

SWAT Model Guide: Malibu Creek Woolsey Fire Example using ArcSWAT

A. Before setting up SWAT model prepare input datasets

1. DEM raster
2. Mask raster (optional)
3. Soil cover raster (option to use ArcSWAT pre-loaded STATSGO or SSURGO)
4. Burn severity raster
5. Pre-fire land cover raster
6. Post-fire land cover raster – Creating post-fire land cover raster requires a combining a soil burn severity map for the fire of interest with the pre-fire land cover raster in your watershed. See steps below.
7. Ensure that all rasters are in the same **projected** coordinate system
8. Precipitation and temperature text files – These files require very specific formatting, see SWAT manual for details. Option to use the NASAAccess tool <https://github.com/nasa/NASAaccess>.
9. Subbasin Outlet Location Table – this is a .dbf file that tells ArcSWAT the location of the monitoring gages that you will be using for calibration-validation. Specifying the outlet location in this step tells ArcSWAT that you want to see the model outputs at this location specifically.

Creating Subbasin Outlet Location Table – see page 13 of <https://swat.tamu.edu/media/1293/swatav2000.pdf>. Other helpful resources for making .dbf https://groups.google.com/g/arcswat/c/qZ_G9IGwl-0 and <https://www.youtube.com/watch?v=2NghHDM0n48>.

10. If you have point source discharges, reservoirs, etc. that you want to include in the watershed delineation, additional location tables (.dbf) need to be created and read into ArcSWAT. See <https://swat.tamu.edu/media/1293/swatav2000.pdf> for more.

B. Creating post-fire land cover raster

Burn severity map should be categorical - each pixel value in the soil burn severity map should represent a burn severity (unburned / low burn / moderate burn / high burn).

The NLCD LULC has predefined LULC codes (values) and descriptions. The SWAT descriptions of the NLCD LULC are slightly different. See table below for reference.

Original NLCD Value	Original SWAT Code (No Burn)	NLCD Description	SWAT2012 Database Description
11	WATR	Open Water	Water
21	URLD	Developed, Open Space	Residential-Low Density
22	URMD	Developed, Low Intensity	Residential-Medium Density
23	URHD	Developed, Medium Intensity	Residential-High Density
24	UIDU	Developed, High Intensity	Industrial
31	SWRN	Barren Land	Southwestern US (Arid) Range

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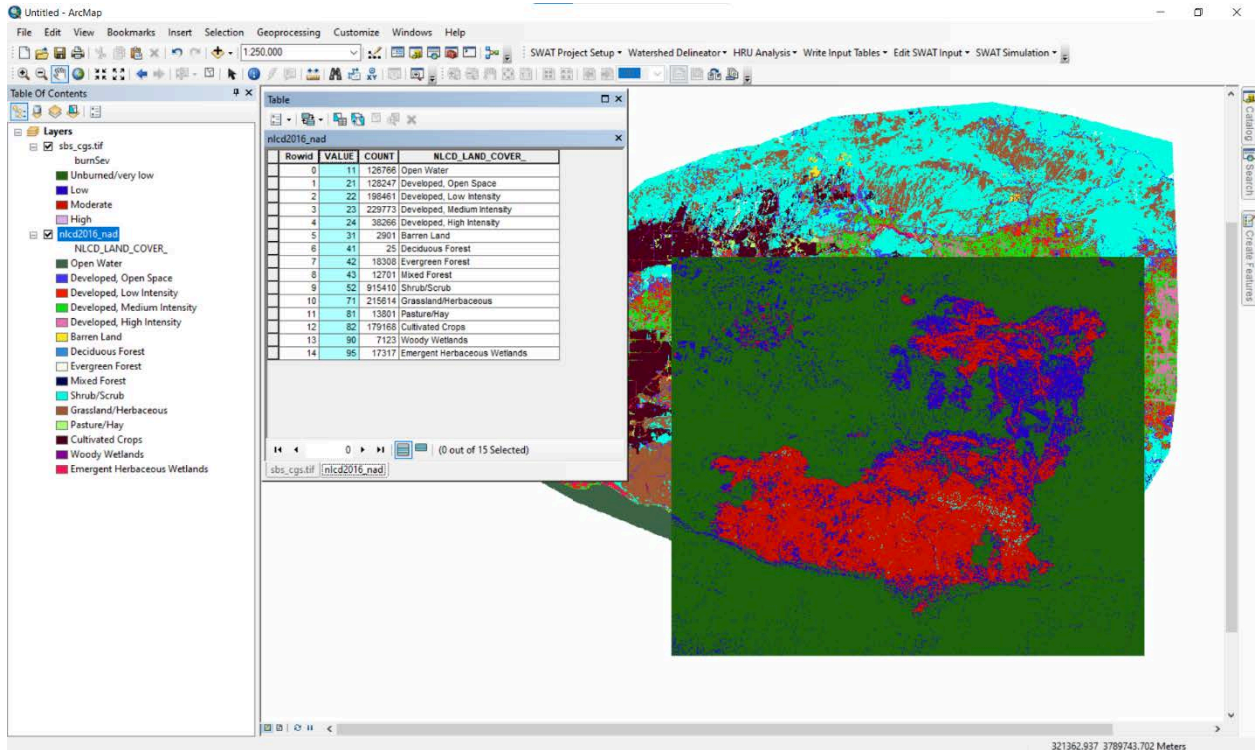
41	FRSD	Deciduous Forest	Forest-Deciduous
42	FRSE	Evergreen Forest	Forest-Evergreen
43	FRST	Mixed Forest	Forest-Mixed
52	RNGB	Shrub/Scrub	Range-Brush
71	RNGE	Grassland/Herbaceous	Range-Grasses
81	HAY	Pasture/Hay	Hay
82	AGRR	Cultivated Crops	Agricultural Land-Row Crops
90	WETF	Woody Wetlands	Wetlands-Forested
95	WETN	Emergent Herbaceous Wetlands	Wetlands-Non-Forested

