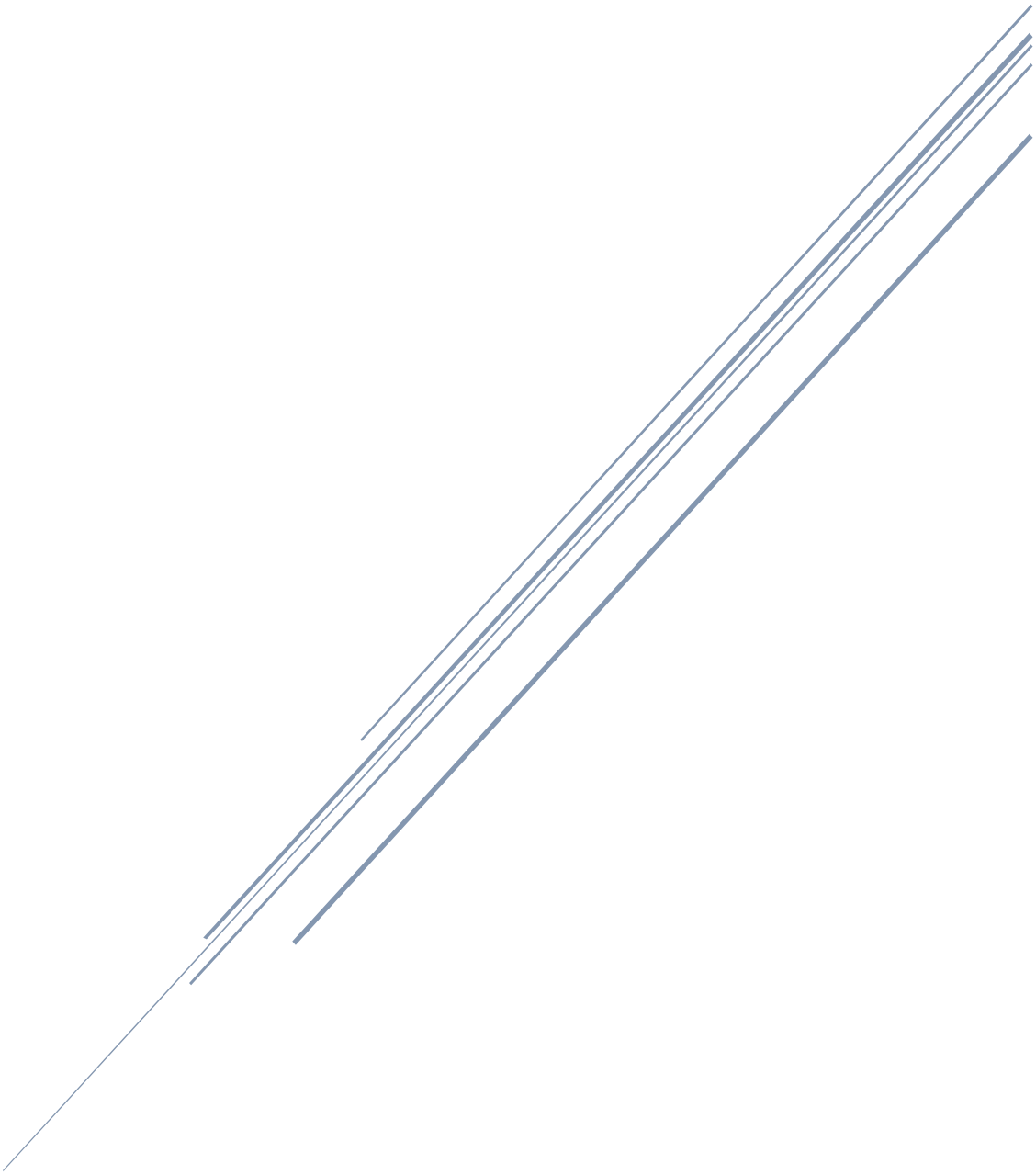
LUC SWAT+ TOOLKIT

Help Documentation



Bangor University-CoESE
Alex Rigby

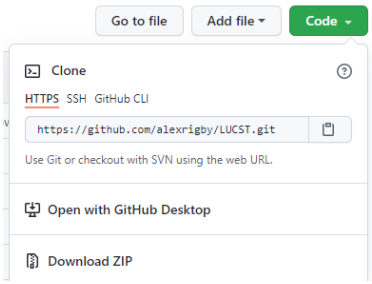
Table of Contents

1 Downloads

1.1 LUCST

Download: https://github.com/alexrigby/LUCST.git

To download go to the GitHub link and under the dropdown ‘Code’ choose ‘Download ZIP’. Extract the zipped files in a safe location on the machine you wish to run the toolkit from.

