Model overview/Introduction:

Soil and Water Assessment Tool (SWAT) model is a continuous-time, semi distributed, process based river basin or watershed scale model developed by Dr. Jeff Arnold for United States Department of Agriculture, Agricultural Research Service (USDA, ARS) (Arnold et al., 2012; Arnold et al., 1998). SWAT is developed to predict the impact of land management practice on water, sediment and agricultural chemical yields on large watersheds with varying soils, land use and management practices over long periods of time (Neitsch et al., 2009). SWAT has been used worldwide for the intended purpose. The current SWAT2009 code incorporates all of the component used in previous model, pre- and post-processing software tools, including widely used ArcGIS SWAT (ArcSWAT) GIS interface (Olivera et al., 2006). Extensive documentation and peer reviewed journal are available for use of SWAT at (http://swat.tamu.edu/). However, the model is not intended to simulate detailed single event flood routing model.

Historical development and application:
The development of SWAT is continuation of USDA Agricultural Research Service (ARS) modeling experience since 1980. Beginning of SWAT was founded in 1980 as mentioned by (Gassman et al., 2007) and base for the SWAT model were Ground water loading effect on agricultural management systems (GLEAMS), chemicals, runoff, and erosion from agricultural land (CREAM), and environmental impact policy climate (EPIC). According to a review of history of SWAT development by (Gassman et al., 2007), SWAT is the combination of simulator for water resources in rural basins (SWRRB) model (Arnold and Williams, 1987) and routing output to outlet (ROTO) to overcome the flaws and awkwardness of both model but retaining all the features of both models at the same time. SWAT has undergone continued review and expansion since it was developed in 1990s and detailed theoretical documents (Neitsch et al., 2009) and user’s manual (Neitsch et al., 2000) are available to give theoretical background and guide to the users. SWAT model is generally used to predict the long term impacts in large basins of agricultural land managements and timing of agricultural practice within a year. However, it is also used to assess the environmental efficiency of best management practice (BMP) and alternative management policies for large watershed.

Basics/Description of model:
For modeling purpose in SWAT, watershed is divided into number of sub watershed or sub-basins. Input information for each sub basin is grouped into following categories: climate; hydrologic unit response units (HRUs), ponds/wetlands; groundwater, and main channel. HRUs are lumped land areas within the sub basin that are comprised of unique land cover, soil, and management combinations. SWAT model operates on a daily time step for each hydrologic unit based on water balance equation Eqn(1). Simulation of hydrology or hydrologic cycle is divided into two phases: land phase and water or routing phases. Land phases controls the loading of amount of water, sediment and nutrients and second phase defines the movement of water, sediments, and nutrients through the channel of the HRUs or watershed outlets. The hydrologic cycle simulated by SWAT is based on the water balance equation as below (on daily basis):

\[ SW_t = SW_0 + \sum R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw} \]

Eqn(1)
Where,

\( SW_t \) and \( SW_0 \) is final soil water content and initial water content, \( t \) is the time in day, \( R_{\text{day}} \) is the amount of rainfall, \( Q_{\text{surf}} \) is amount of surface runoff/discharge, \( E_a \) is amount of evapotranspiration (ET), \( W_{\text{seep}} \) is amount of water entering Vadose zone, and \( Q_{\text{gw}} \) is amount of return flow (all component in day i).

Several other inputs are required to calculate the components mentioned on Eqn( 1). Reader are directed to refer the document (Neitsch et al., 2009) and (Neitsch et al., 2000). Key process and algorithm used in SWAT are as follows:

- **Climate**: Weather generator WXGEN or user’s input
- **Hydrology**: Canopy interception, runoff (SCS curve number, infiltration (Green-Ampt), Evapotranspiration (Penman-Monteith, Priestley-Taylor, or Hargreaves Samani)
- **Land Cover/Plant growth**: MRLC,NLCD or user define, water and nutrient uptake, crop and plant growth database
- **Erosion**: MUSLE using peak runoff rate
- **Nutrient**: Nitrogen and phosphorus cycle
- **Agricultural management**: planting, tillage, irrigation, fertilization, pesticide management, grazing, and harvesting. SWAT also handles auto fertilization and auto irrigation.
- Urban management: Build up and wash off approach
- Routing: Variable routing or Muskingum routing methods
- Sediment Transport: Based on stream flow and various equation are used to calculate sediment concentration and sediment transport

**Model inputs details:**

Major model components include: weather, hydrology, soil temperature and properties, plant growth, nutrients, pesticides, bacteria and pathogens, and land management. Weather inputs used in SWAT include daily precipitation, maximum and minimum temperature, solar radiation data, relative humidity, and wind speed data, which can be input from measured records and/or generated. Three alternatives for ET estimation; namely Priestly-Taylor, Hargreaves Samani and Penman-Monteith are available in the model. Likewise, three options exist in SWAT for estimating surface runoff from HRUs, which are combinations of daily or sub-hourly rainfall and the USDA Natural Resources Conservation Service (NRCS) curve number (CN) method (USDA-NRCS, 2004) or the Green-Ampt method.

The overall hydrologic balance is simulated for each HRU, including canopy interception of precipitation, partitioning of precipitation, snowmelt water, and irrigation water between surface runoff and infiltration, redistribution of water within the soil profile, and evapotranspiration. In short following inputs are required to run the model within the watershed or basin.

- Land uses (Potential source: MRLC and others)
- Soil (Potential source: SSURGO and others)
- Sub watersheds (Potential source: Derived manually or Digital Elevation Model based)
- Point source (Potential source: EPA database)
- Climate data (Potential source: NOAA COOP stations for daily temperature, precipitation, solar radiation, and wind speed or any other measured data)
- Crop and management databases (Database from farm)
- Flow data (Potential source: USGS flow data for calibration)
- Long-term watershed quality data (Potential source: USGS for model calibration)

**Model output and applications:**

Model can provide output for basin, HRUs and reaches. Model output summary file provides watershed average loadings from the HRUs to the stream. HRU output file contains summary information for each of the HRUs in the watershed. Basin output file is the total amount of weighted average of all HRUs within the basin. The main channel output file contains the summary information for each routing reach in the watershed. These outputs are analyzed and used to predict the impact of land management practices to study on

- Hydrology
- Nonpoint source pollution
Model assumption limitations and strengths (Neitsch et al., 2009):

Assumptions:
- SCS CN approach (Green-Ampt approach for infiltration was also implemented but requires hourly data) and MUSLE are appropriate for the area being modeled
- Flows in streams and reservoirs are one-dimensional

Limitations:
- Not intended for single storm event
- Only for simulating conservative metal species from the point source input
- Only route one pesticide each time through the stream network
- Cannot specify actual areas to apply fertilizers
- A large watershed can be divided into hundreds of HRUs which might be difficult to manage

Strengths:
- Physically based
- Well documented
- Can be used on GIS interface
- Most of the input data are easily available

Reference:


http://swat.tamu.edu/. Soil and Water Assessment Tool (SWAT).