Low Burn NLCD Value	Low Burn SWAT Code	Low Burn NLCD Description
111	LBWA	Open Water Low Burn
121	LBLD	Developed, Open Space Low Burn
122	LBMD	Developed, Low Intensity Low Burn
123	LBHD	Developed, Medium Intensity Low Burn
124	LBDU	Developed, High Intensity Low Burn
131	LBRN	Barren Land Low Burn
141	LBSD	Deciduous Forest Low Burn
142	LBSE	Evergreen Forest Low Burn
143	LBST	Mixed Forest Low Burn
152	LBGB	Shrub/Scrub Low Burn
171	LBGE	Grassland/Herbaceous Low Burn
181	LBHA	Pasture/Hay Low Burn
182	LBRR	Cultivated Crops Low Burn
190	LBTF	Woody Wetlands Low Burn
195	LBTN	Emergent Herbaceous Wetlands Low Burn

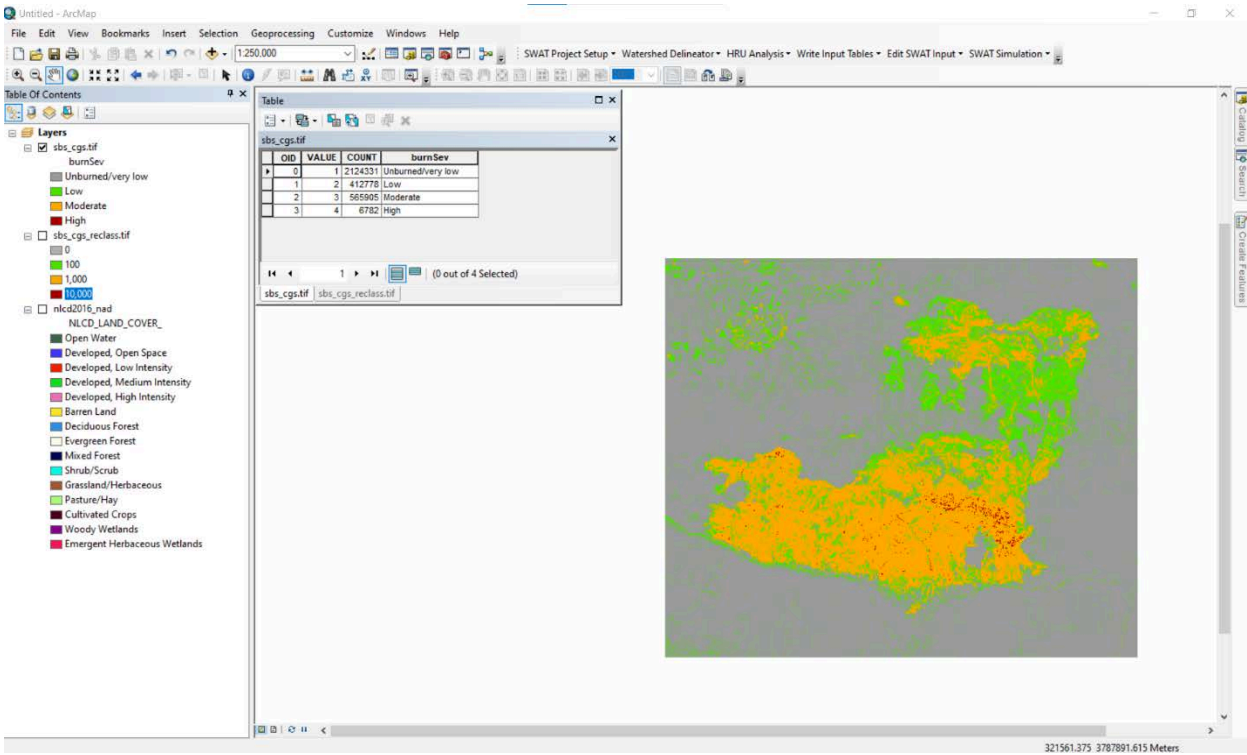
Moderate Burn NLCD Value	Moderate Burn SWAT Code	Moderate Burn NLCD Description
1011	MBWA	Open Water Moderate Burn
1021	MBLD	Developed, Open Space Moderate Burn
1022	MBMD	Developed, Low Intensity Moderate Burn
1023	MBHD	Developed, Medium Intensity Moderate Burn
1024	MBDU	Developed, High Intensity Moderate Burn
1031	MBRN	Barren Land Moderate Burn
1041	MBSD	Deciduous Forest Moderate Burn
1042	MBSE	Evergreen Forest Moderate Burn
1043	MBST	Mixed Forest Moderate Burn
1052	MBGB	Shrub/Scrub Moderate Burn
1071	MBGE	Grassland/Herbaceous Moderate Burn
1081	MBHA	Pasture/Hay Moderate Burn
1082	MBRR	Cultivated Crops Moderate Burn
1090	MBTF	Woody Wetlands Moderate Burn
1095	MBTN	Emergent Herbaceous Wetlands Moderate Burn