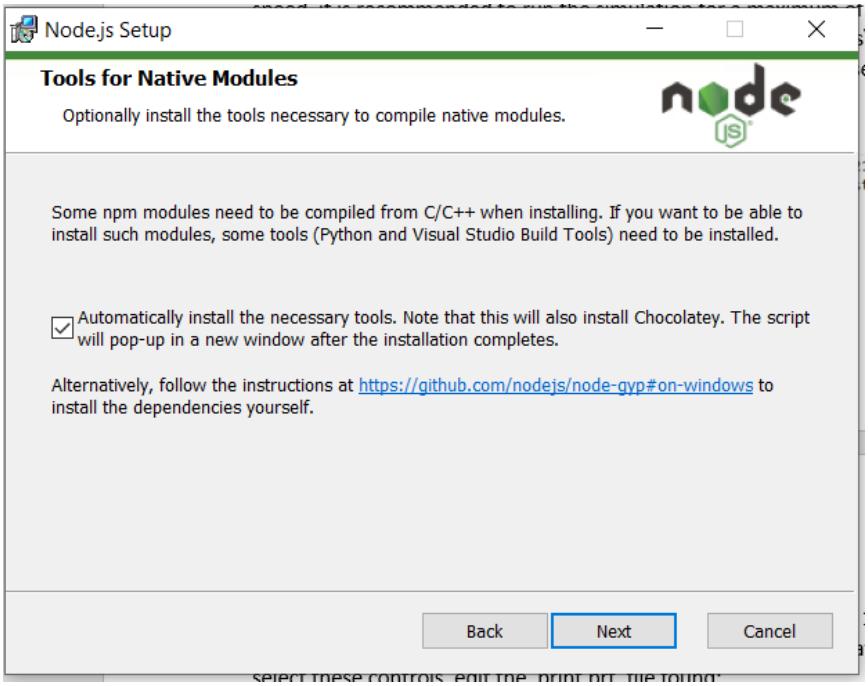


***IMPORTANT**: Depending on the number of scenarios and size of catchment the folder can become large, to prevent complications save LUCST in a location not synced to drop box or any other cloud storage service.*

1.2 Node.js, npm, Python

Installed Node.js, npm and Python 3 as a package: [Download | Node.js (nodejs.org)](nodejs.org) Choose the 64-bit version for Windows (.msi)

Follow the default instillation process, **TICK** the ‘automatically install the necessary tools’ in the ‘Tools for Native Modules’ window. Once node is installed a CMD (command line interpreter) window will appear displaying status of the ‘necessary tools’ instillation (this will take a few minutes).



2 Set Up

2.1 SWAT+ Catchment Generation

As its input data, the toolkit requires:

- A properly calibrated SWAT+ catchment model
- The catchments associated shape files produced in QSWAT+

If you are not familiar with SWAT+ please visit the links bellow:

- SWAT+ download: Installation - SWAT+ Documentation (gitbook.io)
- A Useful short video series on getting started with SWAT+: https://youtu.be/dBARtcejaPM
- A useful SWAT+ calibration tool is SWAT+ Toolbox, download and documentation: celray.github.io/docs/swatplus_toolbox/introduction.html

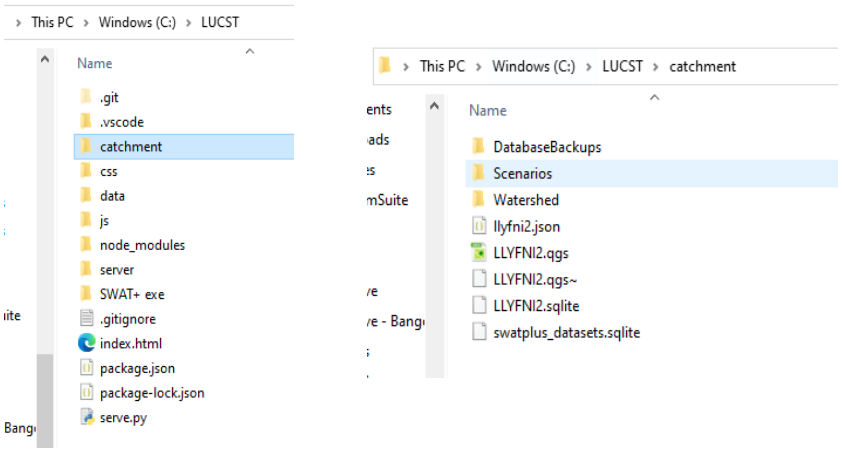
IMPORTANT: *The accuracy of the toolkit's outputs are fully reliant on the accuracy of the original input SWAT+ model. To ensure an acceptable accuracy only properly calibrated catchments with an acceptable NSE (Nash Sutcliffe Efficiency) of 0.5 and above should be studied using the toolkit.*

2.2 Catchment Preparation for Toolkit

2.2.1 Importing a Catchment to the Toolkit

To prevent accidental corruption of local files the ability to navigate and connect to local file systems was excluded from the toolkits interface.

