

# Guide for Hydrological Modeling using QSWAT

# PARADeS – Open Education Resource



Prepared by

# Dr. Joshua Ntajal

Ecohydrology and Water Resource Management Department of Geography, University of Bonn

### Prof. Dr. Mariele Evers

**PARADeS Project Director** Head of the Research Group: Ecohydrology and Water Resource Management Department of Geography, University of Bonn Email: mariele.evers@uni-bonn.de

November 2023





# **Table of Content**

1.	l.	ntroduction	2
	1.1	The objectives and expectations from this training module	2
	1.2	Hydrological model	.2
	1.3	The SWAT model	2
	1.4	Summary of SWAT hydrological modeling processes	3
2.	S	Setting the mode using QSWAT tool	3
	2.1	Computer/technical requirements	3
	2.2	Installation of QGIS and QSWAT	4
	2.3	Input data requirement and organization	.5
3.	C	Creating a new SWAT hydrological model	.5
	3.1	Create a new project	.5
	3.2	Delineate Watershed	6
	3.3	Create the Hydrological Response Units (HRUs)	6
	3.4	Editing Input Files and Running SWAT	.8
	3.5	Visualize model result or outputs	16
4.	A	Appendix 1	19
5.	F	Reference and links to additional support	22



# 1. Introduction

# 1.1 The objectives and expectations from this training module

The objective of this module is to provide the potential audience with the basic skills and system steps for building a hydrological modeling, using the QSWAT tool. This training material is part of the aims of the PARADeS project to develop Open Education Resources for human capacity building, increase public awareness of flood disaster risks, and provide training materials on flood disaster management, using results and examples from project outcomes in Ghana. Overall, the OER serves as a valuable resource for learning about flood-related topics and research outcomes, while promoting knowledge exchange and awareness within both scientific and non-scientific communities. The White Volta River catchment in Ghana and Burkina Faso, West Africa, is used as an example.

#### What is the motivating factor to use this training material?

After going through this training module on hydrological modeling, the user is expected to gain knowledge and basic experience on building a hydrological model with QSWAT, its usefulness in flood and water resources management, and basic skills in model calibration and validation. This can then be a foundation for building advanced hydrological models for even more complex and large river catchments in any part of the globe and at varying scales.

# 1.2 Hydrological model

Hydrological models represent or simplify the complex interactions and movement of water within the water cycle of a watershed. It provides coordinated guidance for water resource management, river runoff, and flood forecasts based on return periods of river flow (observed and simulated) under climate change and land use scenarios (Marshall, 2014). Numerous Hydrologic models exist and have been widely adapted based on the expected outcome or the purpose of the modeling and the spatial conditions or scale of the catchment. The PARADeS project adopted the SWAT hydrologic model, due to its suitability for relatively large and data-scared catchments, such as the White Volta.

# 1.3 SWAT model

SWAT is a computer simulation hydrologic model, which uses the water-balanced approach or equation and has been widely applied in data-scared catchments. The Soil and Water Assessment Tool (SWAT) is a widely used hydrologic model for simulating the complex processes of the hydrologic cycle at the watershed scale. The SWAT model is a powerful tool for studying watershed-scale hydrology, land use planning, and water resource management. It allows for the assessment of various scenarios and the development of strategies to address water-related challenges and flood forecasting in a watershed. The SWAT model is integrated into GIS software (ArcGIS and QGIS) as a plugin to delineate watersheds, run simulations, and optimize the visualization of model outputs.

The input data for the SWAT model broadly include a digital elevation model (DEM), soil data, climate data, and land use. In catchments where dams or reservoirs exist, the dam management parameters are required as part of input data. The simulated results can be calibrated, using SWAT-CUP software. However, the calibration process requires observed data (e.g., river discharge data at either daily, monthly, or annual scale) using measured river discharge data with catchment-specific parameter ranges as input data. As part of the training materials, some basic data sets such as the DEM, soil, daily rainfall, and minimum and maximum temperature, and land use data for the White Volta catchment have been provided to be used as input data to set up the model and run the simulations.





## 1.4 Summary of SWAT hydrological modeling processes

- 1. Data preparation: Gather necessary data for the watershed, including topographic data (elevation, slope, aspect), land use/land cover, soil properties, climate data (precipitation, temperature, wind, solar radiation), and streamflow measurements. The historical climate data can be (e.g., daily precipitation, daily minimum and maximum temperature). SWAT requires daily weather data for simulation. Ensure that the data are in the required format and spatial resolution for the SWAT model. Climate data can be prepared, using SWAT Weather Generator
- 2. Watershed Delineation: Define the boundaries of the watershed of interest using digital elevation models (DEMs) and GIS software.
- **3.** Creation of Hydrological Response Units (HRUs): Assigning land use and soil properties to each sub-basin based on their similarities. SWAT categorizes land use into various classes and soils into different soil types, each with specific hydrological properties.
- 4. Hydrologic Simulation: Set up the SWAT model by specifying input data, parameters, and model options. Run the SWAT model for specific time periods (e.g., annually, or monthly time steps) using the prepared input data. Depending on your objective and data availability, the SWAT model has the capability to simulate various hydrologic processes, including precipitation, runoff, infiltration, evapotranspiration, and groundwater flow.
- 5. Running SWAT check and visualization of model outputs: once the model simulation is complete, you can run SWAT check to see the water balance ratios of your model before you proceed to save your simulations output such as the *output.rch, output.hru, res,* or *output.sub*. After saving the simulation, you can then proceed to visualization of results.
- **6. Calibration:** calibrate the model by adjusting various parameters to match observed streamflow and other hydrologic data.
- **7.** Validation: validate the model's performance by comparing simulated results to independent datasets for different time periods.
- **8. Output Analysis:** Analyze the model outputs, which may include streamflow, groundwater recharge, sediment yield, and nutrient loads.
- **9.** Evaluate the impact of land use and land management scenarios on water resources, using scenarios: use the calibrated model to simulate different land use and management and climate change scenarios to assess their effects on the watershed's hydrology. Summarize the results and findings of the hydrologic modeling study in a clear and understandable manner, and communicate the findings to stakeholders, policymakers, and the public. This step is crucial for decision-making and water resource management, land-use planning, and flood risk management.
- **10.** Model Maintenance and Updating: continue to monitor and collect new data to keep the model up to date. Periodically re-calibrate and re-validate the model as conditions change.

