BRIEF STEP BY STEP TUTORIAL ON QSWAT MODEL SET-UP

A Case Study of the Upper Olkeriai Catchment, Kajiado County, Kenya

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1. THE CASE STUDY AREA

The Case Study in this tutorial is Olkeriai catchment Kajiado County in Kenya. For the purpose of reducing the simulation time, we have chosen a small area in the upstream of the catchment (Figure 1).

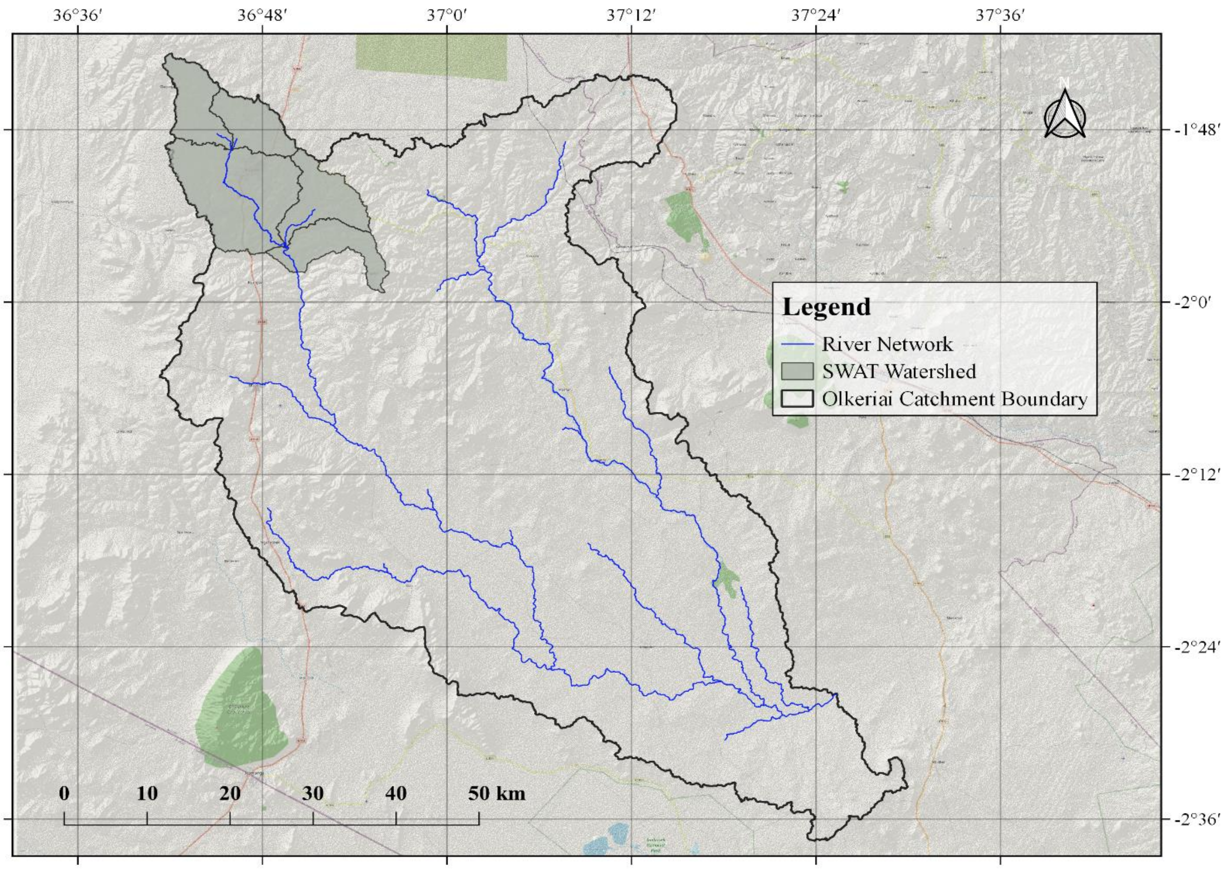


Figure 1: The Case Study Area

2. INTRODUCTION TO SWAT AND QGIS (QSWAT)

The **Soil and Water Assessment Tool (SWAT*)*** is a physically-based continuous-event hydrologic model developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds with varying soils, land use, and management conditions over long periods of time (Dile et al., 2016). For simulation, a watershed is subdivided into a number of homogenous sub-basins referred referred to as hydrologic response units (HRUs) (Yihun et al., 2020). HRUs have unique a soil and land use properties. The input information for each sub-basin is grouped into categories of weather; unique areas of land cover, soil, and management within the sub-basin; ponds/reservoirs; groundwater; and the main channel or reach, draining the sub-basin (Reddy et al., 2018). QSWAT is a QGIS interface for SWAT. In this tutorial, learners will be able to acquire the following:

i. Understand the environment and tools Required for running QSWAT and the installation process
ii. Introduce and familiarize with hydrological modeling using QSWAT3 v1.0 in QGIS 3.4.1

3. ENVIRONMENT AND TOOLS REQUIRED

- Microsoft Windows (any version, as far as we are aware)
- Microsoft Access, as the interface uses an Access database
- Text editor (e.g. WordPad, NotePad, NotePad++) that enables you to read and edit ASCII text files.
- A tool like WinZip that can uncompress.zip files (not needed with recent versions of Windows)

System requirements for SWAT Editor Version 2012.10.19

- Microsoft Windows XP to 10
- Microsoft .Net Framework 3.5
- Adobe Acrobat Reader Version 7 or higher. Acrobat Reader may be downloaded for free from: http://www.adobe.com/products/acrobat/readstep2.html

4. INSTALLATION

- Install QGIS by running **QGIS-OSGeo4W-3.10.9-1-Setup-x86.exe**. It can be downloaded from https://qgis.org/downloads/QGIS-OSGeo4W-3.10.9-1-Setup-x86.exe. Use the default folder *C:\Program Files (x86) \QGIS 3.14*. Currently you must use the 32-bit version on 64-bit machines. It is recommended that you select the long-term release version of QGIS, 3.10 for which QSWAT3 has been tested.
- Install SWAT Editor 2012 version in its standard place *C:\SWAT\SWATEditor*. For the SWAT 2012.10.21 version, unzip the installation archive Swateditor_Install_2012.19_5.21.zip (https://swat.tamu.edu/software/swat-editor/).
- The SWATEditor folder will consist of Databases folder, SwatCheck folder, SWATEditor Help, and other SWAT executables. The database folder consists of SWAT2012 databases which require updating based on user available information (e.g. user soil, weather generator).
- Download and install https QSWAT3. To use it is highly recommended to install the 32-bit version of QGIS3, preferably version 3.10 otherwise, you may not activate QSWAT with 64-bit.

5. DATA REQUIREMENT AND PREPARATION

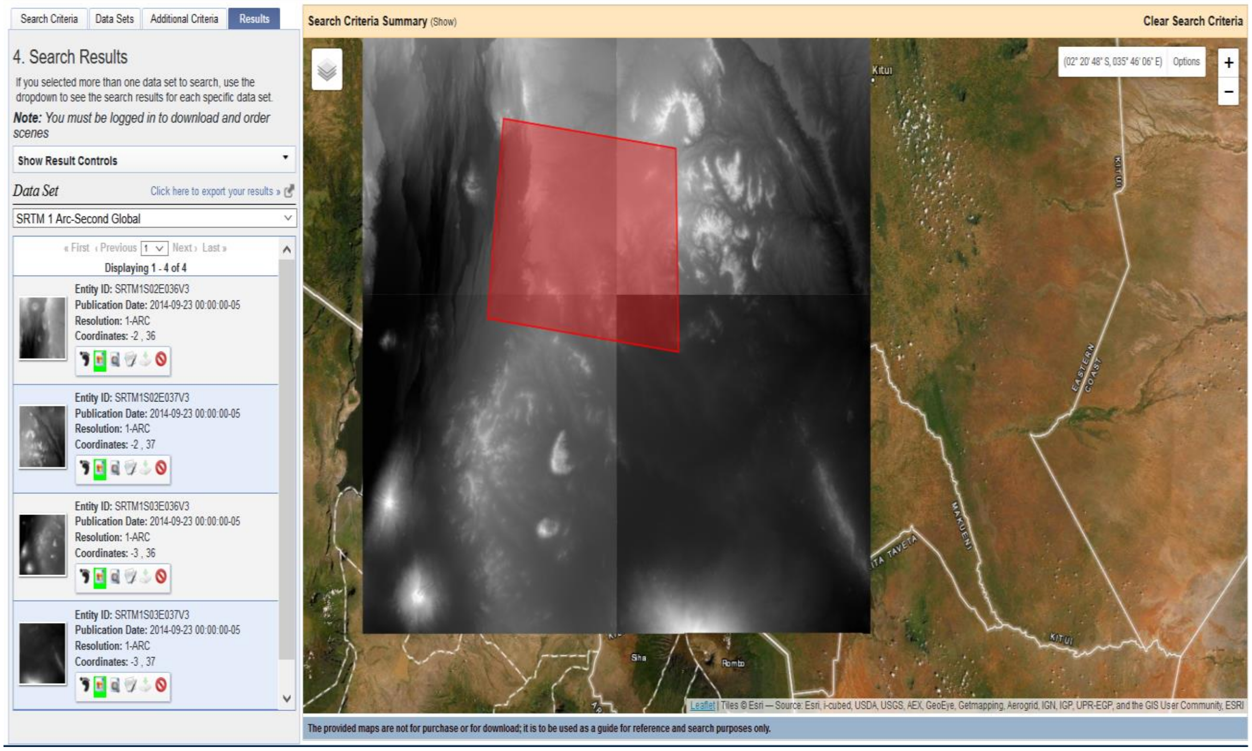
The following data is requiring:

- Spatially distributed Data Digital Elevation Model (DEM) 30m, Soil and land-cover/land-use)
- Hydrological/hydromet data (Precipitation, Temperature, Solar Radiation, Relative humidity, Wind and Flow)
- Look-up tables for landuse and soil.