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High Burn NLCD Value	High Burn SWAT Code	High Burn NLCD Description
10011	HBWA	Open Water High Burn
10021	HBLD	Developed, Open Space High Burn
10022	HBMD	Developed, Low Intensity High Burn
10023	HBHD	Developed, Medium Intensity High Burn
10024	HBDU	Developed, High Intensity High Burn
10031	HBRN	Barren Land High Burn
10041	HBSD	Deciduous Forest High Burn
10042	HBSE	Evergreen Forest High Burn
10043	HBST	Mixed Forest High Burn
10052	HBGB	Shrub/Scrub High Burn
10071	HBGE	Grassland/Herbaceous High Burn
10081	HBHA	Pasture/Hay High Burn
10082	HBRR	Cultivated Crops High Burn
10090	HBTF	Woody Wetlands High Burn
10095	HBTN	Emergent Herbaceous Wetlands High Burn

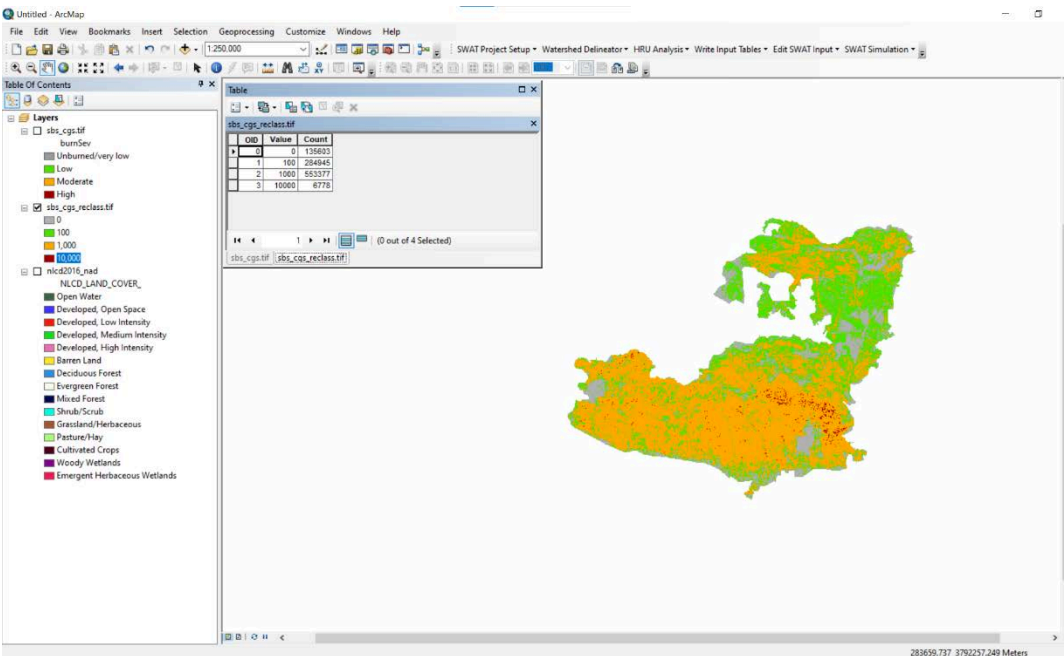


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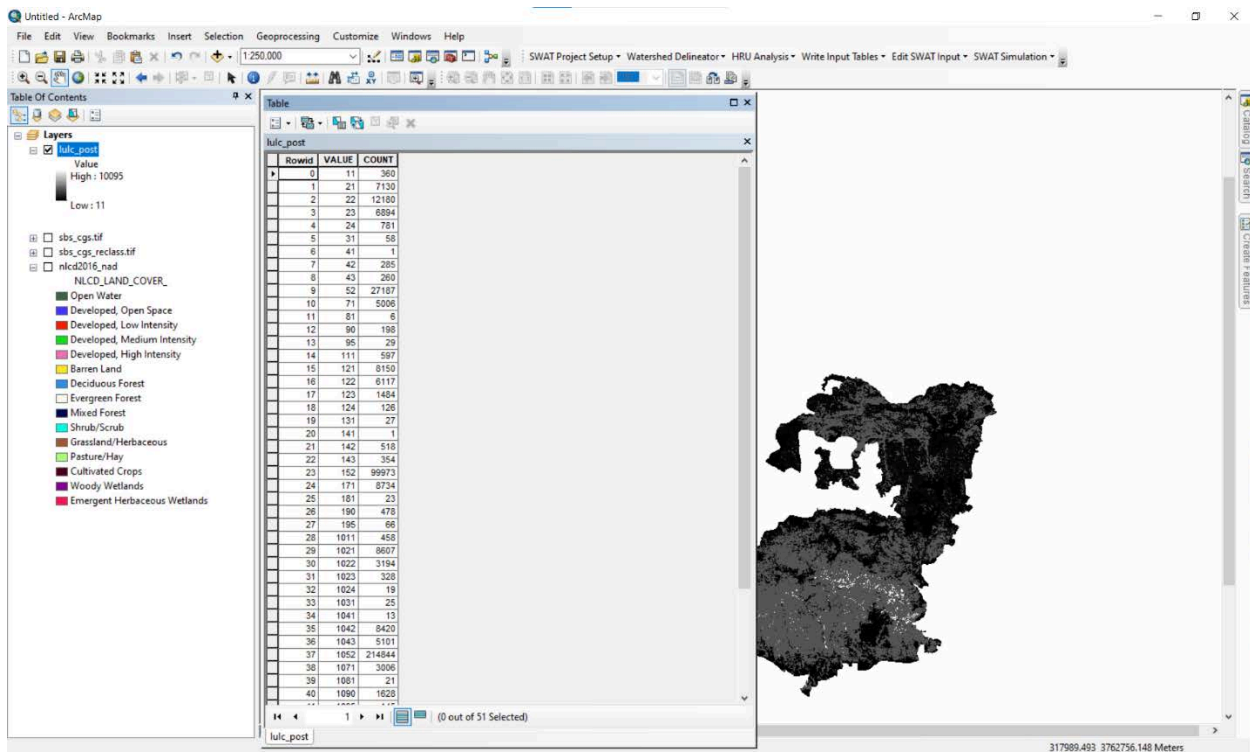