# 2. Setting the model using QSWAT

# 2.1 Computer/technical requirements

For your personal computer requirements, you can the important and updated requirements on the SWAT webpage (https://swat.tamu.edu/software/qswat/). Regarding the software requirements, you need not older software versions stated below:

- Microsoft Windows (32 or 64 bits) with free hard drive space of not less than 125 GB
- Microsoft .Net Framework 3.5
- Adobe Acrobat Reader version 7 or higher (<u>Download Adobe Acrobat Reader: Free PDF viewer</u>)
- You also need to download and install (<u>Microsoft Access Data Engine Redistributable 2016</u>) Remember to choose *accessdatabaseengine\_X64.exe* if your PC is 64 bits. Otherwise, choose 32 bits version
- QGIS 3.16 or newer version such as 3.22. These are the long-term release versions





- SWAT Editor 2012
- QSWAT3\_9 (or QSWAT3 the older version. Check the suitable version for Microsoft Operating system) (See Figure 1)
- SWAT Check 1.2.0.10
- You can download all the required software for QSWAT listed above from the main webpage: <u>QSWAT |</u> <u>SWAT | Soil & Water Assessment Tool (tamu.edu)</u>

# **QSWAT**

QSWAT is a QGIS interface for SWAT. Join the QSWAT Google group to interact with other members of the community. Download QSWAT3 v1.6.5 for QGIS3 (30 August 2023).

Download QSWAT3_64	Download QSWAT3_9						
Download the user manual 🗈	Download QSWAT3 32-bit						
Figure 1. Interface of the QSWAT download site							

## 2.2 Installation of QGIS and QSWAT

In the case of this training exercise, we are installing QGIS 3.22 and QSWAT3\_9 version because the computer used for building this training material is 64 bits.

After the installation, open QGIS and check for QSWAT plugin. On the QGIS menu bar, go to plugin and click on *Manage and Install Plugins*. Click on *"Installed"* and check the *QSWAT3\_9* (figure 2)

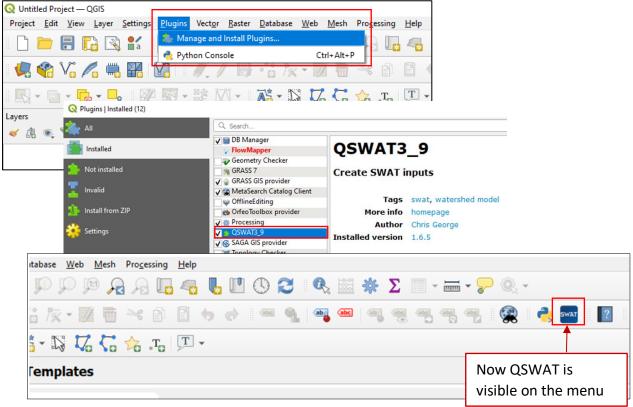


Figure 2. Activation of QSWAT plugin after installation





## 2.3 Input data requirement and organization

- 1. SWAT hydrological model requires (for this training, the input data has been provided for free)
  - DEM (grid or .tiff)
  - o Soil (grid)
  - Climate data (daily rainfall, minimum and maximum temperature) (prepare with weather generator "WGEN")
  - o land use data (raster format)
  - River outlet point (shapefile)

Please note that all the input data must have the same projections. For example, for Ghana it is **WGS84 / UTM 30 N** 

- 2. To start building a SWAT model, the input data must be prepared and organized into a single a folder, where you can easily gain access.
- 3. For help on how to prepare the input data, you may need support from various sources, including (the links and additional materials in the references section on Page 22).

# 3. Creating a new SWAT hydrological model

### 3.1 Create a new project

Click the SWAT icon (Labelled **#1**) in the toolbar (Figure 3). This will open a new window where you can either create a new project or select an existing project (in our case, we will create a new project). Click on *New Project* and name it as *"SWAT\_Volta"* and save it in your working directory (the folder you created for the input data). After saving the project in the working directory, the next steps in "Select Project" frame will be activated. You will notice that Step 1 (**#2**) is now active and other two are still inactive.

Also, you will see location of your working directory in the bottom left corner.

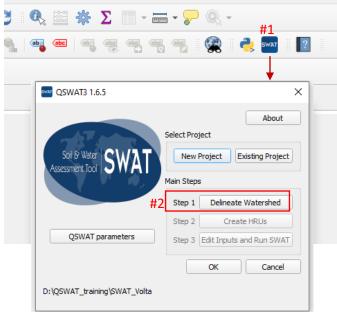


Figure 3. Creating a new SWAT project





## 3.2 Delineate Watershed

To delineate watershed, go to *Step 2* and click on *Delineate Watershed*. A new window will open for you to import the *DEM* **(#1)**. Next, we need to define threshold by specifying the number of cells (e.g., 470) (**#2**). Click on *create streams* **(#3)**.

Note! when you get warnings or messages related to firewall access, simply cancel those messages for the program to proceed

After creating the stream networks, the next step is creating the stream outlet to set the boundary of the catchment. In our case, the stream outlet points are provided so all you need is to import it to assist you locate the outlet. Click on *Draw inlets/outlets* (#4). Zoom in to the outlet as much as possible to a place where you want to place the outlet point. Now, click on outlets (#5) and move to the map and place your outlet. Return to inlet/outlet window and press **OK**.

Q Delineate Watershed -	
Select DEM D:\QSWAT_training\SWAT_Volta\Source\DEM.tif	#1 ····
✓ Use an inlets/outlets shapefile         D:/QSWAT_training/SWAT_Volta/Watershed/Shapes\drawoutlets_sel.shp         #4 Draw inlets/outlets       Select inlets/outlets       2 selected         Snap threshold (metres)       300       #6       Review snapped       #7       2 snapped       #8	#3         reate streams            #9         te watershed
Merge subbasins Select subbasins Add reservoirs and point sources Select reservoir subbasins Add point source to each subbasin           8 <ul> <li>Number of processes</li> <li>Show Taudem output</li> <li>OK</li> </ul>	Merge Add Cancel

Figure 4. Steps for delineating watershed

When the outlet you have created is placed far from the main streamline, you can click on *Snap threshold* (meters). The default value is 300 meters (#6). You can change it if appropriate. Click on Review *Snapped* (#7). A message "2 snapped" (#8) will show. Now go ahead and click on "Create watershed" (#9). Depending on the speed of your computer, it may take about 5 to 10 or more to create the watershed. Once the watershed is created, click on Ok (#10) to complete process under step 2.