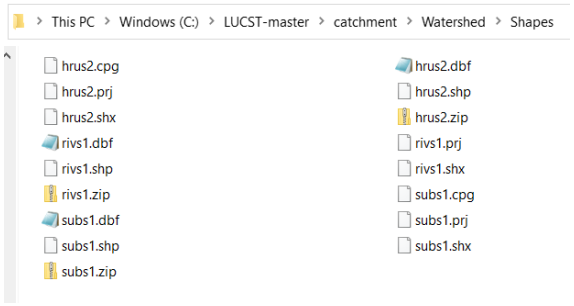
To study a catchment in the toolkit, make a copy of the SWAT+ generated project folder and paste the copy into the 'LUCST-master' folder. Then rename the SWAT+ project folder 'catchment' (once all desired scenarios are studied the project can be copied out of the folder and renamed accordingly). See file structure:



2.2.2 Zipping Shape Files

The toolkit uses zipped shapefiles to generate the catchment map layers. Navigate to 'LUCST-master\catchment\Watershed\Shapes'. Compress (zip) all files with the prefix's:

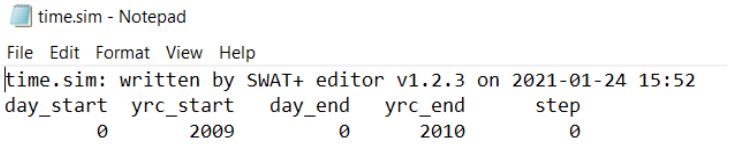
- 'hrus2' (hrus2.zip)
- 'rivs1' (rivs.zip)
- 'subs1' (subs1.zip)



****To compress: With the files selected, right click the files, choose 'send to' and 'compressed (zipped) folder'.*

2.2.3 Simulation Run Time

Before it is loaded on the browser the SWAT+ simulation must be run once. To maximise toolkit speed, it is recommended to run the simulation for a maximum of 2 years. Control model run time by editing the 'time.sim' file: 'LUCST-master\catchment\Scenarios\Default\TxtInOut\time.sim'. 'yrc_start' represents the first year of the model, 'yrc_end' represents the last. See example:



It is recommended to allow for 1-year warm up period (therefore 1-year printed data). The controls to print the monthly 'hru_wb' and daily 'channel_sd' in CSV format also need to be selected. To select these controls, edit the 'print.prt' file found:
'LUCST-master\catchment\Scenarios\Default\TxtInOut\print.prt'. See example:

print.prt - Notepad

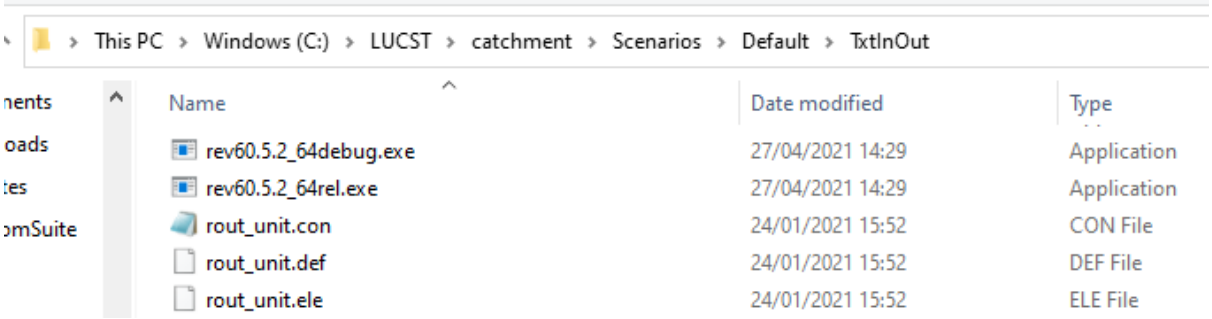
File Edit Format View Help

```
print.prt: written by SWAT+ editor v1.2.3 on 2021-01-24 15:52
nyskip     day_start  yrc_start  day_end   yrc_end   interval
1          0          0          0         0         1
aa_int_cnt
0
csvout       dbout         cdfout
y            n             n
soilout      mgtout        hydcon        fdcout
n            n             n             n
objects                 daily       monthly        yearly         avann
basin_wb                   n             n             n             n
basin_nb                   n             n             n             n
basin_ls                   n             n             n             n
basin_pw                   n             n             n             n
basin_aqu                  n             n             n             n
basin_res                  n             n             n             n
basin_cha                  n             n             n             n
basin_sd_cha               n             n             n             n
basin_psc                  n             n             n             n
region_wb                  n             n             n             n
region_nb                  n             n             n             n
region_ls                  n             n             n             n
region_pw                  n             n             n             n
region_aqu                 n             n             n             n
region_res                 n             n             n             n
region_cha                 n             n             n             n
region_sd_cha              n             n             n             n
region_psc                 n             n             n             n
lsunit_wb                  n             n             n             n
lsunit_nb                  n             n             n             n
lsunit_ls                  n             n             n             n
lsunit_pw                  n             n             n             n
hru_wb                     n             y             n             n
hru_nb                     n             n             n             n
hru_ls                     n             n             n             n
hru_pw                     n             n             n             n
hru-lte_wb                 n             n             n             n
hru-lte_nb                 n             n             n             n
hru-lte_ls                 n             n             n             n
hru-lte_pw                 n             n             n             n
channel                    n             n             n             n
channel_sd                 y             n             n             n
aquifer                    n             n             n             n
reservoir                  n             n             n             n
recall                     n             n             n             n
hyd                        n             n             n             n
ru                         n             n             n             n
pest                       n             n             n             n
```