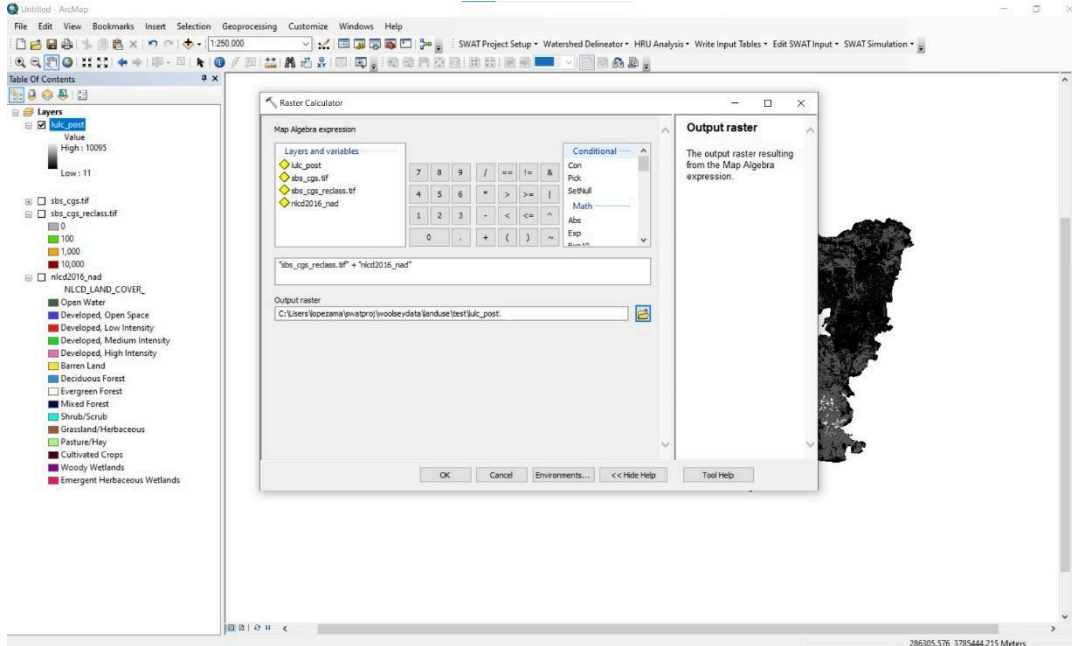
1. Reclassify ArcGIS tool: reclassify the soil burn severity map values. See example of reclassification below.

Original SBS map	Reclassified SBS map
1 = unburned / very low burn	0 = unburned / very low burn
2 = low burn	100 = low burn
3 = moderate burn	1000 = moderate burn
4 = high burn	10000 = high burn



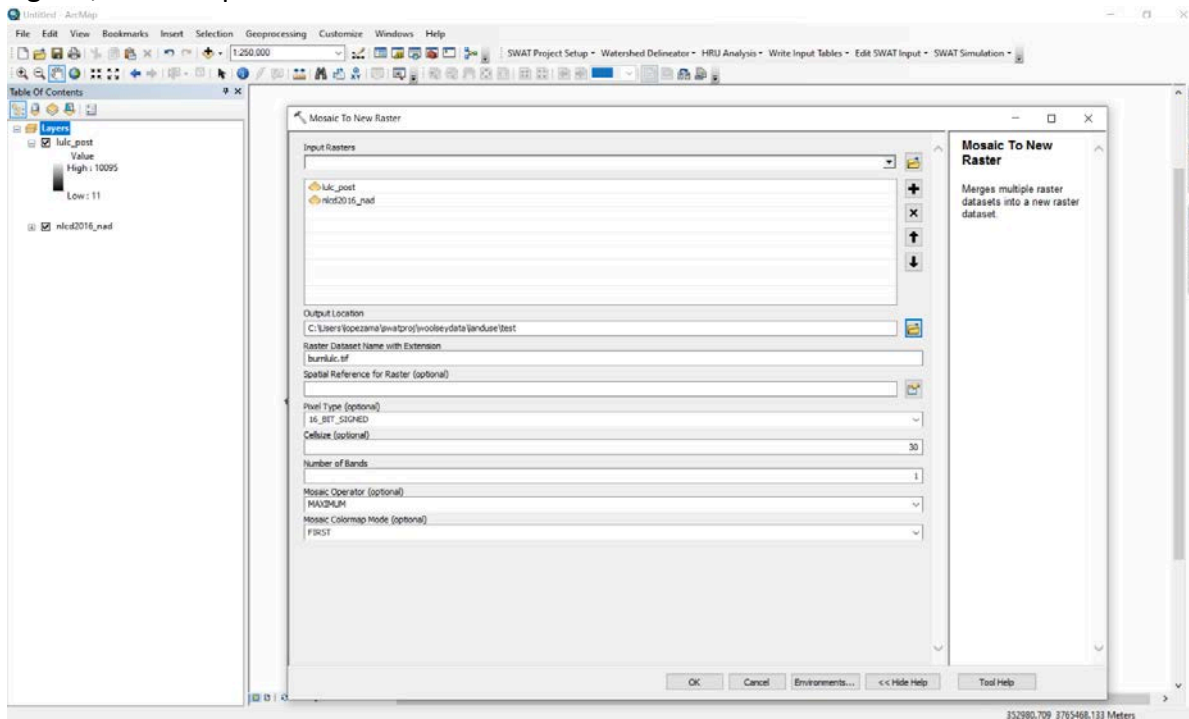
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2. Use Raster Calculator ArcGIS tool to add the reclassified SBS map to the NLCD land use land cover map - will create a raster of the fire outline with the newly created burned area land use classes. Example: developed, open space (NLCD value 21) that gets low burned would become developed, open space low burn (NLCD value 21 + SBS reclassified value 100 = 121).