# 3.3 Create the Hydrological Response Units (HRUs)

After the *Step 1* is completed, the *Step 2* will be activated for the creation of the HRUs. Land use, soil, and slope data are required to create the HRUs.





QSWAT3 1.6.5			×		
-57	Select Proje	ect	About		
Soil & Weter SWAT	New Project Existing Project				
	Done	Vatershed			
	Step 2	Create	HRUs		
QSWAT parameters	Step 3	Edit Inputs an	d Run SWAT		
		ок	Cancel		
D:\QSWAT_training\SWAT_Volta					

Figure 5. Step 2 frame is now activated for creating HRUs

Now click on *Create HRUs* (Figure 5), and a new window will open (Figure 6). Choosing land use **(#1)** and for the landuse table, select *csv file* **(#2)**. This will allow you to select the *landuse* table in the next steps. Next, select *soil map* **(#3)** and import the soil map provided (select the *hdr.adf* file). For the *Soil data section* click on *usersoil* **(#4)**, if not already selected by default. Next, for the *Soil Table* **(#5)**, select *usersoil* and load soil data. This allows SWAT to communicate with the *usersoil* integrated in the database (*QSWATRef2012*).

Create HRUs		– 🗆 X						
Select landuse map								
D:\QSWAT_training\SWAT_V	D:\QSWAT_training\SWAT_Volta\Source\crop\LULC2020_Res.tif							
		Landuse table landuse_lookup1 • #2						
Select soil map								
D:\QSWAT_training\SWAT_V	/olta\Source\soil\soil\hdr.adf	#3						
Soil data								
#4 ● usersoil ○ STAT	SGO O SSURGO/STATSGO2	Soil table soil_lookup  #5						
		J #5						
Generate FullHRUs Rea	d choice	#8 Read						
- shapefile	Read from maps							
0	Read from	Full HRUs count: 5951						
	previous run							
Set bands for slope (%)	Single/Multiple HRUs	#10 Set landuse, soil, slope thresholds						
#6 Insert #7	Opminant landuse,							
Clear	Dominant HRU	0 Landuse (%) 33 10						
Slope bands	• Filter by landuse, #9	Go #11						
80, 35, 40, 45, 50, 9999]	<ul> <li>soil, slope</li> </ul>	0 Soil (%) 26 10						
Optional	<ul> <li>Filter by area</li> </ul>							
Split landuses	<ul> <li>Target number of HRUs</li> </ul>	Go						
	Threshold method	0 Slope (%) 56 10						
Exempt landuses	Percent of subbasin	<u> </u>						
Elevation bands	🔿 Area (Ha)							
	#12 Create HRU	ls Cancel						
	<u></u>							

Figure 6. Illustration for creating HRUs





The next step is to define the slope (in %). Go to *Set bands for slope* and enter values (5, 10, 15, 20, 25, etc.) in the box **(#6).** You must enter the slope values one after the other. Once you enter e.g., 5, you must click on *Insert* **(#7)**, and repeat the steps until you have completely defined all your preferred slope values. Once you click on *Read* **(#8)**, you will be prompted to choose the Landuse and soil lookup tables (then navigate to the SWAT training folder and select *Landuse lookup* file (repeat the steps to import the soil lookup table).

Now move to the next stage under *Single/Multiple HRUs* frame and click on *Filter by landuse, soil, slope* (**#9**). To create HRU by using the combined land use, soil and slope data, we have to input the threshold in either percentage or area. Define the threshold for land use, soil and slope (**#10**), as shown in Figure (6). Proceed by entering "10" each for land use, soil, and slope, which are widely and usually preferred in SWAT models. Depending on the version of QSWAT, you may be required to push the *Go* button (**#11**) after specifying one threshold and then move to another. This process must be repeated for soil and slope. After the thresholds are specified, push the *Create HRUs button* (**#12**).

Note! The HRUs window may automatically close when the process is successful

Once Step 2 is completed, you may see it marked "done"

## 3.4 Editing Input Files and Running SWAT

The *Step 3* allows you to edit inputs and run the SWAT model. When you click on the *SWAT Editor* a window will open for you to connect your SWAT project to the Database. If your working directory is saved on a different Disk Drive, you must copy the path in **(#1)** and paste it in **(#2)** (this will connect to your local soil database). If not done, the default soil from the USA will be used. Now click on connect to database **(#3)**. This step allows input of Weather/climate data.

wat QSWAT3 1.6.5	×
Soil & Water Assessment Tool	About Select Project New Project Existing Project
	Main Steps Done Delineate Watershed
QSWAT parameters	Done Create HRUs
Select report to view	Step 3 Edit Inputs and Run SWAT
D:\QSWAT_training\SWAT_Volta	SWAT Editor – C × Write Input Tables Edit SWAT Input SWAT Simulation Help SWAT Project Geodatabase D:\QSWAT_training\SWAT_Volta\SWAT_Volta.mdb SWAT Parameter Geodatabase D:\QSWAT_training\SWAT_Volta\QSWATRef2012.mdb #1 SWAT Soils Database (Required for re-writing tables) D:\QSWAT_training\SWAT_Volta\QSWATRef2012.mdb #2 SWAT Executable Folder C:\SWAT\SWATEditor\
	Exit #3 Connect to Databases

Figure 7. Steps to creating input tables





Before creating SWAT input tables, remember to integrate your Weather generator (*WGEN\_Volta.xlsx*) (which is provided in the *QSWAT\_training* folder) file into the *QSWATRef2012 dabase*. This database contains the weather data you created. For support on how import these files into the database, see appendix (page 19).