The model can be run via SWAT+ Editor (downloaded with the SWAT+ model), SWAT+ Toolbox or using the exe files found in the 'SWAT+ exe' file (downloaded with this toolkit).

2.2.4 Add the model exe files

Finally, copy and paste the two .exe files from the 'SWAT+ exe' folder (downloaded with LUCST) into 'LUCST-master\catchment\Scenarios\Default\TxtInOut'. These executable files are used to run the model.



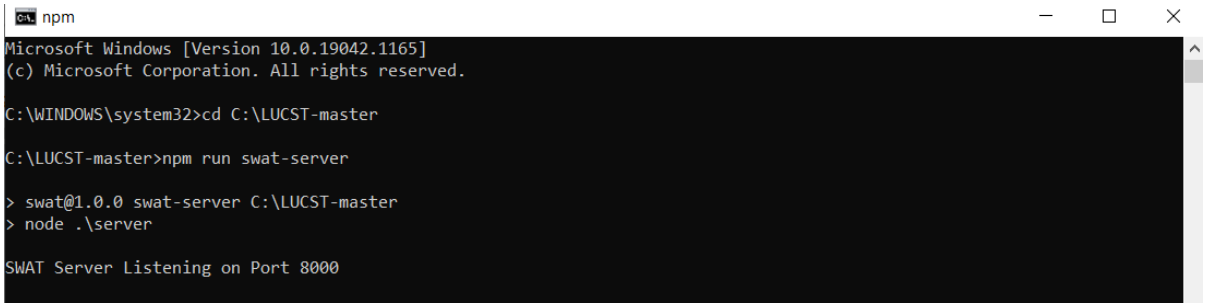
****LUCST runs with 'rev60.5.2_64rel' of SWAT+. This can be changed by altering the config file at '\LUCST-master\server\config.js'.*

IMPORTANT: *LUCST is a personal development and is not updated regularly therefore it is not guaranteed that revisions to SWAT+ in later releases will work as expected through the toolkit.*

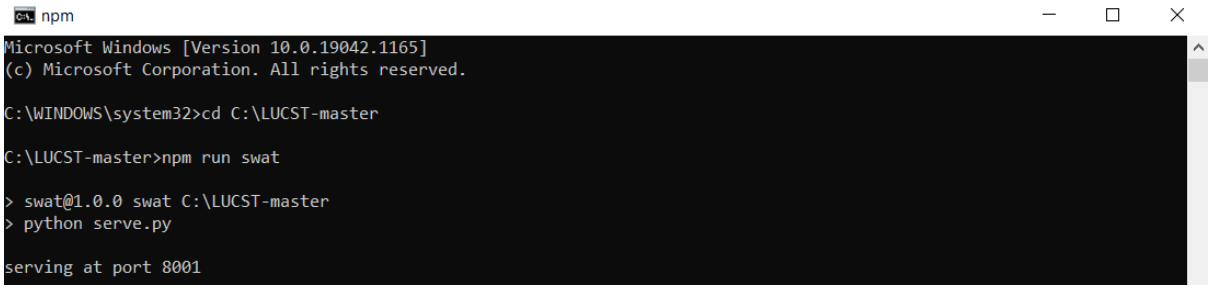
2.3 Server Set Up

IMPORTANT: *If this is the first time the toolkit has been used on this machine then in CMD (Command Prompt) navigate to the toolkit location by typing 'cd [file location]\LUCST-master' and pressing enter. From here type the command 'npm install' to install all relevant packages.* ***DO NOT*** *follow this step if you have previously installed the relevant packages, go straight to section 2.3.2.*

Launch the "data server" (back end): Open CMD and navigate to the toolkit location by typing '*cd [file location]\LUCST-master'* and pressing enter. Launch the server by typing '*npm run swat-server'* and pressing enter on the keyboard.



Launch the front-end server: In a new CMD window navigate to the file location again. Launch the Python server by typing '*npm run swat'* and hitting enter on the keyboard.