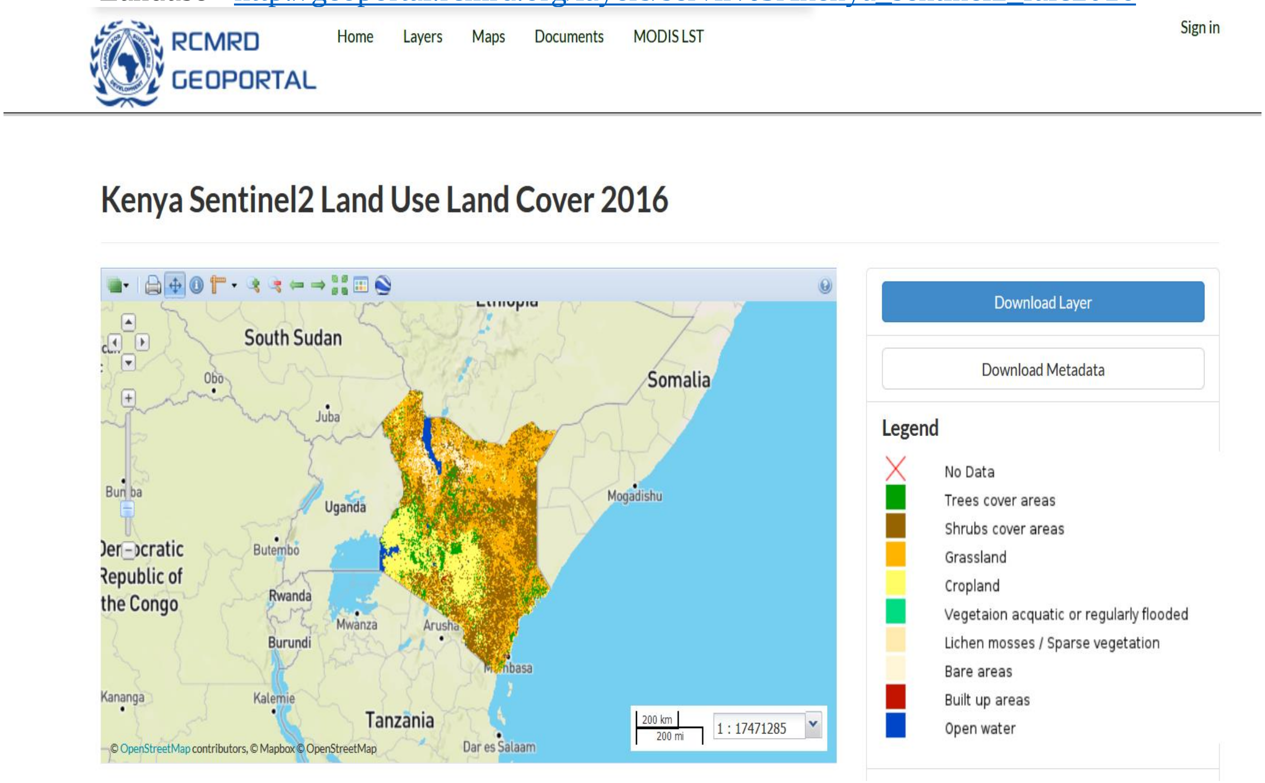
Note: In this tutorial, all the datasets are provided:

Note following sources for the data used in this tutorial.

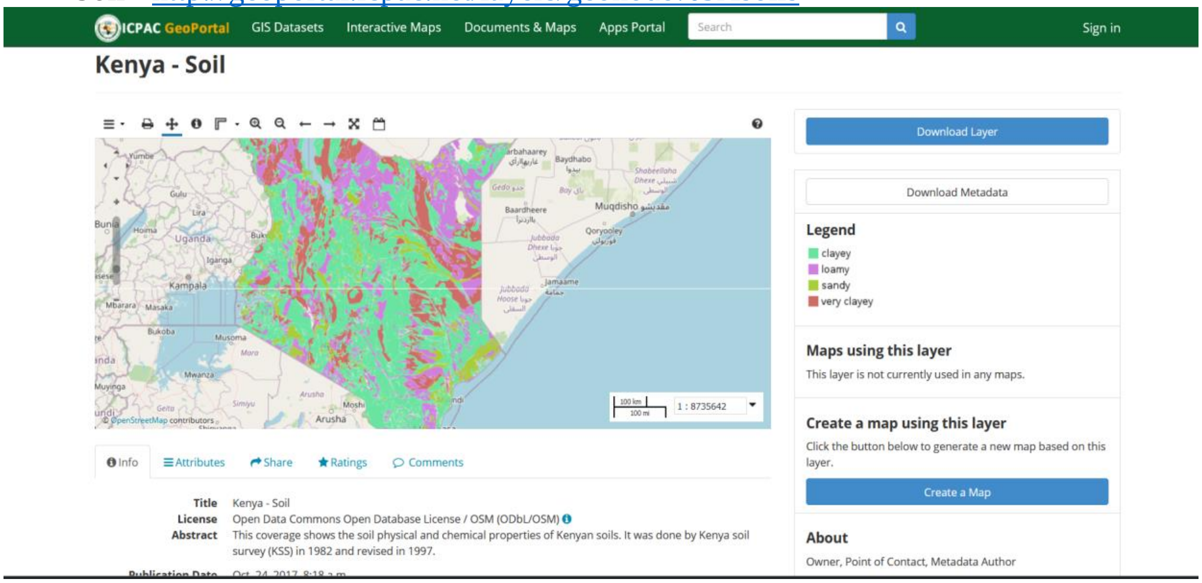
- DEM – https://earthexplorer.usgs.gov/



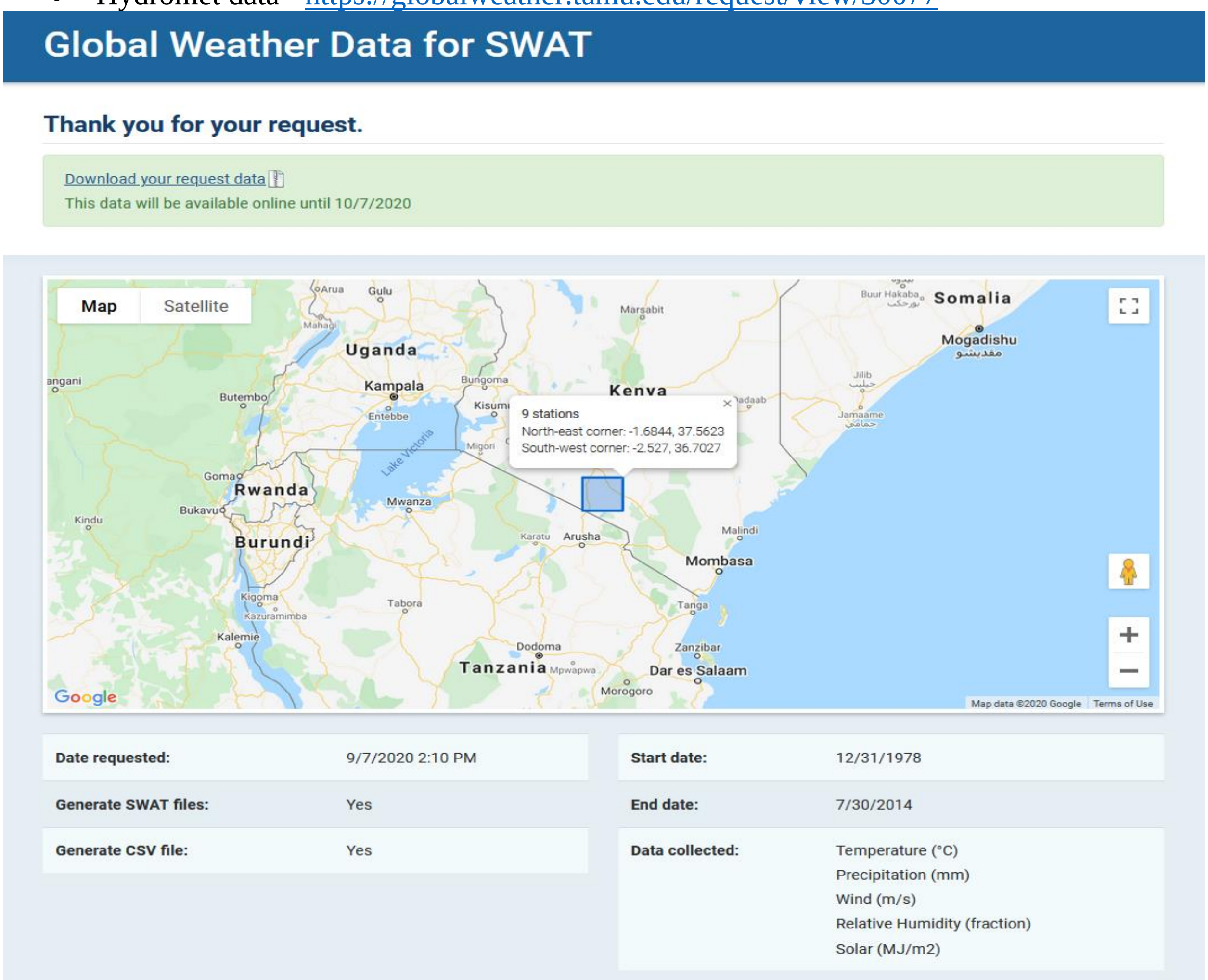
- Landuse - http://geoportal.rcmrd.org/layers/servir%3Akenya_sentinel2_lulc2016



- Soil - http://geoportal.icpac.net/layers/geonode%3Asoils



- Hydromet data - https://globalweather.tamu.edu/request/view/30077



6. STEP 1: SETUP – UPPER OLKERIA CATCHMENT

Start **QGIS** and select **Plugins** menu → **Manage and Install Plugins** and find **QSWAT3**. Click its checkbox to install, which takes a few seconds (Figure 2). The SWAT icon will appear in the toolbar (Figure 3). If it fails to appear confirm that you are running a 32-bit version of QGIS and not 64-bit.

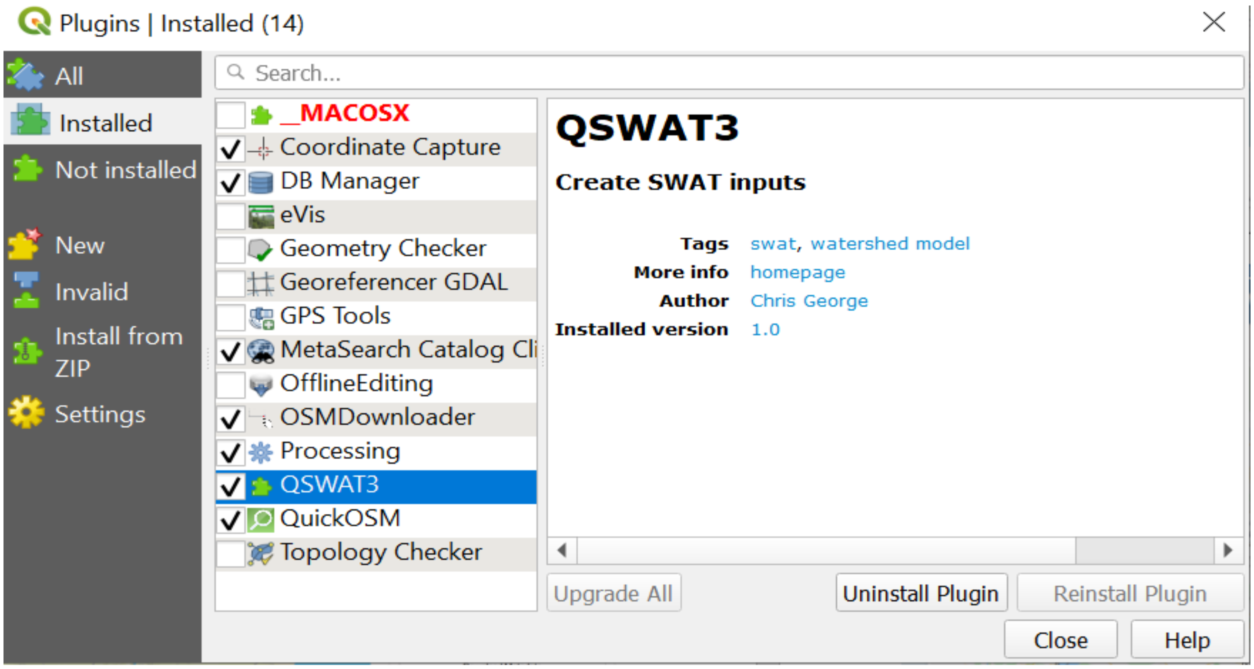


Figure 2: Manage Plugins dialogue

Start QSWAT3 by clicking the SWAT icon. QSWAT3 main interface will appear. Click the box **New Project** and browse to the location you want to save the project (Figure 4). You may work from any location/Drive of your computer.