Now go to *Write Input Tables* (Figure 8) and load the weather geodatabase ("*WGEN\_Volta.xlsx*") (#4) from the dataset provided. Next, load the *Rainfall Data* but you must choose *Dailly* for the *Precip Timestep* in figure 9 (because the data provided was on daily time scale), but check the *Raingages* box (In case the measured data is missing, you can choose *simulation option*). Go to the *QSWAT\_training* folder, open the "swat-weatherdatabase" folder, further open the PCP folder, and select the *StPCP.txt file* for Rainfall (#5). Repeat the same step in figure 9 for Temperature Data (#6), by selecting the *StTMP.txt. file and* check the *Climate stations* box (#7) (figure 9).

Finally, click OK (#8). This will create a weather database for the study area.

Then, you will get a message that *processing complete* (#9). Now, click OK (#10) on the dialogue box. Now, click on *Cancel* on the *Weather Data Definition* window (#11).

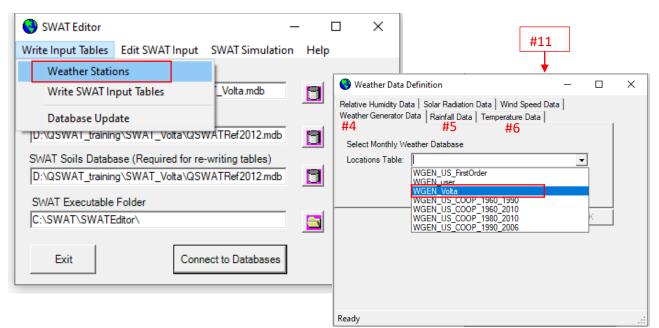


Figure 8. Steps for importing input data

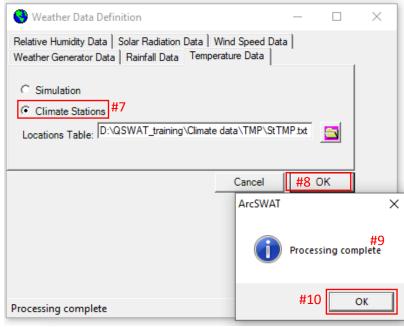


Figure 9. Further steps for importing input data





#### A. Write Input Tables

After generating weather database, create all input files by selecting *Write Input Tables* (**#1**) in figure 10. A new window named *Write SWAT Database Tables* will be displayed. Click on *Select All* (**#2**) and then click on *Create Tables* (**#3**). The order of the steps are labelled A, B, and C in figure 10.

😌 SWAT	Editor	Α	- C	] 😽 Write SWAT I	Database Tables C — 🛛	X		
Write Inpu	ut Tables Edit SWAT	Input SWAT Simulatio	on Help		to Write	_		
Weat	ther Stations			Completed	Confirguration File (.Fig)			
Write	e SWAT Input Tables	#1 _Volta.mdb	8	Completed	Soil Data (.Sol)			
Data	base Update			Completed	✓ Weather Generator Data (.Wgn)			
JD:\QSW	SWA1_training\SWA1_Volta\QSWATRef2012.mdb		8	Completed	Subbasin/Snow Data (.Sub/.Sno)			
SWAT So	oils Database (Required	d for re-writing tables)		Completed	HRU/Drainage Data (.Hru/.Sdr)			
D:\QSW	/AT_training\SWAT_Vol	ta\QSWATRef2012.mdb	8	Completed	Main Channel Data (.Rte)			
SWAT E	xecutable Folder			Completed	Groundwater Data (.Gw)			
C:\SWA	T\SWATEditor\			Incomplete	✓ Water Use Data (.Wus)			
	1	<b></b>	,	Incomplete	Management Data (.Mgt)			
Exi	t	Connect to Databases		Incomplete	Soil Chemical Data (.Chm)			
			-	Incomplete	Pond Data (.Pnd)			
	ArcSWAT	×		Incomplete	▼ Stream Water Quality Data (.Swq)			
В	Use weather database to calculate heat units to maturity (US only)?			Incomplete	Septic Data (.Sep)			
D		Yes No		Incomplete	ete 🔽 Operations Data (.Ops)			
l				Incomplete	Watershed Data (.Bsn/.Wwq)			
	ArcSWAT		×	Incomplete	Master Watershed File (.Cio)			
	Do you want to re-write the o	exiting 'pp' (point source) information?		#2 Select All	Cancel Create Tables	]#		
	ArcSWAT		×	Building Wus tab	le			
	Do you want to re-v	vrite the exiting 'ppi' (inletr) informat	tion?					
		Yes	10					

Figure 10. Writing Input Tables

A series of queries will pop up (see **B**) click no to all, and click yes to write new inlet tables, because our study area is different from the default SWAT study area which is in the USA.





#### B. Database updates

The next step is to update the SWAT database (See Figure 11). Select all the components **(#1)** and click on Update database **(#2)**. Once complete, you will receive a success message. Click Ok **(#3)** to exit. Now close that frame.

- 0	
Help	😽 Update Database — 🗆 🗙
8	Select SWAT Tables to Update
_	sol
8	sub ArcSWAT X
	hru rte
8	gw and a second s
	wus SWAT Project Database Updated!
	chm #3
_	pnd
	swq bsn #1
	wwa
	res Update SWAT Range Tables
	ops Update Database #2

Figure 11. Steps to update SWAT database

#### C. Edit SWAT Input

Next, go to *Edit SWAT Input* and choose the *PET* mothed **(#2)** that can help simulate the missing PET for our study area (White Volta). Hargreaves method is the best for estimating PET when measured data is unavailable for your catchment. Start from **(#1)**, **(#2)**, and **(#3)** to open and choose the PET method as illustrated in figure 12.

SWAT Editor	#1 – 🗆 ×
Write Input Tables	Edit SWAT Input SWAT Simulation Help
SWAT Project Geo	Databases
D:\QSWAT_trainin	Point Source Discharges
SWAT Parameter (	Inlet Discharges
D:\QSWAT_trainin	Neservoirs
SWAT Soils Databa	Subbasin Data #3
D:\QSWAT_trainin	Watershed Data $#2 \rightarrow$ General Data (.BSN)
SWAT Executable	Re-Write SWAT Input Files Water Quality Data (.WWQ)
C:\SWAT\SWATE	Integrate APEX Land Use Update (.LUP)
Exit	Connect to Databases

Figure 12. Editing the SWAT input

#### Selecting the Potential evaporation (PET) method

Once the *General Data (.BSN)* frame is open, click on *Edit Data* **(#4)** to activate the frame for editing. Nex, locate the *PET Method* section **(#5)** and click on it. You will find a number of methods among which you can choose the *Hargreaves*. After choosing the PET method, click on *Save Edits* **(#6)**, and then *Exit*.