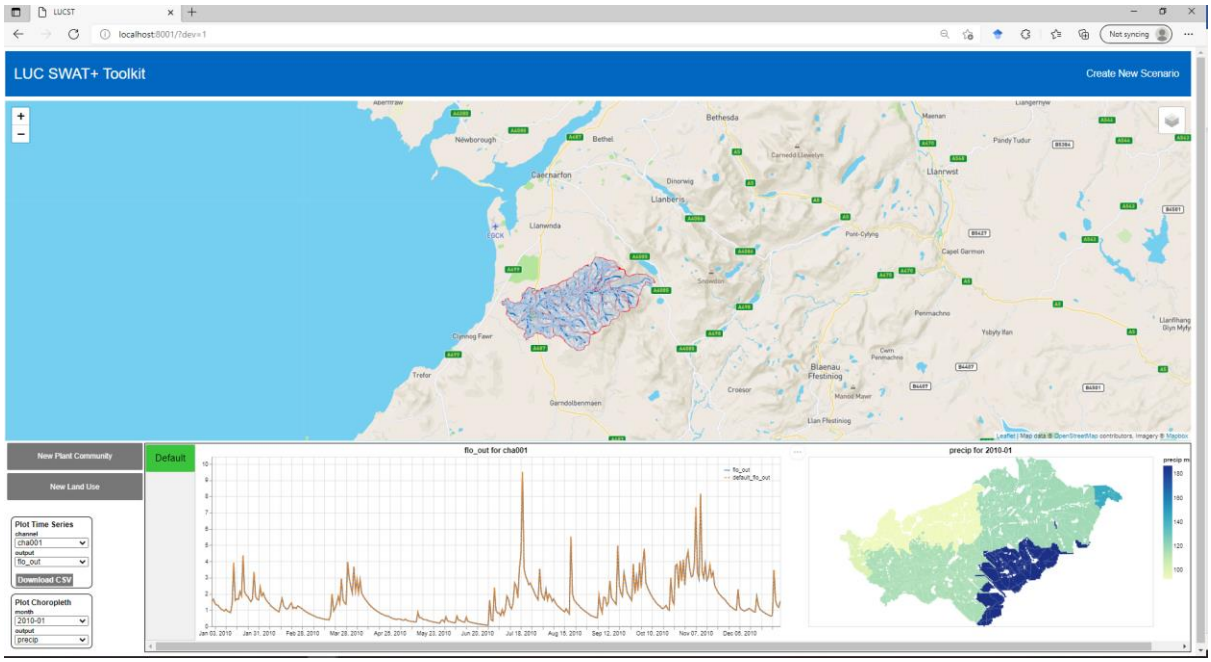


3 Using the Toolkit

3.1 Opening the Toolkit

Navigate to the URL in your chosen browser: http://localhost:8001/?dev=1

The toolkit should now be running on the server port 8001 on your local machine (step 2.3). The toolkit should now open with your SWAT+ catchment displayed in the map window. See example:

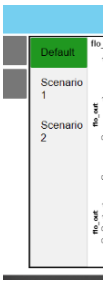


IMPORTANT: *If any changes are made to the SWAT+ files manually the window must be refreshed for those changes to be displayed on the interface*

3.2 Scenarios

3.2.1 Scenario Tab List

The grey sidebar to the left of the time series and choropleth plots in the lower half of the page is the scenario tab list. All scenarios for your catchment will display in this list. When a scenario is selected (highlighted green) the entire window will display the data of the current scenario. Any changes made when a scenario is selected will save to that scenario (therefore changes can be overwritten).



3.2.2 Default Scenario

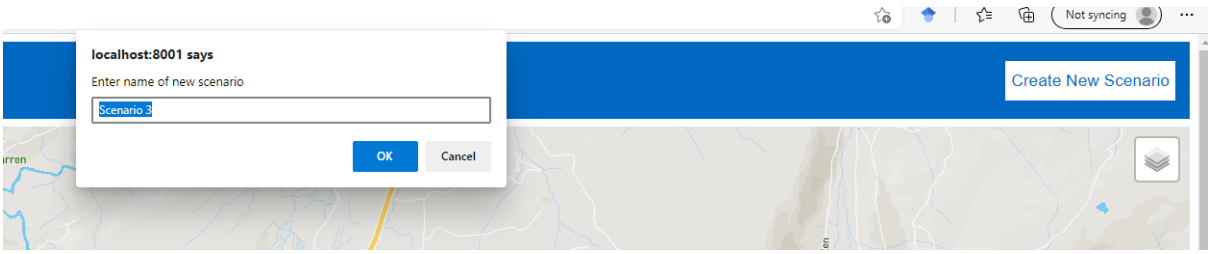
When the toolkit loads the 'Default' scenario is selected as the current scenario, therefore all data displayed is from 'Default'.