Figure 3: Main Toolbar with QSWAT3 Icon circled in red.

Note that at this stage, all your maps should be prepared in an equal area projection. All the maps should be in the same projection coordinate system. The interface you see now is a step-by-step configuration to be followed in order to prepare the SWAT simulation. At this stage the project database is created as umba.mdb in the project folder, and a copy of the SWAT reference database QSWATRef2012.mdb is also created there. For this example, you need to update the reference database with details of weather generation stations. To do this, copy the SWAT database that was given to you in the SWAT project directory. The three main steps in QSWAT set-up will appear with step 1 activated (Figure 5)

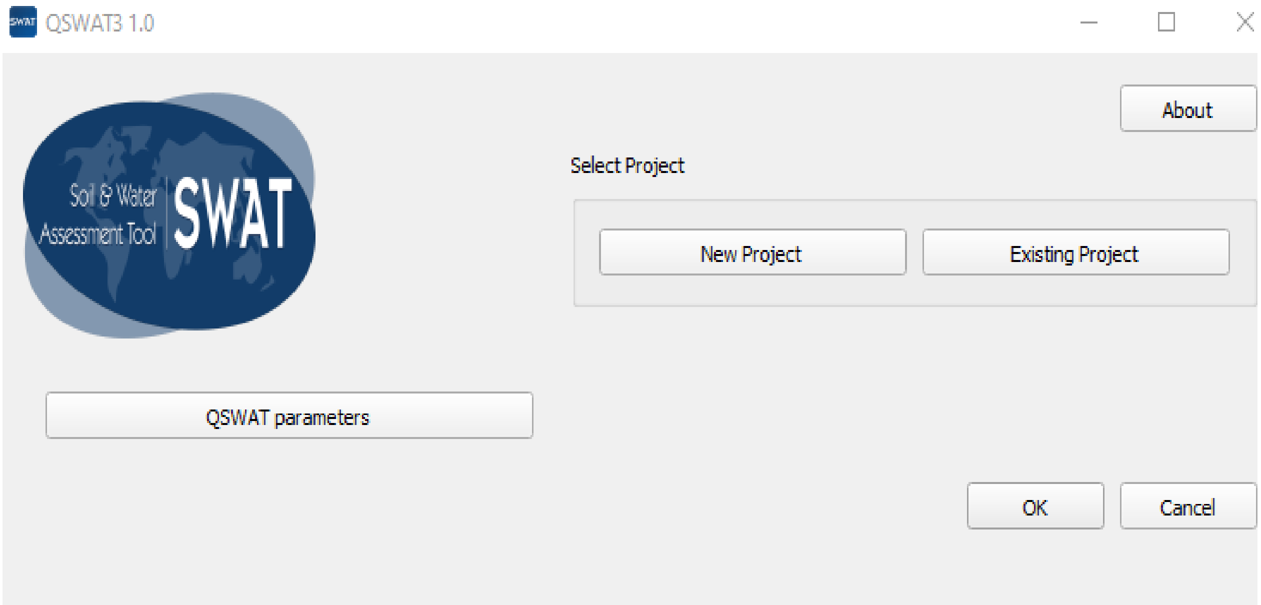


Figure 4: QSWAT3 Main Interface

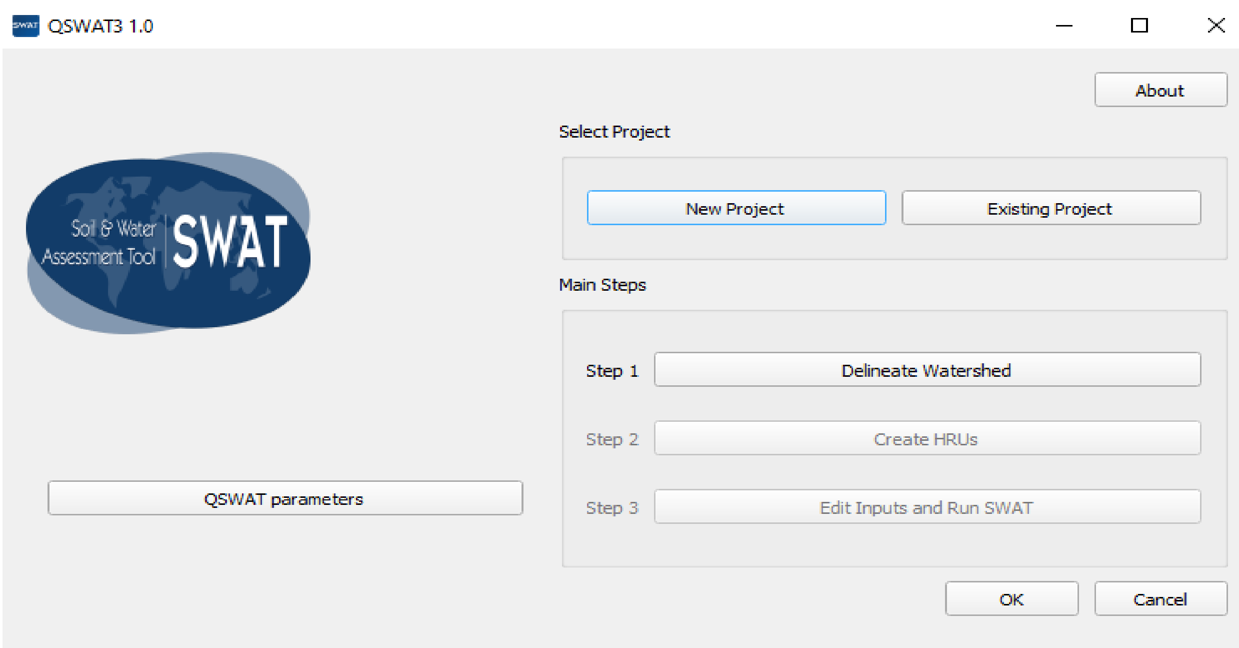


Figure 5: QSWAT3 Main Interface with the three steps: activated.

7. STEP 2: WATERSHED DELINEATION

To start automatic watershed delineation, click the ***Delineate Watershed*** button. When the prompt box is opened browse to the data source in the dialogue box next to **Select DEM**. The name of the elevation map grid will be displayed in the DEM text box below the Watershed dialogue box. The selected DEM will be copied to the projects Source folder and, if necessary, converted to GeoTiff format (.tif). If your DEM's units are not meters you can select the DEM properties tab and change them.

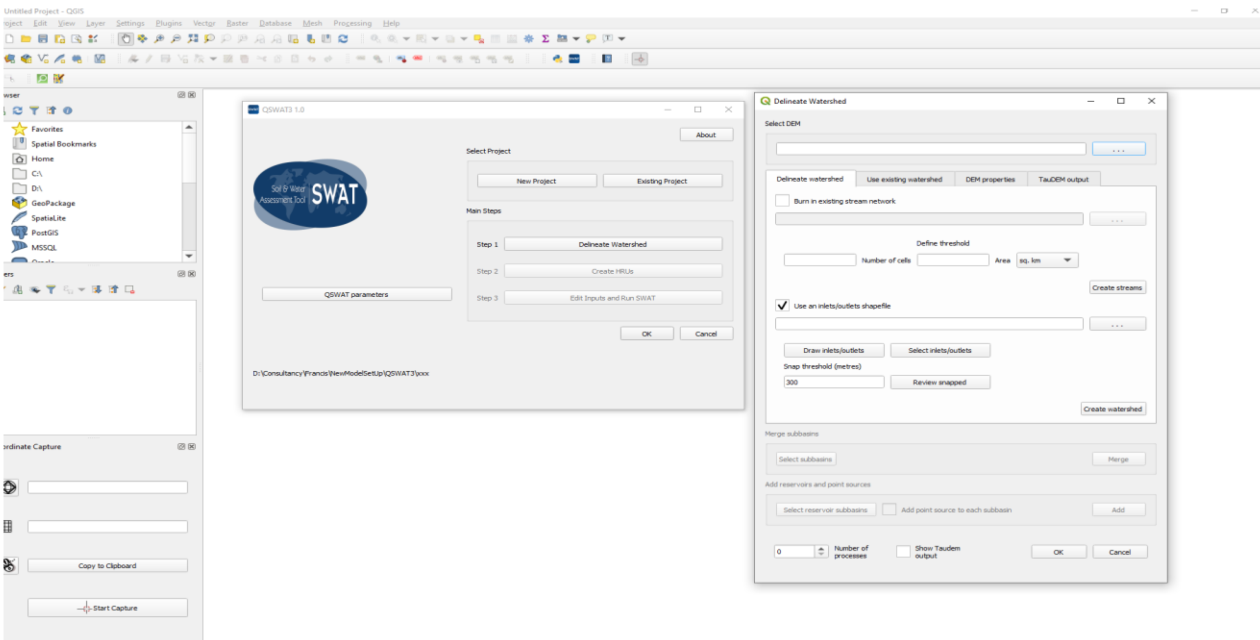


Figure 6: Watershed Delineation Dialogue Box

7.1. CREATE STREAMS

The delineation form allows for a predefined watershed and stream network by selecting the **Use existing watershed** tab. This implies that users can burn in an existing stream network using the option Burn in existing stream network. The threshold size for creating subbasins should be set next. It can be set by area, in various units such as sq. km or hectares, or by number of cells. For now, we shall **uncheck the Burn in existing stream network** and click **create streams**. This step will create the streams to be added on the map canvas (Figure 7).