Return to *Editing SWAT* frame and click on the *Re-write SWAT input files*. This will allow you to select all **(#7)** the components and write tables **(#8)** once again, due to new PET data that was generated by the Hargreaves method (see figure 13 for illustrations).





dit General Watershed					- 🗆	×			
ter Balance, Surface Ru	noff, and Reaches Nutr	ients and Water Quality	Basin-Wide Managem	ent Urban Management/	Sub-Daily Erosion				
Vater Balance SFTMP (C)	SMTMP (C)	SMFMX (mm/C-day)	SMFMN (mm/C-da	ay) TIMP					
1	0.5	45	4.5	1					
SNOCOVMX (mm)	SNO50COV	PET Method	#5	PET File					
1	0.5	Penman/Monteith		•					
ESCO	EPCO	Priestley-Taylor Penman/Monteith		DEPIMP_BSN					
0.95	1	Hargreaves Read-In PET		0					
Surface Runoff									
Rainfall-Runoff Method		ICN	CNCOEF	CN_FROZ	_				
"Daily Rain/CN/Daily F	Route (0)"		1	0.000862					
Crack Flow	SURLAG	ISED_DET	ADJ_PKR	TB_ADJ	_				
Inactive 💌	4	Triangular Dist. 💌	1	0					
PRF	SPCON	SPEXP							
1	0.0001	1		Rewrite SWA	Tlagut	_	-	×	
Reaches Channel Routing Variable Storage Stream Water Quality Active		MSK_CO2 0.25 EVRCH 1	MSK_X  0.2 Routing Pesti	Select Input Fil .Wwg .Res/.Lwg	es to Rewri	ite:	#7		
4	#6			.Sep .Ops					
t Values Cancel	1	Exit		.Lup			Select All		
				plant.dat				ArcSWAT	>
				urban.dat		#	8		
				pest.dat			Write Files		
				fert.dat				]	
				till.dat					Done!
				septwq.dat point source/inl	oto	Υ.	Cancel		
				point source/ini	CLS	Ţ			
						_		_	OK

Figure 13. Selecting the Potential evaporation method rewriting input files

#### D. Running SWAT Simulation

Click on SWAT Simulation and chose Run SWAT as illustrated in figure 14.

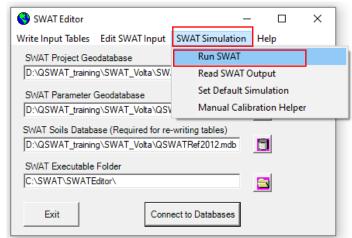


Figure 14. Step to defining and runing the SWAT simulation

Set the period of simulation *Starting Date* **(#1)** 01/01/2004 and *Ending Date* 12/31/2010 **(#2)** (These time frames will show by default because the datasets provided for this training exercise falls within that period). Change the printout settings to *daily* **(#3)** and leave other default options unchanged. NYSKIP means model simulation warm-up period (the period used to train the model) and for this training, we will use *NYSKIP as 2 years* **(#4)**. For the *SWAT extension version*, can choose the *64-bit*, *release* **(#5)** because it is faster for running simulations. Click on *Setup SWAT Run* **(#6)**. You will get a message indicating SWAT Setup is finished. Now, click on *Run SWAT* **(#7)**.





Setup and Run SWAT Model Simulation		- 🗆 ×
Period of Simulation #1 Starting Date : 1/1/2004 Min Date = 01/01/2004	#2 Ending Date : 12/31/2010 Max Date = 12/31/2010	
Rainfall Sub-Daily Timestep Timestep:	Printout Settings #3 © Daily O Yearly Print Log Flow O Monthly NYSKIP 2 #4 Print Hourly Output	Print Pesticide Output Print Soil Storage
Rainfall Distribution     Skewed normal     Mixed exponential     1.3	Print Soil Nutrient     Print Water Quality Output     Print Water Quality Output     Print WTR Output     Print WTR Output	Print Son Storage Print Son Storage Print Vel./Depth Output Print Calendar Dates
SWAT.exe Version C 32-bit, debug C 32-bit, release C 64-bit, debug • 64-bit, release #5 C Custom (swatUser.exe in TxtInOut folder)	Output File Variables All	#7 SWAT Cancel
	,	

Figure 15. Defining the simulation periods and running SWAT

While SWAT is running (see figure 16), you will see a DOS window showing the progress, and when the simulation is done, you will get a final completion message and click Ok.

C:\WINDOWS\system32\cmd.exe	_	$\times$
SWAT2020		~
Rev. 681		
Soil & Water Assessment Tool		
PC Version		
Program reading from file.cio executing		
Executing year 1		
Executing year 2		
Executing year 3		

Figure 16. SWAT simulation in progress

When the simulation is successful, close the SWAT simulation setup window. You are now ready to *Read SWAT Output* (see figure 17) and visualize the model output.

SWAT Editor	– 🗆 X
Write Input Tables Edit SWAT Input	SWAT Simulation Help
SWAT Project Geodatabase	Run SWAT
D:\QSWAT_training\SWAT_Volta\SW	Read SWAT Output
SWAT Parameter Geodatabase	Set Default Simulation
D:\QSWAT_training\SWAT_Volta\QSV	Manual Calibration Helper
SWAT Soils Database (Required for re-	-writing tables)
D:\QSWAT_training\SWAT_Volta\QSV	VATRef2012.mdb
SWAT Executable Folder	
C:\SWAT\SWATEditor\	
Exit Conn	ect to Databases

Figure 17. Steps to reading SWAT output





#### E. Checking the simulation for Errors

The SWAT Error Check tool is used to find out issues with the modeling in the early stage. It enables us to find out any hidden problems and reduce the time in regenerating or recalibrating the model at a later stage. SWAT Check performs three operations; i). it reads the output and notify the users if the values lie outside the possible limits, ii). it produces process-based figures for quick visualization, and iii). also find and notify the common model errors. In figure 18, illustrations show how to select the *output.rch* file (**#1**) and import files to database (**#2**). Also, SWAT simulations can be saved using the *Save SWAT Simulation* with a user input name. Type simulation name as *Volta Simulation* (**#3**) and save *the* Simulation (**#4**). You will receive a message indicating that your simulation has been saved. You can find saved simulation in your SWAT folder (in the Scenarios folder). Finally, click on Run *SwatCheck* option (**#5**).