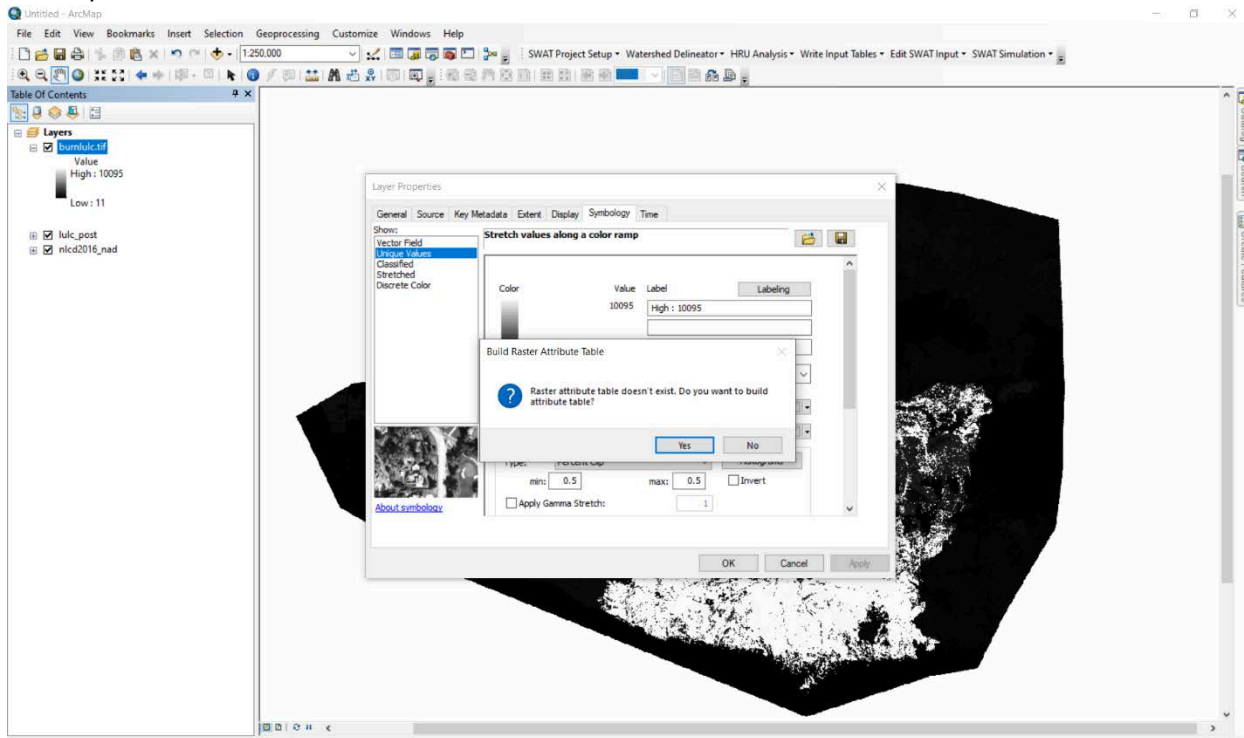


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3. Mosaic to New Raster ArcGIS tool - this merges the raster from step 2 with original (non-burned) NLCD for study area. Cell size = 30, number of bands = 1, pixel type = 16 bit signed, mosaic operator = maximum.

