transport accurately in similar contexts. Accordingly the following nine parameters where selected; Ground water delay (V_GW_DELAY.gw) [days], runoff curve number II (R_CN2.mgt SCS), Threshold depth of water in the shallow aquifer required for return flow to occur (V_GWQMN.gw) [mm H2O], Manning's "n" value for the main channel (R_CH_N2.rte), Available water capacity of the 1st soil layer (R_SOL_AWC (1).sol ) [mmH2Ommsoil$^{-1}$], Saturated hydraulic conductivity at the1st soil layer (R_SOL_K (1).sol) [mmh−1], Average slope length (R_SLSUBBSN.hru) [m], Deep aquifer percolation fraction (R_RCHRG_DP.gw) and Base flow alpha factor (V_ALPHA_BF.gw) [day$^{-1}$].

**Data and Time Periods for Calibration and Validation**

For the sensitivity analysis, calibration, and validation, observed data for water discharge and sediment load were used. These data were measured at the outlet of the Fincha Reservoir, located at the Fincha Dam, during the period 1986-2008.

- ✓ Calibration refers to adjusting the model parameters to match the observed data as closely as possible.
- ✓ Validation is the process of testing the calibrated model against a different set of observed data (usually from another time period) to see if it can predict future or unseen events accurately.

Most of the studies performed using SWAT divided stream flow and sediment data for calibration and validation equally. However, according to the study conducted by Arnold et al. (2012), in the case of watersheds characterized by a scarcity of data, most of them should be used for calibration, while a minor part of the data is for validation. As an example, Ait M'Barek etal. (2023) used 75% of hydrological data for calibration and 25%for validation. As the Fincha watershed is also characterized by data scarcity, a similar approach was followed, using the observed monthly stream flow and sediment at the Fincha reservoir close to the Fincha Dam outlet from1986 to 2008.

To ensure the model had time to stabilize and avoid overfitting to initial data, the period was split into three phases:

- ✓ Warm-up period (1986–1988): This initial period allows the model to "settle" and adjust to the hydrological conditions of the watershed, ensuring that any initial imbalances or biases in the model don't affect the calibration phase.

- ✓ Calibration period (1989–2002): In this period, the model was fine-tuned using observed streamflow and sediment data. The calibration process involves adjusting the model's parameters so that the model outputs (such as streamflow and sediment yield) match the observed values as closely as possible.
- ✓ Validation period (2003–2008): After calibration, the model's performance was tested against data from this period to check whether the model could accurately predict streamflow and sediment load under different conditions.

**Performance Metrics**

Once the model was calibrated and validated, its performance was assessed using several statistical measures to determine how well the simulated results compared with the observed data. The three most common performance metrics used in hydrological modeling are:

- ✓ Coefficient of Determination ($R^2$): This statistic measures how well the observed data and the model's simulated data correlate. An $R^2$ value close to 1 indicates a good fit between the simulated and observed data, meaning the model explains most of the variance in the data.

$$R^2 = \left[\frac{\sum_{i=1}^{n}(Q_{Obs}-\bar{Q}_{Obs})(Q_{cal}-\bar{Q}_{Cal}}{\sum_{i=1}^{n}(Q_{Obs}-\bar{Q}_{Obs})^2\sum_{i=1}^{n}(Q_{Cal}-\bar{Q}_{Cal})^2}\right]^2$$

Where $Q_{Obs}$ is a variable of an actual data, $\bar{Q}_{\mathrm{Obs}}$ is a variable of an average actual data, $Q_{\mathrm{Cal}}$ is a variable of simulation result and, $\bar{Q}_{\mathrm{Cal}}$ variable of average simulation result.

- ✓ Nash-Sutcliffe Simulation Efficiency (NSE): The NSE is a more advanced metric that evaluates the model's performance by comparing the variance of the observed data and the simulated data (Leta et al., 2023). The closer the NSE value is to 1, the better the model's ability to predict the observed data. An NSE value less than 0 indicate that the model is performing worse than a simple mean-based prediction.

$$NSE = 1 - \frac{\sum_{i=1}^{n}(Q_{Obs} - Q_{Cal})^2}{\sum_{i=1}^{n}(Q_{Obs} - \bar{Q}_{Obs})^2}$$

- ✓ Percent Bias (PBIAS): This metric assesses the overall bias in the model's predictions. A PBIAS close to 0 indicates that the model's predictions are very close to the observed data. A positive value indicates under-prediction, and a negative value indicates over-prediction. The goal is to minimize PBIAS, as it reflects the degree to which the model over- or under-predicts the observed quantities.

$$PBIAS = \frac{\sum_{i=1}^{n}(Q_{Obs} - Q_{Calc}) * 100}{\sum_{i=1}^{n} Q_{Obs}}$$

Multiple investigations have demonstrated that the Arc SWAT (Soil and Water Assessment Tool) model is a valuable tool for identifying Best Management Practices (BMPs) in a watershed, as well as for evaluating their effectiveness in terms of implementation. BMPs refer to practices that aim to improve land and water management, particularly in terms of reducing soil erosion, improving water quality, and sustaining agricultural productivity.