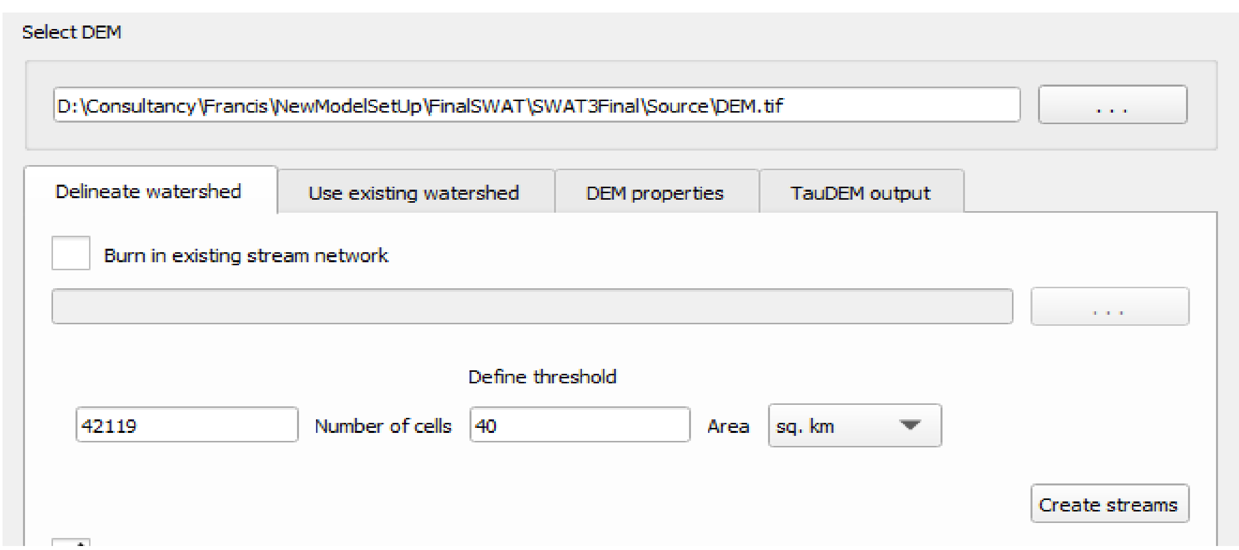


Figure 7: Create Streams

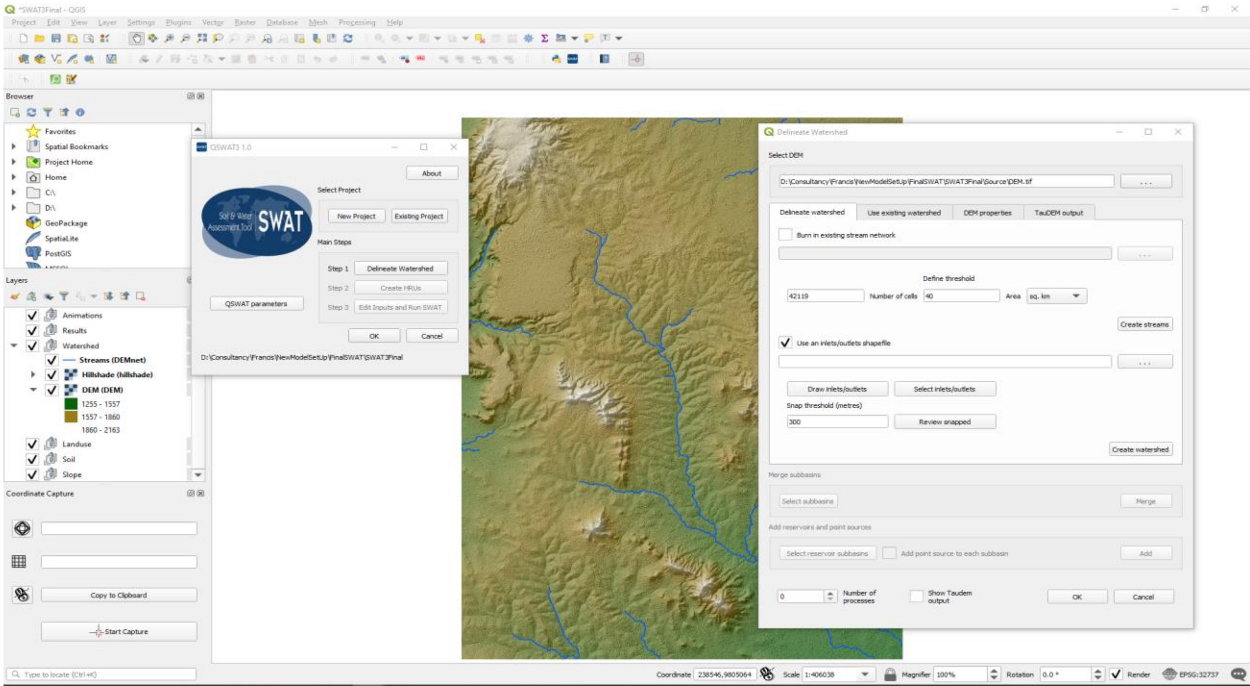


Figure 8: Stream created

7.2. CREATE WATERSHED

To generate watersheds, users are provided with two options: 1) **Use inlet/outlet shapefile**, or 2) **Add outlets/inlets using the Draw inlets/outlet options**. For this purpose, we shall choose the latter. Having made this choice, select **Draw inlets/outlets**, and click on the map to place it at the appropriate place. Points need to be placed on the stream network, and you may need to zoom in to place them precisely. Only points within the snap threshold of a stream reach will be counted as points. Once the outlet point is added, choose Select Inlets/Outlets and choose the intended outlet. When selecting multiple points, hold Ctrl and select the points by dragging the mouse to make a small rectangle around them. Selected points will turn yellow, and a count will be shown at the bottom left of the main window. Clicking **Review snapped** shows the snapped inlets/outlets, i.e. those within the defined threshold distance. Click **Create Watershed** to create the watershed after a few minutes (Figure 9). Note that this may take some time depending on the size of the watershed.

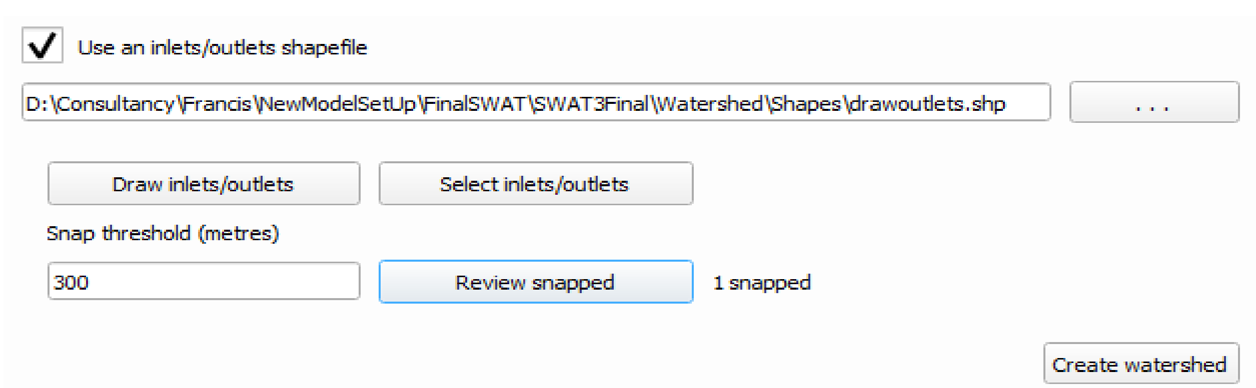


Figure 9: Create Watershed

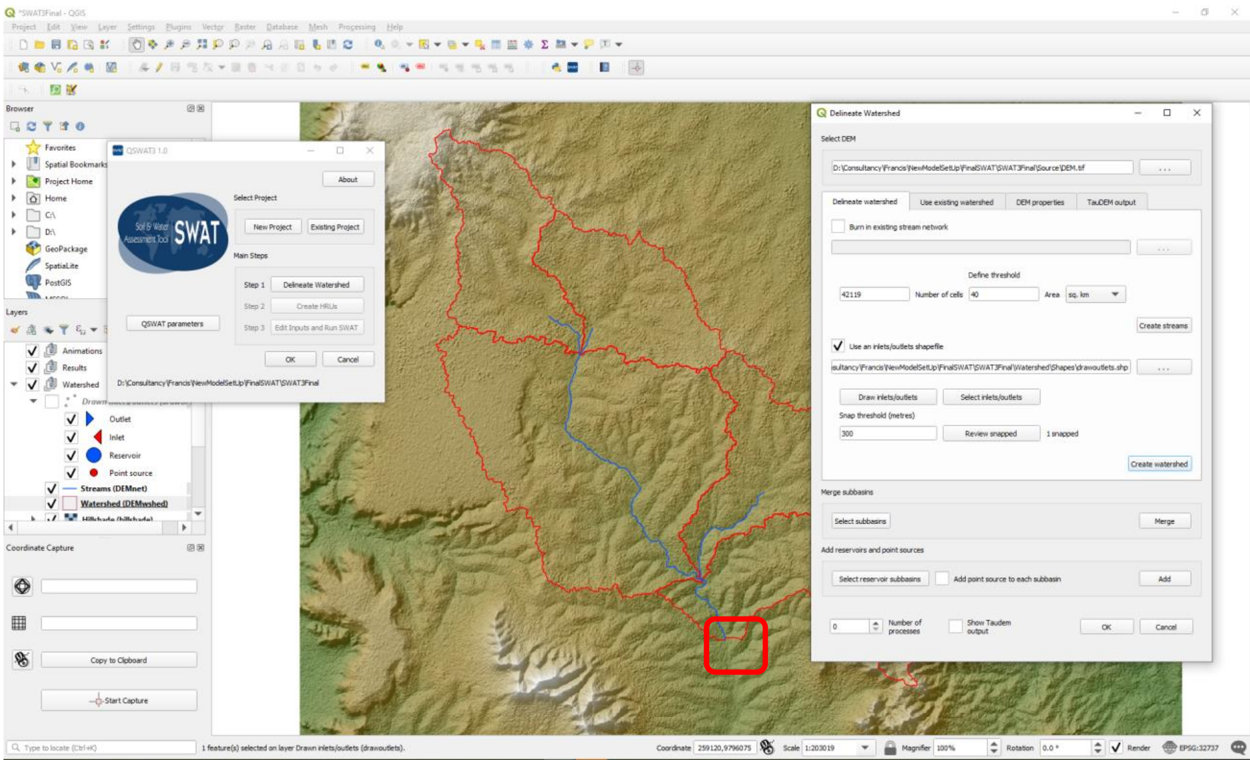


Figure 10: Watershed Created. Note the location of the outlet circled in **RED.**

You can as well merge some of the basins created and add reservoirs and point sources. For now, we skip this step and click Ok (Figure 11). The second step shall be activated.