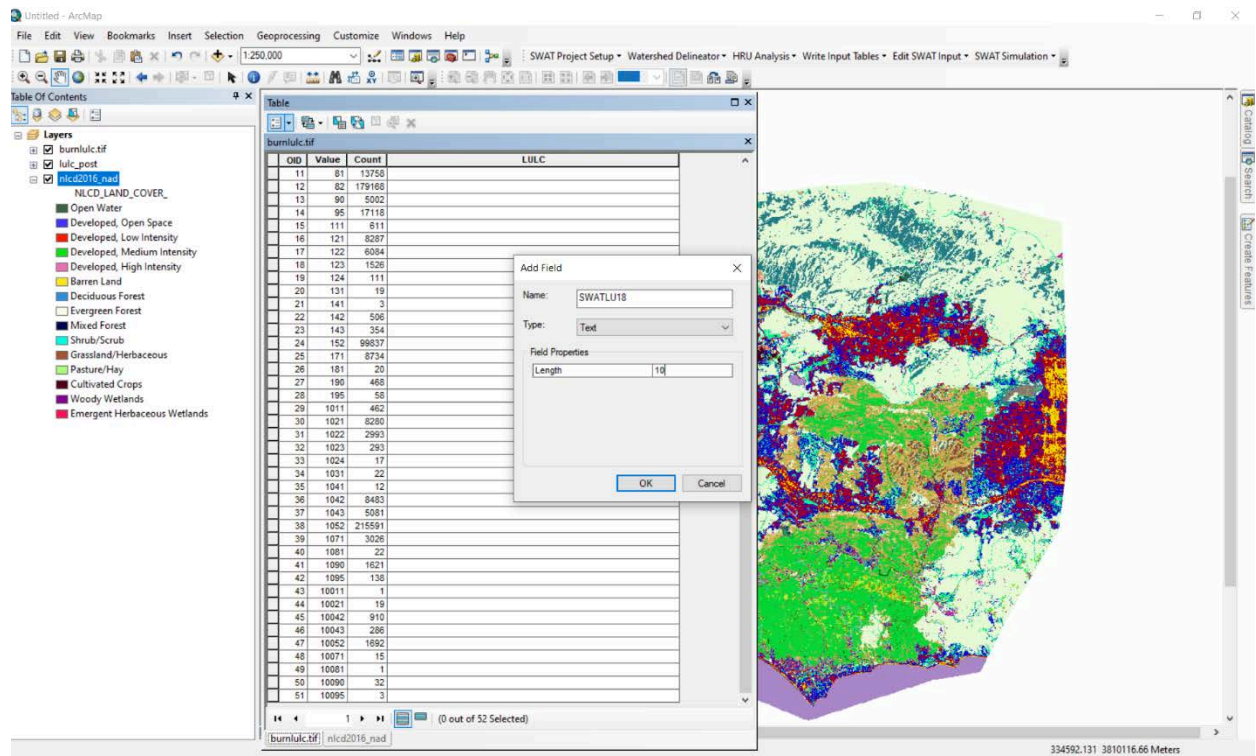
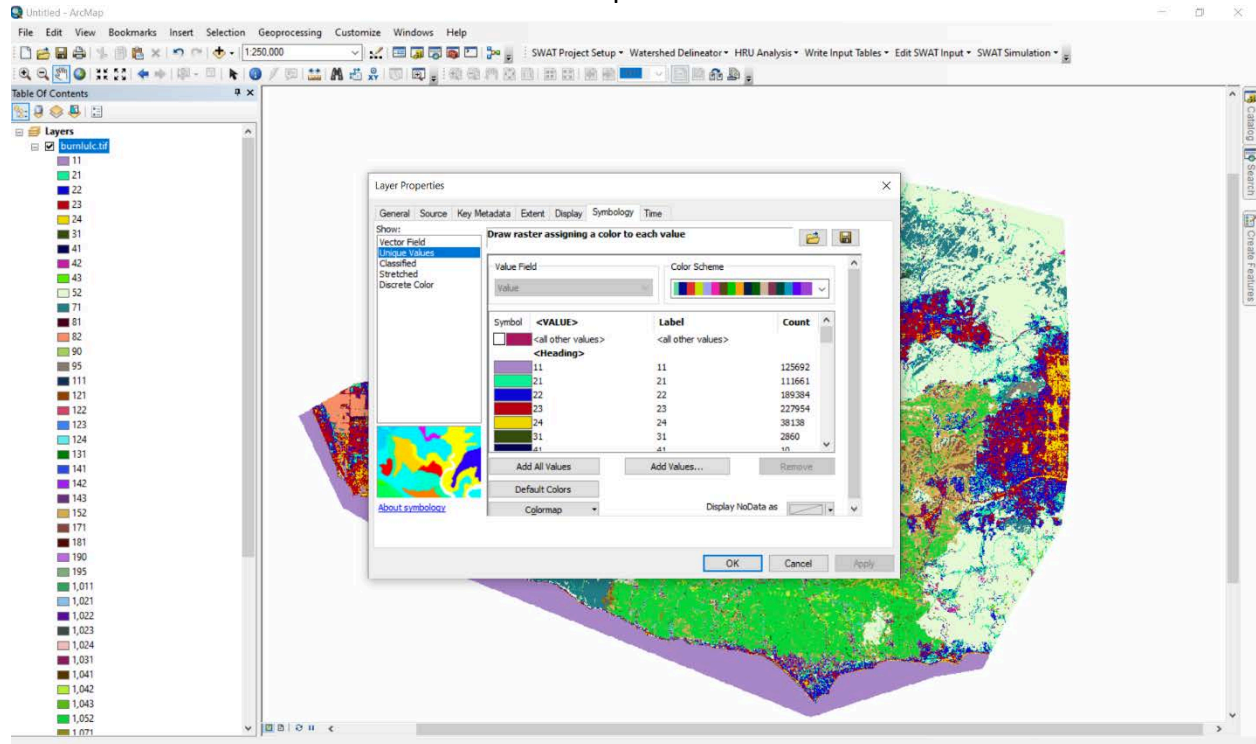