The 'Default' scenario is created by SWAT+ when the catchment is defined (section 2.1). 'Default' represents the current state of the catchment and must remain unchanged to be used as a baseline scenario for comparison.

To avoid making changes to 'Default' all functions which allow changes to be made are disabled when 'Default' is selected. Visualization controls are enabled as these are 'passive', i.e., read, but do not alter the SWAT+ files.

3.2.3 Creating a New Scenario

To create a new scenario, click 'Create New Scenario' (top right of page). This will prompt you with a pop-up window with an automatically assigned new scenario name (different scenario name can be chosen). Click 'ok' to make the new scenario. The new scenario should appear in the scenario tab.

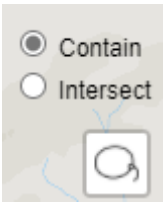


The new scenario is an exact copy of the 'Default' scenario and will now appear in your catchment file 'LUCST-master\catchment\Scenarios'.

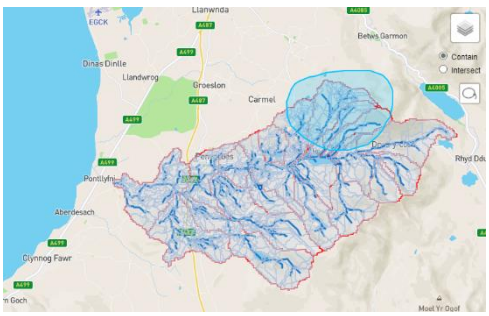
3.3 Making Land Use Changes

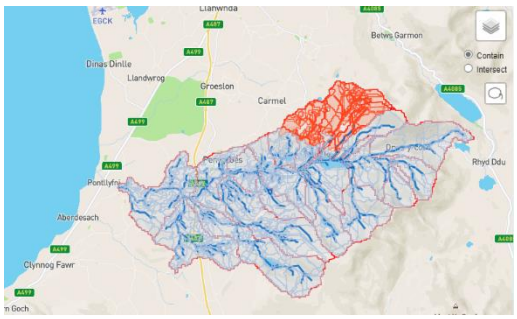
3.3.1 Lasso selection

When not in 'Default' the lasso controls will appear in the top right of the map. Choose between the 'contain' and 'intersect'.



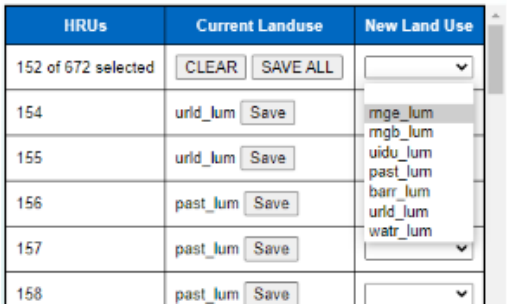
To make a selection, click the lasso icon in the top left of the map, the cursor will turn into cross head indicating the 'lasso tool' is activated. Press and hold the mouse on the map and either circle or intersect an area, release the mouse when the selection is made. The selected layers will turn red and the land use change table will generate to the right of the map.





3.3.2 Land use change table

Selected HRUs along with their current land use populate the land use change table (pop-up to the right of the map once a selection is made).



In the 'New Land Use' column select a land use from the drop-down menu, click 'SAVE ALL' in the top row to change the land uses for of the entire selection. Alternatively, do the same but for individual HRUs and pressing 'Save'. Pressing the 'CLEAR' button will clear the selection.

IMPORTANT: *The land uses you see in the drop-down menu are limited to the existing land uses in the catchment. If you wish to create a new land use that does not exist in the catchment, please perform the steps described in Section 3.3 and then repeat the above Lasso procedure.*

Hover the mouse over a land use code in the dropdown menu to display some of its defining parameters.

The HRUs 'id' and corresponding land use are taken from SWAT+'s 'hru-data.hru' file and the land use dropdown menu is generated from the 'landuse.lum' file. More information on these files and their parameter codes can be found in the SWAT+ input documentation: [SWAT+ IO Documentation - SWAT+ Documentation (gitbook.io)]