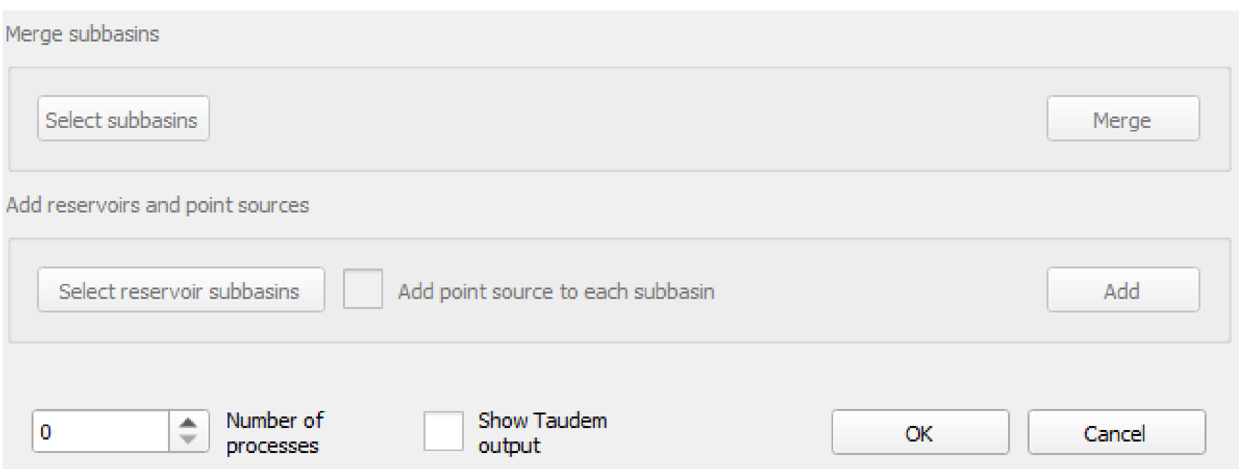


Figure 11: Merge sub-basins and add reservoirs/point sources.

8. STEP 3: CREATE HYDROLOGIC RESPONSE UNITS (HRUs)

Having calculated the basins, we will now calculate the details of the Hydrological Response Units (HRUs). HRUs are divisions of basins into smaller units each of which has a unique soil/landuse (crop)/slope range combination. To do this we will click **Create HRUs,** select: Landuse and soil files which should be prepared prior to this exercise.

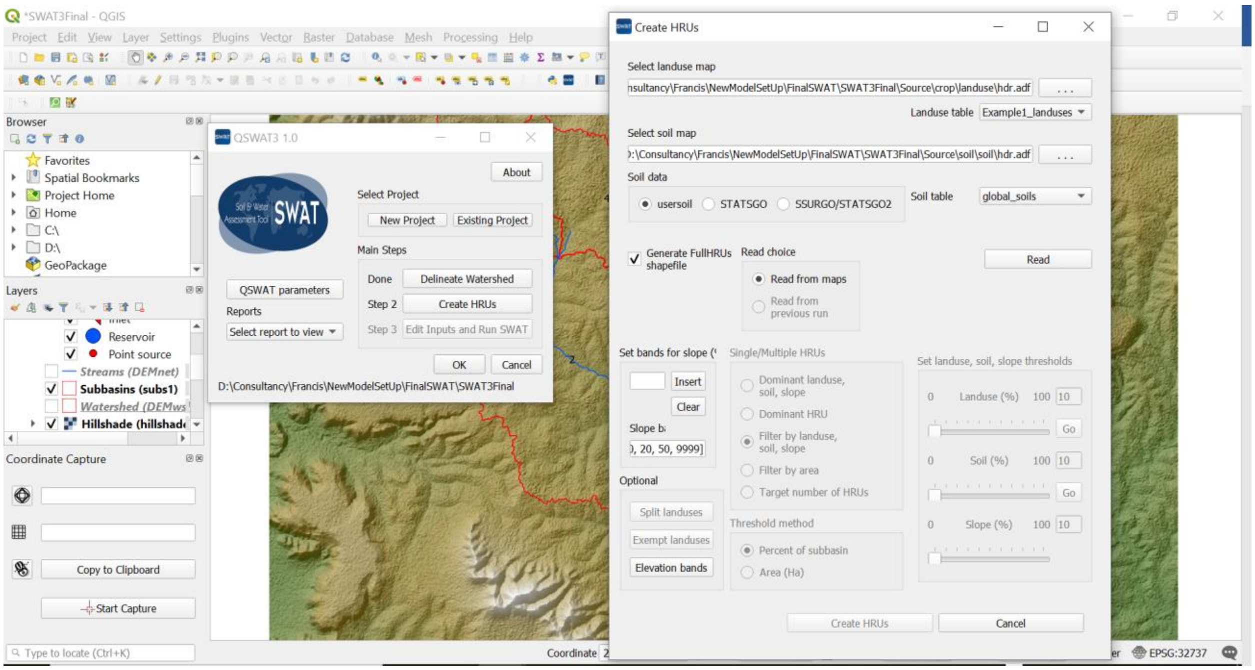


Figure 12: Create HRUs

We need lookup tables to convert from the numeric values found in the landuse and soil maps to SWAT landuse codes and soil names respectively. For the purpose of this tutorial, we have prepared the lookup tables for the landuse based on the SWAT landuse classification illustrated in Table 1 below. For soils, we will adopt the global soil lookup table. The tutorial on preparing landuse and soil lookup tables has been separately prepared. Note that the lookup tables are added to the project database. Import the landuse and soil files by clicking the buttons shown in Figure 13.

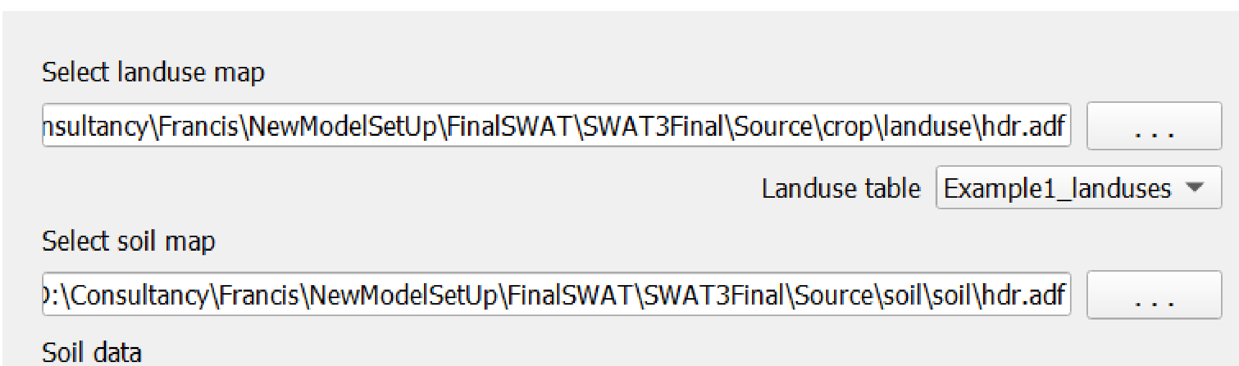


Figure 13: Select soil and landuse maps

For landuse, select the option *Example1_landuses* in the **Landuse table** pull-down menu. Make the same selection for **Soil table**. Make sure the **Soil data** option is set to *global_soil*. We will form HRUs based on slope as well as landuse and soil. We add an intermediate point for slopes (e.g. 12) to divide HRUs into those with average slopes in the range 0-12% and those with average slopes above 12%. Type 12 in the box and click **Insert**. The **Slope bands** box shows the intermediate limit is inserted. To generate the **Full HRUs** shapefile, click in the check box. To read in the data from the DEM, landuse, soil and slope maps and prepare to calculate HRUs, make sure Read from maps is checked and click Read (Figure 12).

Table 1: SWAT Landuse Classification

LANDUSE	DETAIL
WATR	Water
URML	Urban Medium Density
URHD	Urban High Density
UCOM	Urban Commercial
UINS	Urban Institutional
UIDU	Urban Industrial
UTRN	Urban Transportation
SWRN	South Western Range + Bare Rock
SWRN	South Western Range + Quarries/Mines
SWRN	South Western Range
FRSD	Deciduous Forest
FRSE	Evergreen Forest
FRST	Mixed Forest
RNGB	Range Shrubland
ORCD	Orchards/Vineyard
RNGE	Grasslands/Herbaceous
PAST	Pasture/Hay
AGRR	Row Crops
AGRC	Small Grains
AGRL	Generic
WETF	Woody Wetlands
WETN	Emergent/Herbaceous Wetlands

Once the data is read and stored, the Single/Multiple HRUs choice is enabled with five options:

- Dominant landuse, soil, slope provide just one HRU for each subbasin Dominant landuse, soil, slope chooses the landuse with the biggest area in the subbasin, the soil with the biggest area in the subbasin, and the slope range with the biggest area in the subbasin and uses them for the whole subbasin.
- Dominant HRU options provide just one HRU for each subbasin (i.e. option of Single HRU). Dominant HRU selects the largest of the potential HRUs in each subbasin and makes its landuse, soil and slope range the ones chosen for the whole subbasin.

- The options with Filter by landuse, soil, slope will ignore any potential HRUs for which the landuse, soil or slope is less than the selected threshold. The areas of HRUs that are ignored will be redistributed proportionately amongst those that are retained.
- Filter by area will ignore HRUs that are below a specified threshold amount (either percent of the subbasin, or area).; and
- Target number of HRUs create Multiple HRUs and limits the number of HRUs to a user preferred amount (i.e. between the lower limit of one HRU per subbasin and the upper one of retaining all potential HRUs).

For this exercise, use the method of Filter by landuse, soil and area. Set threshold of landuse, soil and slope to 10 and remember to click **Go** after entering each threshold (Figure 14). At this stage the we can create HRUs by clicking Create HRUs. The number of HRUs created will be reported at the top of the map canvas.