SWAT Output			_		×
Read SWAT Output					
#2 Import Files to Database Open SWATOuput.mdb Open output.std	#1 Check Output F output.rch output.sub output.hru output.dep output.snw	output.s  output.r  output.r  output.r  output.r	sed [] sv [] ost [] wtr []	output.snu output.pot output.vel output.wql output.mgt	
Open input.std					
-Review SWAT Ouput		#5	Run S	) watCheck	
Save SWAT Simulation - Save current simulation Volta Simulation	#3 as: (e.g., Sim1)	#4	Save	Simulation	
				Cancel	

Figure 18. Selecting, saving model output, and running SWAT check

The SWAT check window will open, and you can now continue with the steps to run the *SWAT check*, as illustrated in figure 19. Click on the *Examine model output* **(#6)**. When the SWAT check is complete, you can now assess the results, the watershed characteristics **(#7)**, and read the warning messages **(#8)**.





SWAT Error Checker - Version 1.2.0.10 Released November 6, 2018					_		×
Setup Hydrology Sediment Nitrogen Cycle Phosphorus Cycle Plant Growth	Landscape Nutrient Losses	Land Use Summary	Instream Processes	Point Sources	Reservoirs	About	
Project Location D:\QSWAT_training\SWAT_Volta\Scenarios\Default\TxtInOut Already ran SWAT Check once? Leave this box checked to SWAT Check reads your output files into a SQLite database Check on your project, you may save time on subsequent run	re-read your SWAT output file . If you have already run this v		Simulation E	Examine Mod			
<ol> <li>Specify your path in the text box above</li> <li>If you have run this version of SWAT Check before, check the box if you</li> <li>Press the "Examine Model Output" button near the top right of the windo</li> <li>Click each tab to review related model outputs, statistics and warnings</li> </ol>	-	output files.	s	, mulation Length (y Wamn up (y <b>#7</b> HR Subbasi	rrs) 2 Us 557		
Messages and Wamings	#8			Output Timest Precip Method Watershed Area kr & Water hent Tool	Measured m2 111,15		

Figure 19. Steps to running SWAT checks

Assessment of the hydrology and water balance ratios **(#10)** in figure 20. You can click on each of the components **(#11)** to view the results that are important for your analysis **(#12)**.

	Sediment Nitrogen Cycle	Phosphorus Cycle Plant Growth	Landscape Nutrient Losses Land Us	e Summary Instream Processes Point Sour	ces Reservoirs About	
PET 1,875.9	Evaporation and Transpiration 405.8		#12	Realistic hydrology is the foundation of a attention to evapotranspiration, baseflow Baseflow/streamflow ratios for the US an data are accessible via the button below are general guidelines only, and may not	and surface runoff ratios. e provided by the USGS, these . The ranges specified here	
		/ Precipitation	л	Show Avg. Monthly Basin Values	Show US Baseflow Map	
			Average Curve Number	Messages and	Warnings	
Root Zone	1.1A - 1MI <sup>1 M</sup> 1MA	IV II IV III Infradoroplant uptakel Solt mostave redstrutution	Surface Fundft 162.72			
			Lateral Flow	Water Balance Ratios		
dose (unsaturated). Zone			- 0.42	Streamflow/Precip	0.37 #10	
		Description to shall an envited				
Zone	Revap from shallow aquifer 37.17	Percolation to shallow aquifer 118.96	Return Flow	Baseflow/Total Flow	0.36	
Zone	27 17		Return Flow 91.52	· · · · ·	0.36	
Zone hallow (unconfined) Aquifer	27 17		$\longrightarrow$	Baseflow/Total Flow		
Zone hallow (unconfined)	27 17		$\longrightarrow$	Baseflow/Total Flow Surface Runoff/Total Flow	0.64	

Figure 20. Display of SWAT check outcome with the water balance ratios



PARCADES Participatory assessment of flood-related disaster prevention and development of an adapted coping system in Ghana

### 3.5 Visualize model result or outputs

After running the model and error checks, *Step 4 Visualize* will be activated on the QSWAT main form. Click on *Step 4 Visualise* as shown in figure 21.

QSWAT3 1.6.5		×				
		About				
	Select Pro	ject				
Soil & Water SWAT	New Project Existing Project					
	Main Step	s				
	Done	Delineate Watershed				
	Done	Create HRUs				
QSWAT parameters	Step 3	Edit Inputs and Run SWAT				
Select report to view 💌	Step 4	Visualise				
		OK Cancel				
D:\QSWAT_training\SWAT_Volta						

Figure 21. Visualization of model results

There are three possibilities for visualization: *Static data*, *Animation* and *Plot*. For Static data option, a single summary value is calculated for each sub-basin, reach, or HRU and displayed as a map. For Animation option, we can view the animated display of the value in each sub-basin, reach, or HRU at each time step in the map display. Plot option supports the creation and display of plots of selected variables. First, let us look at Static data option.

Visualise Results — 🗆 🗙	
Choose scenario #1 Choose SWAT output table Volta Simulation  Choose period Start date #3 Finish date	7 8 5 12 4 17 24 15 26 4 22 15 12 12 13 22
1 * January * 2006 31 * December * 2010	
Day Month Year Day Month Year	20 232
#4 Static maps Animated maps Plots Choose results shapefile	36 $41$ $45$ $44$ $30$ $42$ $43$ $43$
_Volta\Scenarios\Volta Simulation\TablesOut\rchresults.shp	$\begin{array}{c} 33 \\ 59 \\ 59 \\ 59 \\ 59 \\ 50 \\ 50 \\ 50 \\ 50$
Choose variables Choose summary	69 (1 70 79 79 (49 57 72) 69 (68 68)
FLOW_OUTcms #5 - Totals - #6	200 54 67 55 55 55 55 55 55 55 55 55 55 55 55 55
#7 Add FLOW_OUTcms Compare scenarios	
All Compare X and Y	91 92 105 <sup>01</sup> 106 83 89 76 77 78 51
Del	88 99 82 81 80 103 100 100 98
Clear #9 Create	102 87 85 1096 23 93 94 95 96 97
Print	96 118 112
Landscape O Portrait Number of maps 1      Print	$\begin{array}{c} 125 \\ 124 \\ 123 \\ 123 \\ 119 \\ 110 \\ 122 \\ 119 \\ 122 \\ 122 \\ 119 \\ 122 \\ 122 \\ 122 \\ 122 \\ 124 \\ 122 \\ 124 \\ 124 \\ 122 \\ 124 \\$
Close	