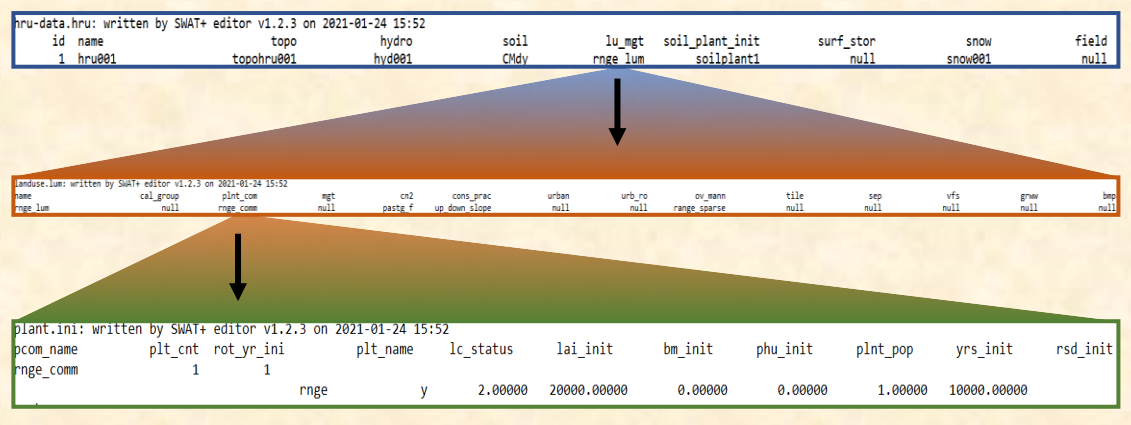
****HRUs (Hydrological Response Units) are the smallest spatial unit that make up the SWAT+ model and are where individual calculations take place. Each HRU has a land use as well as several other parameters. An individual HRUs parameters can be found by clicking the HRU layer on the map.*

3.4 Making New Plant Community and Land Use

3.4.1 SWAT+ File Structure

The SWAT+ model runs by reading codes from files which are defined in connected files. The top-level file is 'hru-data.hru' which contains codes defining each HRU. When making land use changes to 'hru-data.hru' two other files are important: 'landuse.lum' and 'plant.ini'.

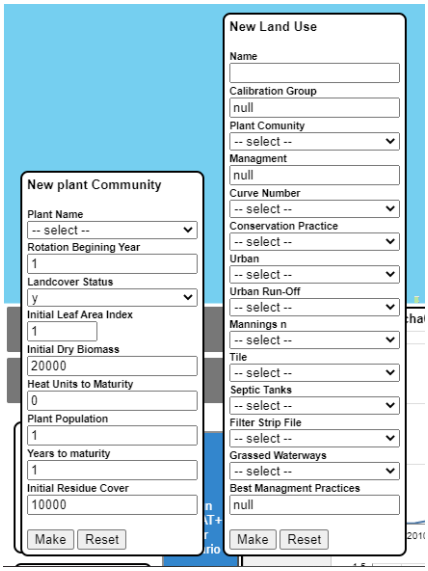
The land use of a HRU is stated in 'hru-data.hru' under lu_mgt (land use management). All land use codes are defined in the 'landuse.lum' file. In turn, the plant community of a land use is stated in 'landuse.lum' under plt_com (plant community). All plant community codes are defined in the 'plant.ini' file.



When the catchment is first set up in SWAT+ (section 2.1) the land uses and plant communities which are present in its current state are added to these files. To incorporate new land uses and plant communities to the catchment they first need to be written to the corresponding files.

3.4.2 Plant Community and Land Use Forms

To make a new plant community or landuse type click the 'New Plant Community' button or the 'New Land Use' button respectively (bottom left of the page) to open up the pop-up forms. Some of the input fields have default values for ease of use but can be changed if required. Each input field must be filled in. Click 'make' to write the new plant community to the plant.ini file or land use to 'landuse.lum'. Click 'reset' to clear the forms. Click on the map area to close both forms.



For each input field drop down list a short description of each code in the list is displayed when the mouse is hovered over it. For a more in depth description of all the input variables refer to the SWAT+ input documentation: [SWAT+ IO Documentation - SWAT+ Documentation (gitbook.io)](#) .

3.4.3 Plant Community Input Fields

Input Name	Field Name in 'plant.ini'	Description
Plant Name	plt_name	Drop down list off all the pre-defined plant types in SWAT+ (connects to 'plant.plt' file)
Plant Community Name	pcom_name	Automatically populated with plt_name + '_comm' suffix
Rotation Beginning Year	rot_yr_ini	Year of simulation plants first come into rotation
Landcover Status	lc_status	Does the plant provide land cover at the beginning of the simulation
Initial Leaf Area Index	lai_init	Leaf area per unit of ground/trunk area of a plant
Initial Dry Biomass	bm_init	Initial dry biomass in kg/ha
Heat Units to Maturity	phu_init	Number of growing degree days needed to bring plant to maturity
Plant Population	plant_pop	Plant Population
Years to Maturity	yrs_init	Number of years from start of simulation until plant is mature
Initial Residue Cover	rsd_init	Initial residue cover/stover in kg/ha

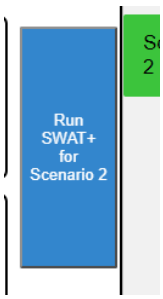
**** 'plt_cnt' value in 'plant.ini' are automatically set to 1. At the current stage of development, the toolkit doesn't have the complexity to add multiple plants to each plant community so there is no use in giving the user control over this variable*