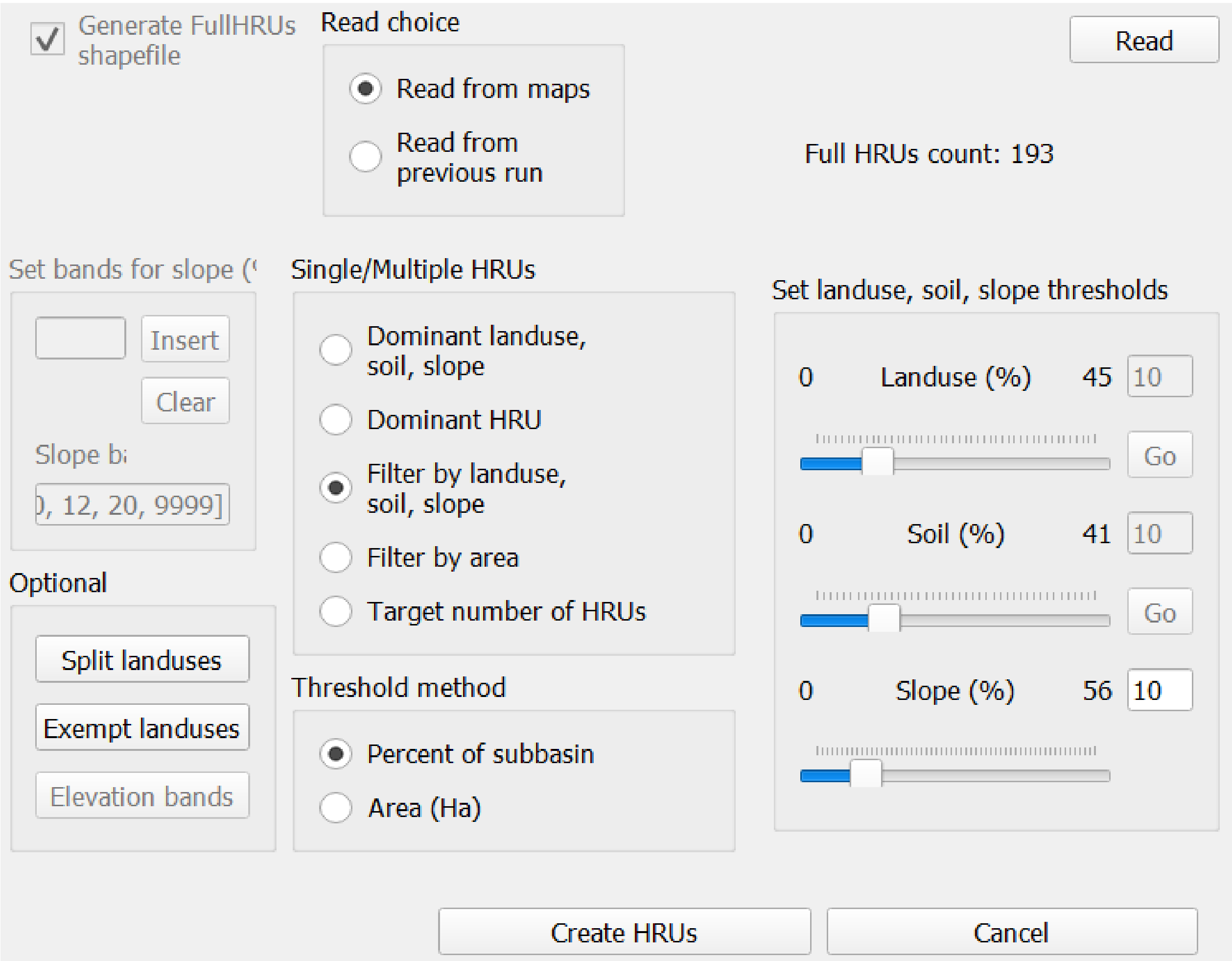


Figure 14: HRU options, set thresholds and create HRUs

Create HRUs is now reported as done and the third step is enabled (Figure 15). If you requested a Full HRUs file you will notice that an Actual HRUs file has now been added. This contains the potential HRUs that were retained as actual HRUs (and so typically has some holes representing those that were not retained). This file also shows the numbering of HRUs as well as subbasins.

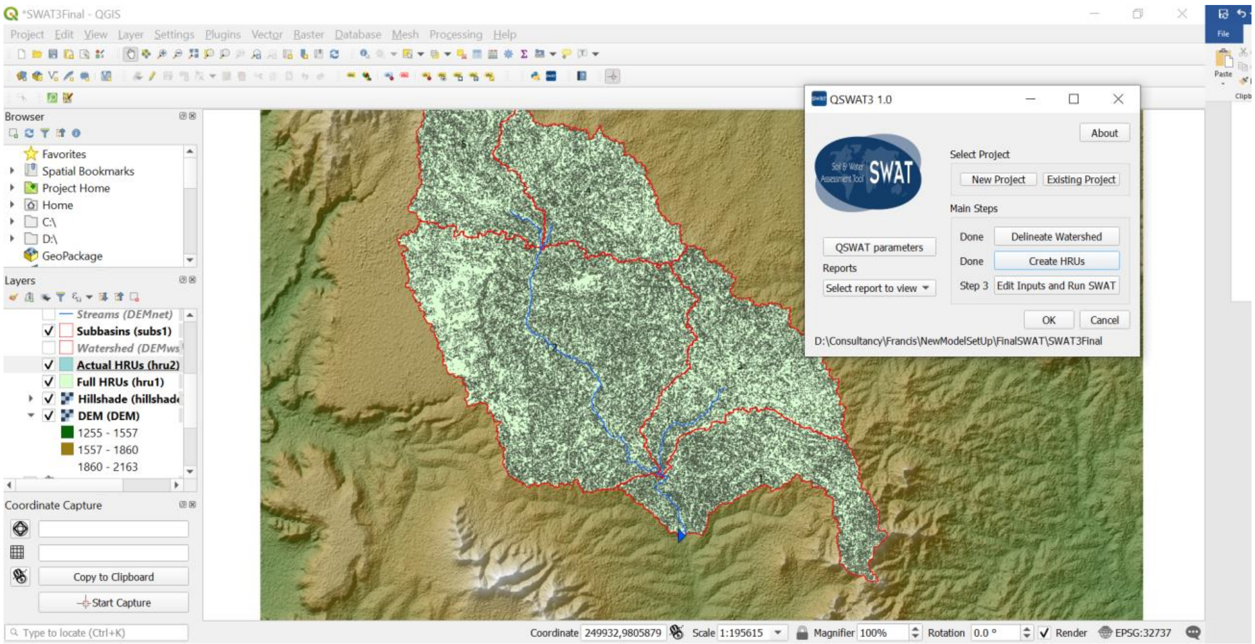


Figure 15: Created HRUs

9. STEP 3: EDIT INPUTS AND RUN SWAT

With the Step 2 completed, Step 3 will be automatically activated. We are now ready to start writing SWAT input files and run the model. Note that the SWAT Editor assumes dates written in mm/dd/yyyy format. Click Edit Inputs and Run SWAT to start the SWAT Editor.

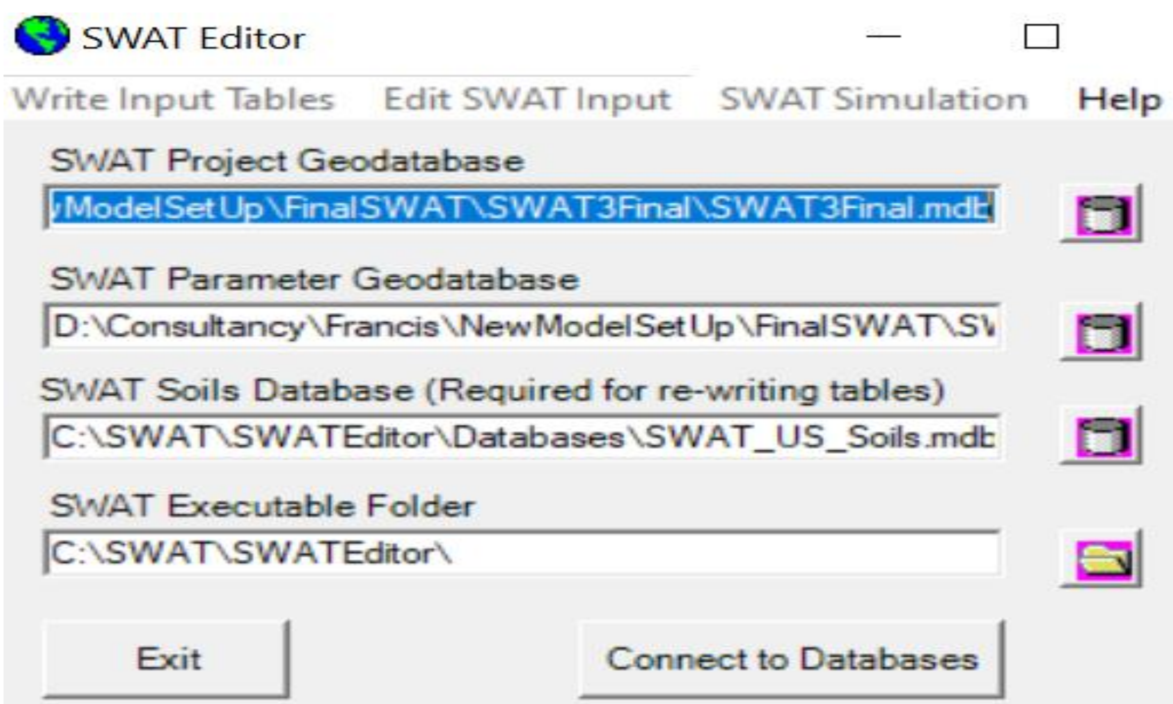


Figure 16: SWAT editor

Select the local **SWAT project database** and **reference database** (referred to as a Parameter Geodatabase) in the first two fields (Figure 17). An American soils database is selected by default in the third, and the SWAT Editor folder is selected in the third which is Ok but can as well be changed if necessary. Click Connect to Databases to connect to the project database and reference. All the tabs of the SWAT editor will now be activated. The QSWATRef2012 is selected in the second SWAT Parameter Geodatabase. Note that QSWAR3Final corresponds to the name of your project.