Figure 22. Visualization of model results





To visualize your simulated results, click on the box under the *Scenarios frame* (#1). This will provide you all the saved simulations in the scenarios folder in your working folder (*SWAT\_Volta*), including the ones saved by default. Now select *Volta Simulation*. For the SWAT output table (#2), select the "*rch*" file because that is the only one you imported into the database. The *Start date* and the *Finish Date* (#3) will remain the same as displayed in figure 23. In the *Static maps* section (#4) go to the variable you want to display and choose "*FLOW\_OUTcms*" (#5) and click on *Add* (#6). Now choose the results *Summary* (#7) you want to visualize and select "*Totals*". You can also explore all other options such as the daily means, annual means, etc. Select the variable you want to display by clicking on "*FLOW\_OUTcms*" (#8). Finally, click on *Create* (#9). The results of river flow within each sub-catchment will be displayed in (#10).

#### Plot the graph

Now, we will use *Plot* option (**#11**), illustrated in figure 23 and follow the steps. Choose your preferred graph type (**#12**) and select the *Subbasin* (**#13**) you wish to visualize. Under the *variable* section, select "*FLOW\_OUTcms*" (**#14**). Next, click on the *Add plot* (**#15**) and go ahead to select the scenario (**#16**) you want to display. Finally, click on *Plot* (**#17**). At this stage, you will be prompted to save the flow time series in your *Volta Simulation* folder.

<b>Q</b> Visualise Results	- 🗆 X
Choose scenario	Choose SWAT output table
Choose period	
Start date	Finish date
1 🔻 January 🔻 2006	31 • December • 2010
Day Month Year	Day Month Year
Static maps Animated maps Plots	#11
Choose observed data file (optional)	
#12	
Graph/bar chart  Subbasin #	+13 HRU #14 <sup>Variable</sup>
#15 Add plot Scenario	Table Sub HRU Variable
Delete plot	
Copy plot	#16
Move up	
Move down	
Add	
observed	#17 Plot
	TTT PIOL
	Close

Figure 23. Illustration to plot hydrographs

The graph for the exercise would look like figure 24. If you have observed data for your watershed, you can include it in *Choose observed data file* option. Also, you can use the Save button to save the plot in different formats with a suitable name





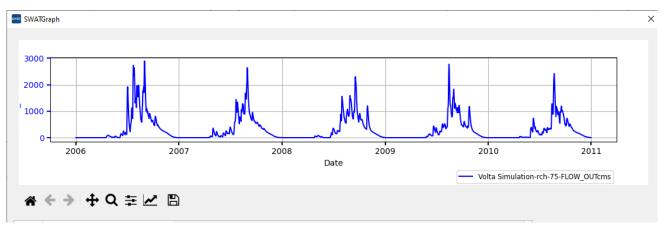


Figure 24. Hydrograph showing river flow at an outlet (75)

#### Next step

Calibration and validation of the model

Requirement

- 1. SWAT CUP (SUFI2 software)
- 2. River discharge data



# 4. Appendix

Adding table into SWAT project database

To be able run SWAT simulations, the table containing the climate data must be integrated into SWAT database (Microsoft database file). In our case, we need to import the table containing the weather stations, daily rainfall, and daily minimum and maximum temperature. To import tables into the SWAT database, navigate to your working folder *QSWAT\_training* and open the *SWAT\_Volta* folder (see illustrations in figure 25). Next, open the *QSWATRef2012.mdb* as indicated in figure 25.

Name	Date modified	Туре	Size
Scenarios	11/17/2023 5:12 PM	File folder	
Source	11/17/2023 6:14 PM	File folder	
	11/17/2023 5:12 PM	File folder	
▲ QSWATRef2012.Idb	11/18/2023 10:42 AM	Microsoft Access	1 KB
DSWATRef2012.mdb	11/18/2023 10:43 AM	Microsoft Access	35,540 KB
SWAT_Volta.mdb	11/18/2023 10:41 AM	Microsoft Access	4,608 KB

#### Figure 25

Once the Microsoft database file is open, under the Tables, locate the *WGEN\_user* and righ-click on it. Now you will have many options so click on *Import* and choose Excel. This will open the windows explorer for you select the table you want to import. In this case, navigate to your working folder *QSWAT\_training, climate data folder,* select *WGEN\_Volta.xlsx* file, and click on open (see figure 26).

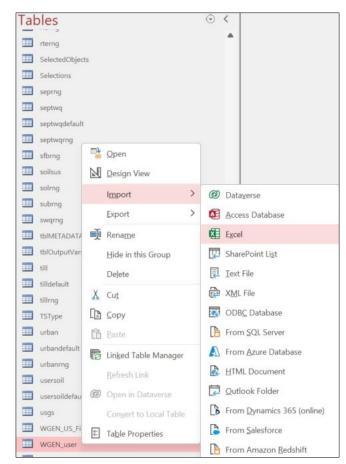


Figure 26. Importing the WGEN\_Volta table into SWAT database





→ ✓ ↑ → This PC → Volume (D:)	<ul> <li>QSWAT_trainir</li> </ul>	ng → Climate data	~	Q	2	Search Clim	ate data
rganize 🔻 New folder						0=	•
Music ^ Name	^	Date modified	Туре	1	Α	В	С
Pictures PCP		11/18/2023 11:01 AM	File folder	1	OBJECTID	STATE	STATI
Videos TMP		11/18/2023 11:01 AM	File folder	2		NA	Navrongo
Local Disk (C:)	dev	11/16/2023 7:06 PM	Microsoft Excel W.	3		NA	Vea
	(15)	11/10/2023 1.00 PW	WICTOSOTE EXCEL W.	4		NA	Zuarungu
-				5		NA NA	Tamale
Albert				6		NA	Man_Baw Pong Tan
ArcSWAT				8		NA	Ouagadou
Climate scenar				9		NA	Fada
FLow map Dati				10		NA	Gaoua
FLowMAP				11		NA	Boromo
GIS				12	11	NA	Walewale
josh				13			
QSWAT_trainin				14			
				15			
DEM V <			>		4 →	e	:
File name: WGEN_Volta.x	ev.				~ Micro	soft Excel ('	".xls;".xlsb;".