4. Build raster attribute table (right click on new raster > layer properties > symbology > unique values).



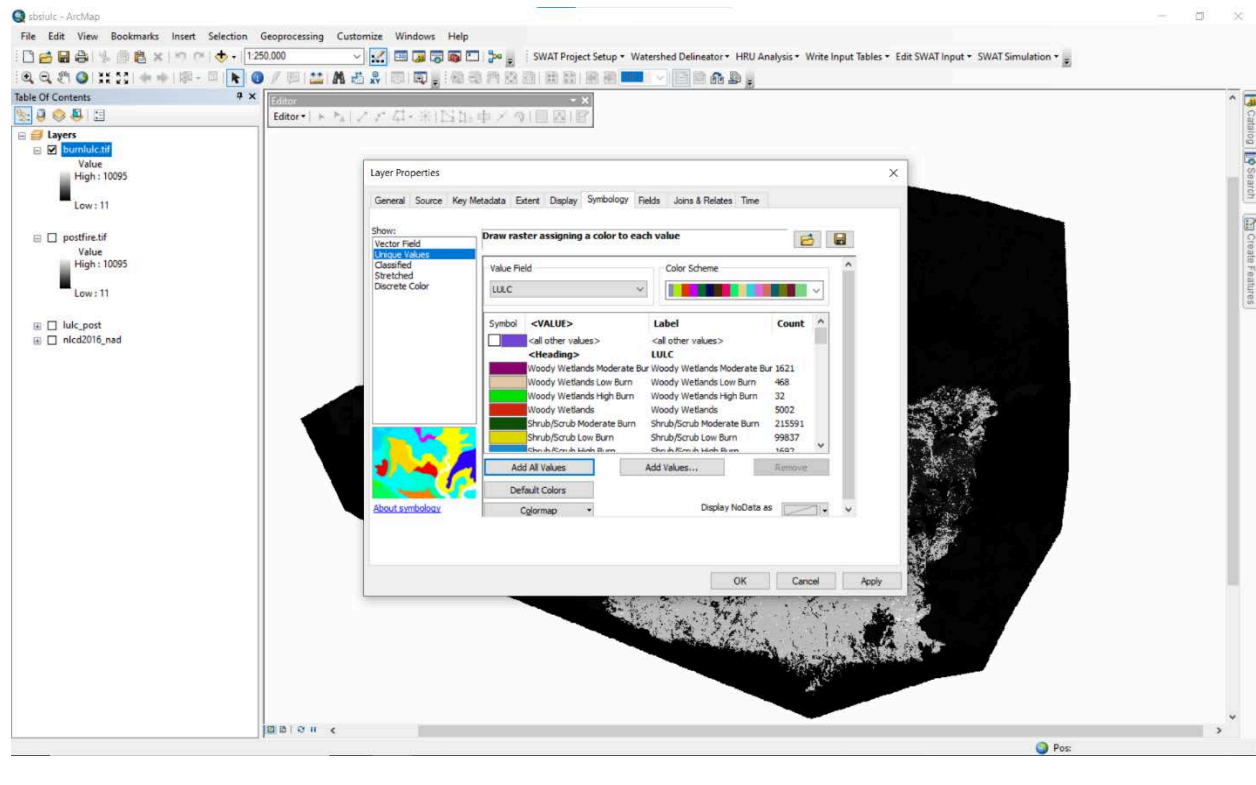
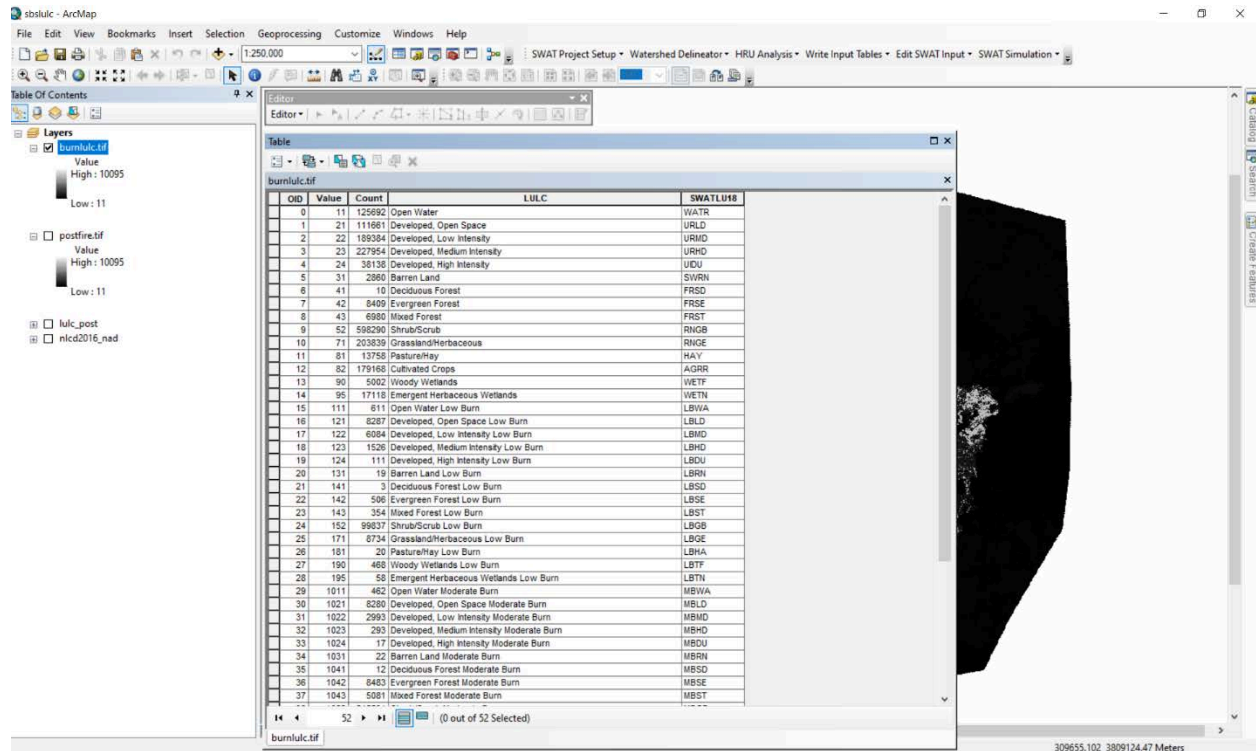
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5. In the new raster - add fields for LULC descriptions and SWAT land use codes.