3.4.4 New Land Use Input fields

Input Name	Field Name in landuse.lum	Connected file	Description
Name	name	n/a	Automatically populated in the toolkit with either plant type or urban, must have '_lum' suffix
Calibration Group	cal_group		Specify land use belongs to specific calibration group
Plant Community	plnt_com	plant.ini	Plant community present in land use if urban value must be 'null'
Management	mgt	management.sch	Management operations, leave value as 'null' if not needed
Curve Number	c2	cntable.lum	Run-off curve number, parameter to predict direct run-off or infiltration from rainfall
Constervation Practice	cns_prac	cons-prac.lum	Code for conservation practices, uses USLE (universal soil loss equation)
Urban	urban	urban.urb	Urban land use, if plant community is selected then urban must be 'null'
Urban Run-Off	urban_ro	n/a	Urban run-off simulation code, determines how urban run-off is calculated, used to estimate sediment and nutrient loadings
Manning's n	ov_mann	ovn_table.lum	Overland manning's n value, estimate of flow over hillslope
Tile	tile	tiledrain.str	Presence of tile drains (drainage of subsurface water, usually from agricultural land)
Septic Tanks	sep	septic.str	Presence/type of onsite wastewater system
Filter Strip File	vfs	filterstrip.str	Presence/type of filter strip, strip of dense vegetation on hillslope to intercept run-off from upslope pollutant
Grassed Waterways	grww	grassedww.str	Presence/type of grassed waterways, vegetation within channels
Best Management Practices	bmp	bmpuser.str	No built in SWAT+ options, allows removal of constituents from model based on user defined management practice

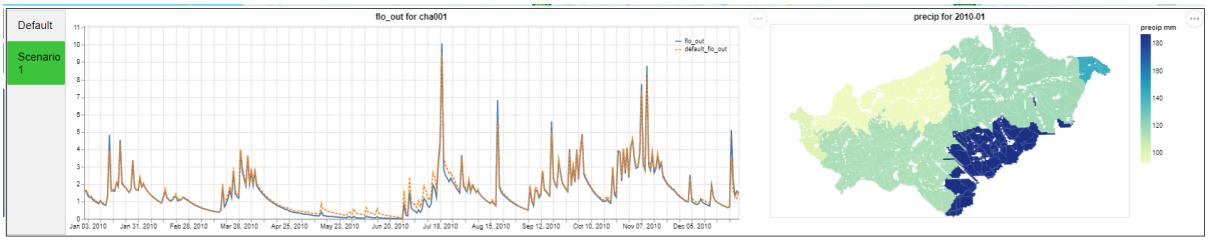
3.5 Running the Simulation

Once all desired changes have been made click the blue button to the left of the scenario tab 'Run SWAT+ for (scenario name)'. A spinner will appear indicating that the model is running. Depending on the size of the catchment and length of simulation this could take several minutes.



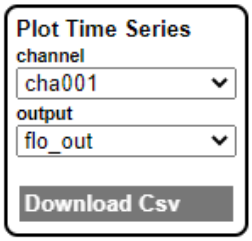
3.6 Visualization Controls and Model Comparison

Data for the time series plot is taken from the SWAT+ output file 'channel_sd_day', data for the choropleth is taken from 'hru_wb_mon'. Descriptions of the plottable data from these files can be found in the SWAT+ output documentation: SWAT+ IO Documentation - SWAT+ Documentation (gitbook.io).



3.6.1 Time Series Plot

A hydrograph (flo_out vs time) for the main channel is plotted by default when the page loads. By selecting from the dropdown lists in the 'Plot Time Series' box (bottom left) a plot for any of the channels and any of the 'channel_sd_day' outputs can be generated.

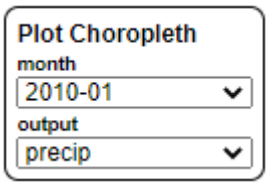


Data for the current scenario is plotted with a blue line and the same data for the 'Default' scenario is plotted with an orange dashed line for comparison of outputs. If no changes have been made to the current scenario then the lines will be plotted on top of one another.

The raw CSV data for the current plot can be downloaded by pressing the 'Download CSV' button in the 'Plot Time Series' box. Alternatively, and SVG and PNG can be downloaded by pressing the three grey dots to the top right of the plot.

3.6.2 Choropleth

Precipitation for the first month of the model is plotted when the page first loads. Like for the time series plot, by selecting from the dropdown lists in 'Plot Choropleth' any of 'hru_wb_mon' outputs for any of the model months can be plotted. An SVG and PNG of the choropleth can be downloaded by clicking the three grey dots to the top right of the choropleth.



****to identify a specific channel, click on the channel on the map and a pop up will appear, the 'Channel' value is the id of that channel and can be selected in the visualization drop down option lists.*