Figure 27

Figure 27 shows the next steps, where you need to only click *Ok* to proceed to the next steps. In figure 28, select *No primary key* and click on next. In the next steps, under the *Import to Table*, rename it as *WGEN\_Volta* as indicated in figure 29. You can also use a different name, but it must begin with WGEN..... Now click on *Finish* to complete the table importation

Get External Data - Excel Spreadsheet	? ×
Select the source and destination of the data	
Specify the source of the definition of the objects.	
Eile name: D:\QSWAT_training\Climate data\WGEN_Volta.xlsx	B <u>r</u> owse
Specify how and where you want to store the data in the current database.	
We will not import table relationships, calculated columns, validation rules, default values, and columns of certain le as OLE Object.	gacy data types such
Search for "Import" in Microsoft Access Help for more information.	
Import the source data into a new table in the current database.	
If the specified table does not exist, Access will create it. If the specified table already exists, Access might ov with the imported data. Changes made to the source data will not be reflected in the database.	erwrite its contents
O Append a copy of the records to the table: autoinpar	
If the specified table exists, Access will add the records to the table. If the table does not exist, Access will cr made to the source data will not be reflected in the database.	eate it. Changes
Link to the data source by creating a linked table.	
Access will create a table that will maintain a link to the source data in Excel. Changes made to the source da reflected in the linked table. However, the source data cannot be changed from within Access.	ata in Excel will be
ОК	Cancel .:

Figure 28. Importing the WGEN\_Volta table into SWAT database



	XXX		ecommends that you ach record in your ta					y key is used t	0
2 xxx xxx 3 xxx xxx	XXX	○Let Access ad	d primary key.						
2 xxx xxx 4 xxx xxx		<u> </u>	vn primary key.			~			
	_	No primary ke							
		<u> </u>							
OBJECTI	D STATE	STATION	LSTATION	ID	WLATITUDE	WLONGITUDE	WELEV	RAIN YRS	TMPMX1
1	NA	Navrongo	Navrongo	1	10.90	-1.10	201.3	10	35.42
2	NA	Vea	Vea	2	10.87	-0.85	183.1	10	34.92
3	AN	Zuarungu	Zuarungu	3	10.78	-0.80	213.3	10	35.60
4	AN	Tamale	Tamale	4	9.42	-0.85	183.3	10	35.79
5	AN	Man_Bawku	Man_Bawku	5	11.02	-0.27	248.9	10	36.10
6	AN	Pong_Tamale	Pong_Tamale	6	9.67	-0.83	182.8	10	36.04
7	NA	Ouagadougou	Ouagadougou	7	12.35	-1.51	316.1	10	32.13
8	AN	Fada	Fada	8	12.07	0.35	301	10	33.41
9	AN	Gaoua	Gaoua	9	10.33	-3.18	333	10	34.03
10	AN	Boromo	Boromo	10	11.75	-2.93	271	10	33.47
11	AN	Walewale	Walewale	11	10.35	-0.80	167.6	10	35.95
									>

Figure 29. Further steps to import the WGEN\_Volta table into SWAT database

🔳 Import Spreadsheet	Wizard	×
W	That's all the information the wizard needs to import your data.	
	Import to Table: WGEN_Volta	
	I would like a wizard to <u>a</u> nalyze my table after importing the data.	
	Cancel < <u>B</u> ack <u>N</u> ext > <u>Finish</u>	

Figure 30. The final steps to import the SWAT tables into database



PARADES Participatory assessment of flood-related disaster prevention and development of an adapted coping system in Ghana



22

# 5. Reference and links to additional support

Basic understanding on SWAT and how it works

SWAT literature database <u>https://www.card.iastate.edu/swat\_articles/</u> YouTube video support: <u>https://www.youtube.com/watch?v=2YW0ZDNfdIU&t=711s</u>

#### **Data preparation**

George, C. (2015). *Preparing global DEM data for QSWAT Chris George. March*, 12. YouTube video support: <u>https://www.youtube.com/watch?v=EafZcQp-Has&t=590s</u> YouTube video on soil data preparation: <u>https://www.youtube.com/watch?v=ztPitjNici8</u> YouTube video on Weather data preparations: <u>https://www.youtube.com/watch?v=OGrlYxUh67g</u>

#### SWAT model setup

Arnold, J. G., Kiniry, J. R., Srinivasan, R., Williams, J. R., Haney, E. B., & Neitsch, S. L. (2013). Soil & Water Assessment Tool: Input/output documentation. version 2012. *Texas Water Resources Institute, TR-439*, 650. <u>http://swat.tamu.edu/media/69296/SWAT-IO-Documentation-2012.pdf</u> Srinivasan, R., & George, C. (2015). *QGIS Interface for SWAT (QSWAT) QSWAT (QGIS SWAT) Step by Step Setup for the Robit Watershed, Lake Tana basin Ethiopia Contents. May.* 

https://swat.tamu.edu/media/114676/gswat-manual.pdf

Arnold, J. G., Moriasi, D. N., Gassman, P. W., Abbaspour, K. C., White, M. J., Srinivasan, R., Santhi, C., Harmel, R. D., Griensven, a. van, VanLiew, M. W., Kannan, N., & Jha, M. K. (2012). Swat: Model Use, Calibration, and Validation. *Asabe*, *55*(4), 1491–1508. <u>https://doi.org/ISSN 2151-0032</u>

#### SWAT group

You can one of the groups created to provide support SWAT modeling. For example: <u>https://groups.google.com/g/qswat</u>





## **Project Partners**





This material is licensed under the Creative Commons Attribution-ShareAlike 4.0 International

It is allowed to:

**Share** — copy and redistribute the material in any medium or format for any purpose, even commercially

Adapt — remix, transform, and build upon the material for any purpose, even commercially

To see a copy of this license, visit visit http://creativecommons.org/licenses/by-sa/4.0/