Table 1. Monthly stream flow during the calibration (1989-2002) and validation (2003-2008) periods.

| Statistical test | $R^2$ | NSE | PBIAS |
|---|---|---|---|
| Calibration | 0.83 | 0.83 | 8.3 |
| Validation | 0.84 | 0.76 | 12.2 |

**Evaluation of Best Management Practices**

Regasa and Nones (2024) emphasized that selecting appropriate BMPs and their associated parameters must take into account regional land use trends. The effectiveness of these practices can vary significantly depending on the local environmental conditions and land use patterns. Additionally, it is important that the selection of BMPs incorporates both modern scientific approaches and traditional knowledge. In the case of the Ethiopian highlands, for example, traditional conservation methods aimed at protecting land and water resources should be considered and integrated with modern techniques. This holistic approach ensures that the management practices are not only scientifically sound but also culturally relevant and adaptable to local conditions.

For the current study, four specific BMPs were considered:

- ✓ Filter strip: A vegetated area planted along the edges of fields, intended to trap sediment and filter runoff water.
- ✓ Contour farming: The practice of tilling and planting crops along the contours of a slope, which helps to prevent soil erosion.
- ✓ Soil or stone bunds: Small embankments or barriers built along the land to reduce soil erosion and water runoff.
- ✓ Terracing: The creation of stepped levels on sloped land, designed to reduce water runoff and soil erosion.

These BMPs were modeled in the SWAT framework by adjusting specific parameters to assess their effects on sediment yield. The primary aim was to understand how each practice could reduce soil erosion and runoff in different sub-watersheds over time.

As shown in previous studies, management strategies, such as the implementation of BMPs, can be simulated within the SWAT model by altering various input parameters. These include:

- ✓ Curve Number (CN2): This parameter represents the land surface's ability to absorb rainfall and its potential for runoff. It is influenced by land use, soil type, and hydrological conditions.
- ✓ Slope Length (SLSUBBSN): Affects the flow of water on the land and the rate at which water and sediment move down the slope.
- ✓ Slope Steepness (HRU_SLP): Determines the degree of slope in a given area, which is important for estimating runoff and erosion potential.
- ✓ Erosion Control Practice Factor (USLE_P): This factor accounts for the impact of erosion control practices on the reduction of soil erosion. Higher values indicate reduced erosion control effectiveness.
- ✓ Filter Strip Width (FILTERW): Represents the width of vegetated strips used to filter runoff water and trap sediment.

For the purposes of this study, these BMPs were applied to Land Use/Land Cover (LULC) maps for the years 2019, 2030, 2040, and 2050. These time points were selected to evaluate how the application of BMPs might affect sediment yield across different sub-watersheds over time. By comparing these results with a baseline scenario (a situation without management interventions), the study aimed to assess the impact of each BMP on soil erosion reduction.

Generally, this study uses the SWAT model to evaluate the effectiveness of four BMPs; filter strips, contour farming, soil or stone bunds, and terracing in reducing sediment yield and soil erosion in a watershed. It adopts a systematic approach, applying these practices to different LULC maps over multiple years (2019, 2030, 2040, and 2050) to assess their impact on erosion control. By comparing the results of these BMP scenarios with a baseline scenario, the study aims to provide insights into the potential benefits of implementing these conservation practices in the Ethiopian highlands. Furthermore, it emphasizes the importance of integrating both traditional knowledge and modern techniques for sustainable land and water management. Here is some result of the selected best managements.

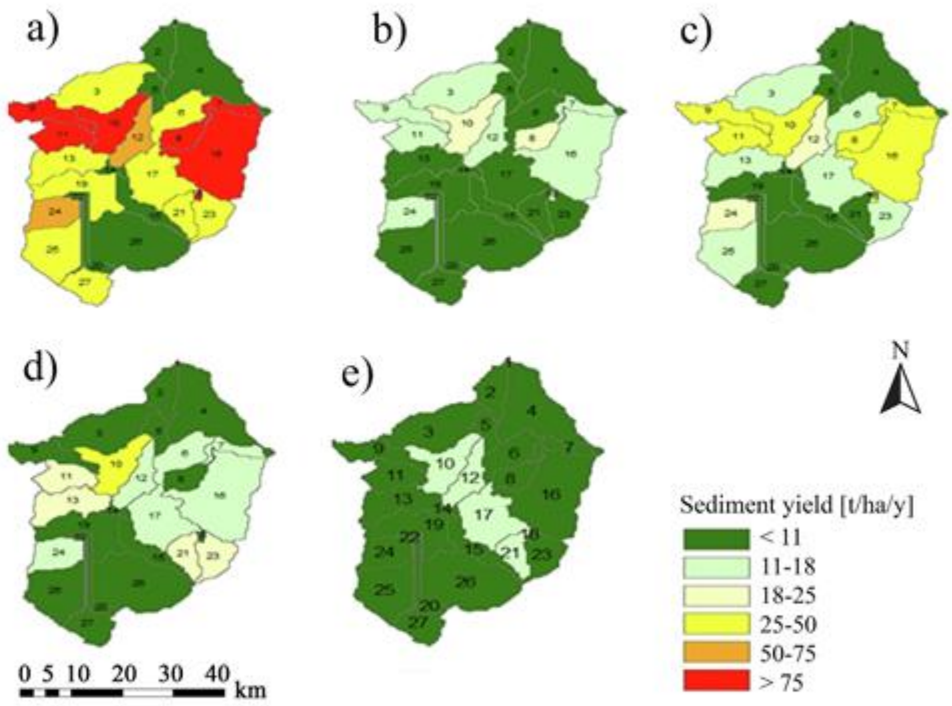


Figure 3. Sub-watershed sediment yield in 2019. Maps referring to (a) baseline; (b) contour farming; (c) filter strips; (d) soil or stone bunds; (e) terracing scenarios

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