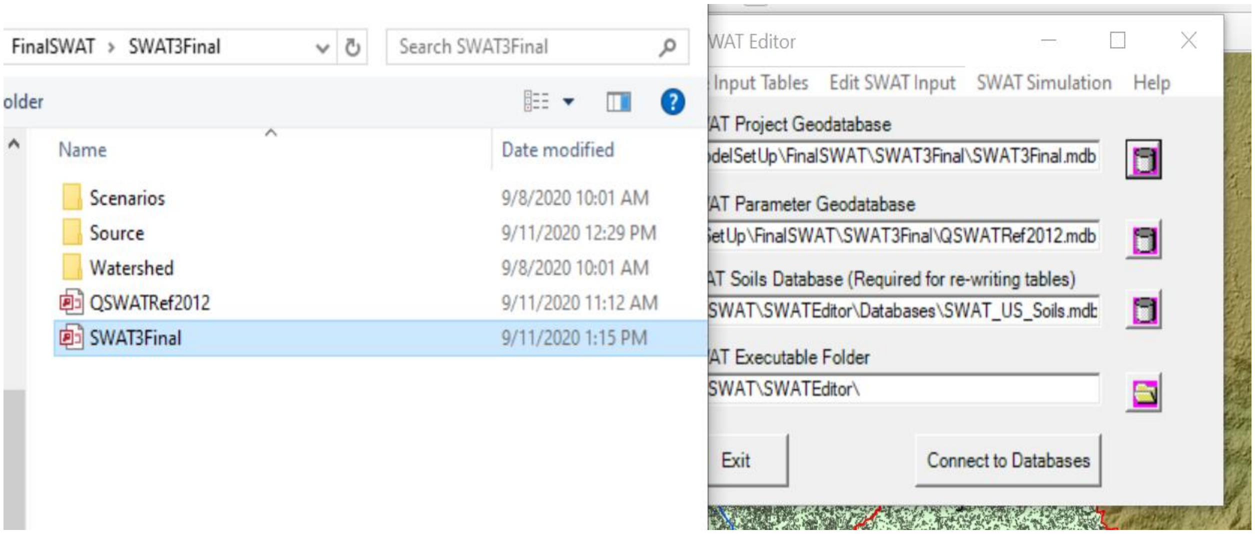


Figure: 17: Connecting the project to SWAT databases

Two categories of weather information are provided for in SWAT: 1) weather generator data and 2) actual weather data. Weather generator data is data about the typical weather in a locality, and its variability. It is input to a weather generator tool that will generate pseudo random data, and this is used when actual weather data is missing, either for particular dates, or for particular categories of weather. Note that SWAT will insist on defining a weather generator even if there is no missing actual data. Weather generator data is provided by a table of virtual weather generator stations, each with its own location and data. Five different types of actual weather data should be defined: precipitation, temperature, solar radiation, relative humidity and wind speed. With each climate data available, two files are specified: station file containing the names and locations of weather stations. and data file containing the data. Tutorial on climate data preparation for SWAT has been prepared separately.

The SWAT Editor should be provided with the station's files, since it can locate the data files. We shall use the Weather generator for now. For each tab for rainfall, temperature, relative humidity etc. check the option for **simulation** and Click **OK**. The climate data will be generated for each of the sub-basins. Note that the typical weather in the locality must be defined in data base. For our case we have defined this in the WGN_USER. Click Cancel to close the Weather Data Definition form.

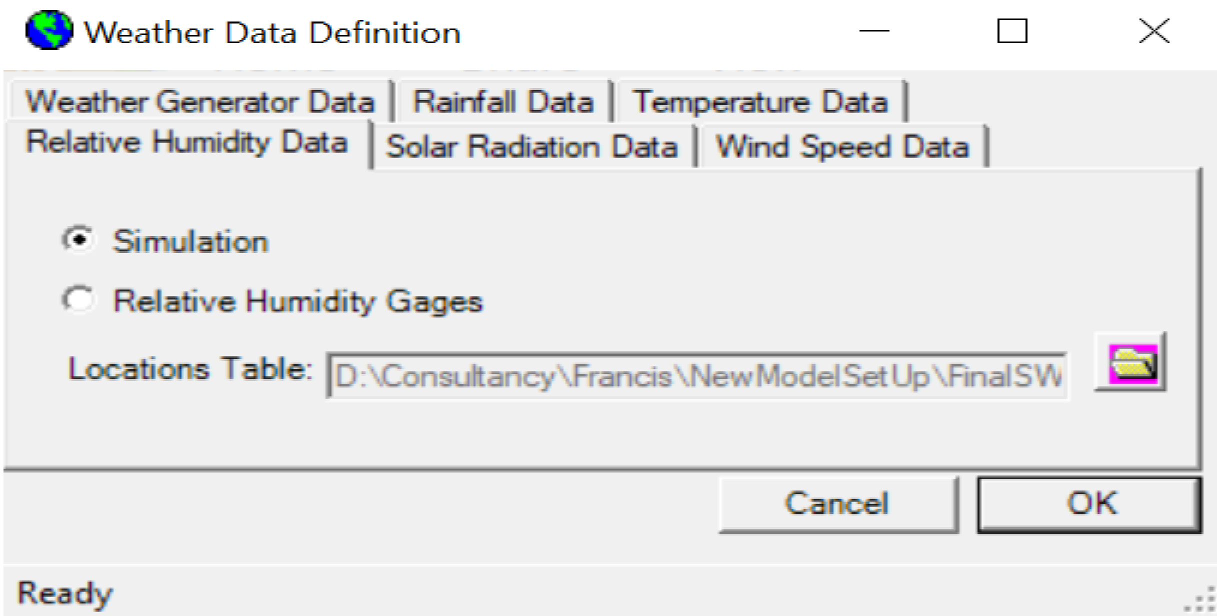


Figure 18: Weather Data Definition

To write the input tables and files ***select Write Input Tables → Write SWAT Input Tables***. Click **Select All** in the list box (Figure 20) and click the Create Tables button. There is a program for estimating the heat units needed for plant growth, using climate data, but it is currently available only for the USA. Since this project is outside the USA, choose the option No.

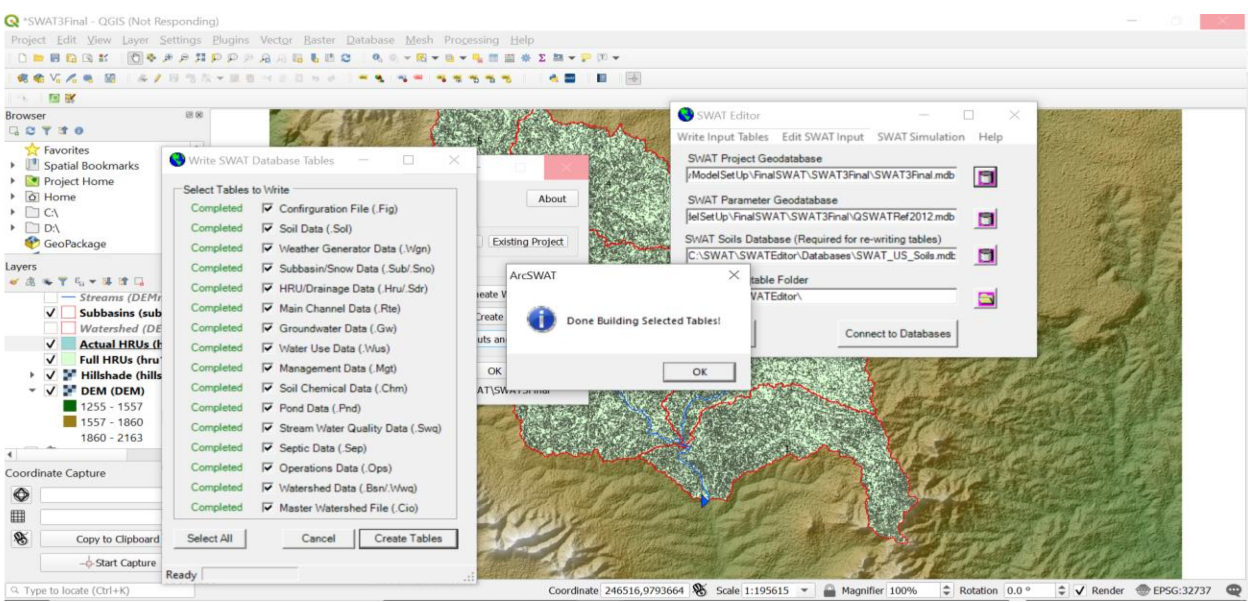


Figure 19: Writing SWAT Database Tables

Also answer No to writing point source, reservoir and inlet information. Writing the database tables can take a few minutes, especially if your simulation covers several years, but it is fast in this case. A form announces that the tables have been built, where you click OK to acknowledge. Click Cancel to exit.

Run SWAT by clicking on **SWAT Simulation → Run SWAT**. Since we did not provide actual climate data, the SWAT Editor will not calculate the minimum and maximum dates that we can use in the simulation. We set our simulation period as shown in Figure 20, chose Monthly time step, and NYSKIP (initial number of years to skip of 3), and leave the Output File Variables set to All. Select a release version of SWAT.exe, 64-bit if you have a 64-bit machine, else 32-bit. Click **Setup SWAT Run** to activate **Run SWAT**. Click **Run SWAT** to launch the SWAT executable command window. The command window will close and a message box will appear with information SWAT was run successfully. Click OK.

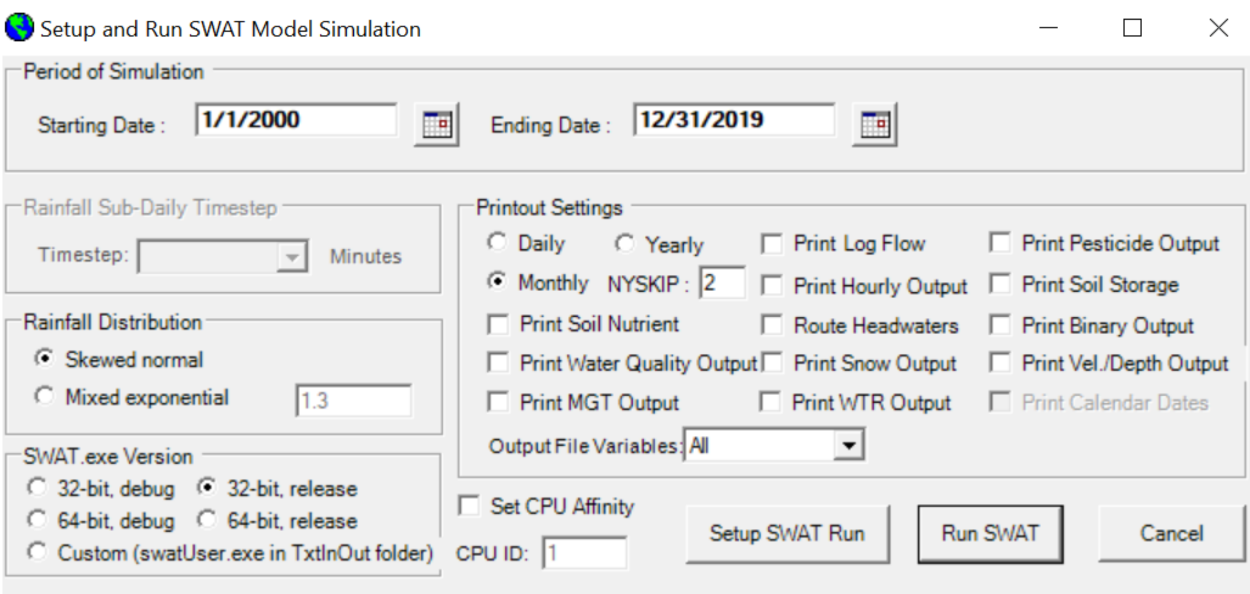


Figure 20: Setup and Run SWAT Model Simulation

10. DATA VISULIZATION

Now that we have run SWAT successfully, we will save the results in the output database. Select **SWAT Simulation**, **Read SWAT Output**. The SWAT Output dialogue will appear. Check the boxes **for output.rch, output.sub, output.hru, output.sed**, and click **Import Files to Database**. Name the simulation as SIM1 and click **Save Simulation** button. Click Cancel to exit from the SWAT Output form, and Exit from the **SWAT Editor**. Note that Step 4: **visualize** appears in the QSWAT dialogue. Click visualize to activate the Visualize results dialogue (Figure 22). Choose scenario as sim1, select sub-basin as SWAT Output Table. Leave the period default settings. Under static data, select SEDPkg_ha and click Add. Select the added variable and click create. A layer of sediment yield will be added to the map canvas. Repeat the same for other variables for sub(sub-basin), rch (reaches), hru (hydrological response units) and sed (sediments).

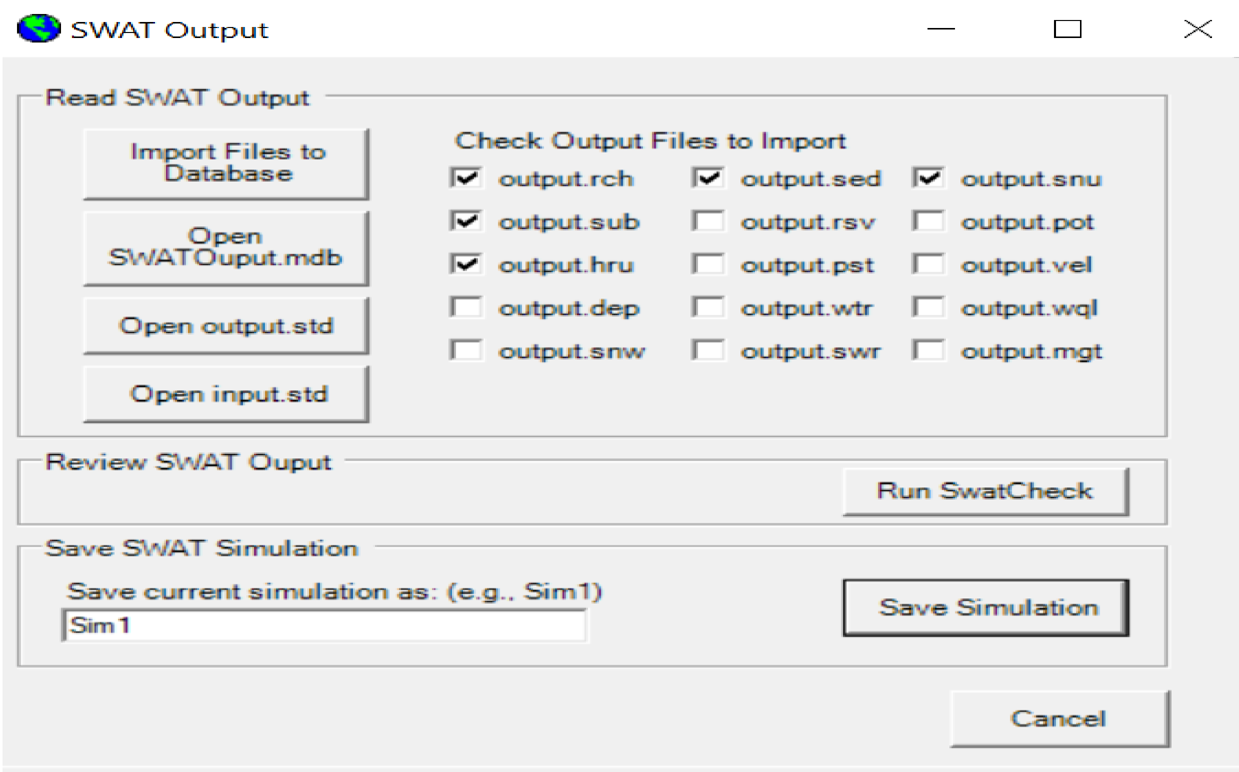


Figure 21: SWAT Output form

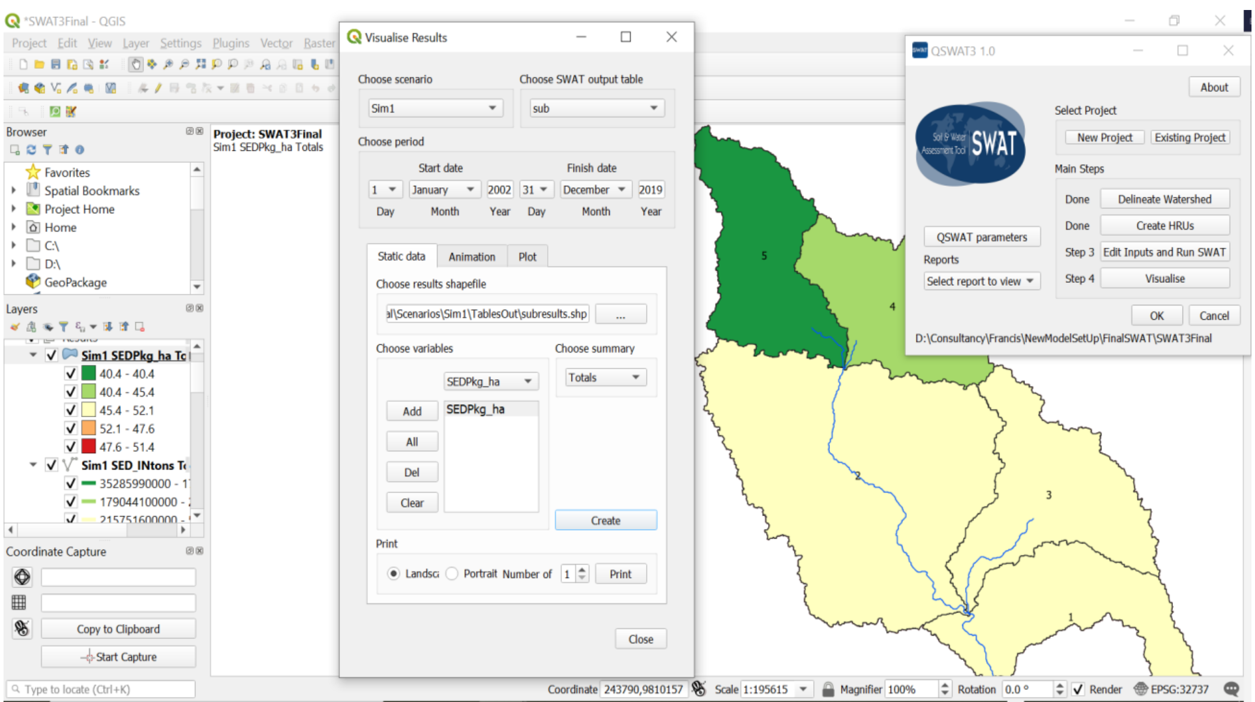


Figure 22: SWAT Results Visualization dialogue

We can now create a printout of the SWAT results by clicking on the **print button** on the **Visualize Results Dialogue**. The area several predefined templated provided in the GIS Print Composer.

You can either select portrait or landscape and choose the number of results to be printed. Note that the templates are not final but rather basic compositions which require further editing.

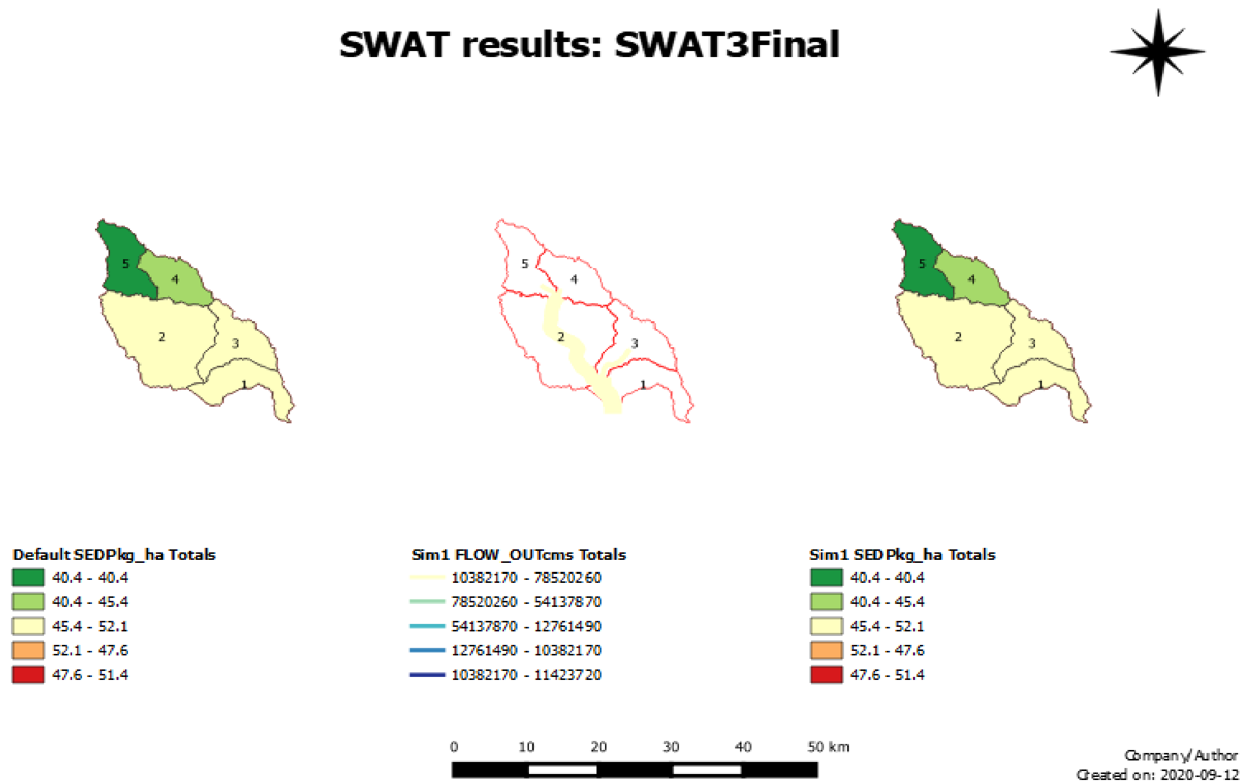


Figure 23: Print composition

11. REFERENCES

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Reddy, N.N., Reddy, K.V., Vani, J.S.L.S., Daggupati, P., Srinivasan, R., 2018. Climate change impact analysis on watershed using QSWAT. Spat. Inf. Res. https://doi.org/10.1007/s41324-017-0159-6

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