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6. Use info from tables above or Excel spreadsheet to fill in LULC descriptions and SWAT land use codes into new raster attribute table.



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C. Setting up and running pre-fire and post-fire SWAT models

1. Open an ArcGIS ArcMap file.
2. Set up SWAT project: SWAT Project Setup > New SWAT Project
 - a. A pop-up will ask about saving the current document > click No
 - b. Navigate to folder where you want your project files (can be an existing folder or you can make a new folder) > click OK

3. Delineate watershed: Watershed Delineator > Automatic Watershed Delineation

DEM Setup box

- a. Open DEM Raster click folder icon > Load from Disk > OK > navigate to folder where your DEM file is and select it > Add
- b. Check Mask box > click folder icon > Load from Disk > OK > navigate to folder where your mask file is and select it > Add
- c. Leave Burn in box unchecked

Stream Definition box: select DEM-based > click Flow direction and accumulation > “End of DEM grid preprocessing” message should pop-up > OK

Modify the Area to 250 Ha > Create streams and outlets > End of stream processing message pop-up > OK

The SWAT software suggested 500 Ha, I reduced this number to 250 Ha because more detail in the stream network is captured with the smaller area. I chose 250 Ha because it was the largest number at which the most detail in the stream network is captured (aka. the 50 Ha threshold captures the same detail as the 250 Ha threshold). Play around with this value for your watershed of interest.

Outlet and Inlet Definition box: Select Subbasin outlet > Add by Table folder icon > navigate to where the subbasin outlet (monitoring gage locations) .dbf file is and select it > Add > 2 pop-ups will appear click OK for both

Watershed Outlets(s) Selection and Definition box: Whole watershed outlet > use mouse to draw box around outlet you want to model > Delineate watershed

Calculation of Subbasin Parameters box > Calculate subbasin parameters

Click Exit to end Watershed Delineation process.

4. Save project and back up project if desired.
To back up a project copy and paste the entire project folder in its current directory.
5. For the post-fire model only (if setting up pre-fire model continue to next step): save and close ArcSWAT model (aka. the project ArcGIS ArcMap Document).

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- a. Ensure that Land Cover Look Up table (luc text file) has all land cover classes that are defined in the land cover raster.
- b. In SWAT2012 Microsoft Access Database that is inside the project folder > modify the crop, urban, and urbandefault tabs as noted below. When done editing, save changes, and close the file.

Modifications to make to burned area land cover classes:

BLAI – set to 1.0

CN – add to initial value +5 for low burn / +10 for moderate burn / +15 for high burn

ALAI_MIN – set to 0.2

Do not make any parameter changes to Open Water Low/Moderate/High Burn (LBWA, MBWA, HBWA) land cover classes! Leave the original parameter values as is.

crop.dat – Add all new burned area land cover classes to the file. Modify BLAI, CN (CN2A, CN2B, CN2C, and CN2D), and ALAI_MIN for the burned area land cover classes.

urban.dat – Add all new burned area land cover classes to the file. Modify CN (CN2A, CN2B, CN2C, and CN2D) for the burned area land cover classes.

urbandefault.dat – Add all new burned area land cover classes to the file. Modify CN (CN2A, CN2B, CN2C, and CN2D) for the burned area land cover classes.

6. (If needed re-open the ArcSWAT model by double clicking the ArcGIS ArcMap Document in the project folder) > HRU Analysis > Land Use/Soils/Slope Definition

Land use tab

> Land Use Grid folder icon > Load Land Use dataset(s) from disk > pop-up confirming that data is projected > Yes > navigate to where the land use file is and select it > pop-up about overlap > OK

Choose Grid Field > Value > OK > LookUp Table > User Table > navigate to where the lookup table file is and select it > Reclassify > OK

Soil tab > Soils Grid folder icon > Load Soils dataset(s) from disk > pop-up confirming that data is projected > Yes > navigate to where the soils file is and select it > pop-up about overlap > OK

Soils – selected “Load ArcSWAT US STATSGO from disk” option (this is the STATSGO database that comes with the SWAT installation). Reclassified using Stmuid.

Slope tab > Multiple slope > set Number of Slope Classes... > Add > Reclassify > OK

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Malibu Creek example: manually set 3 slope classes, class 1 is 0-9% (2947 out of 9028 points), class 2 is 9-18% (3121 out of 9028 points), and class 3 is 18+% (2960 out of 9028 points). There is a roughly equal number of points within each slope class. Play around with this in your watershed of interest and modify accordingly.

HRU Feature Class option *If watershed is >10,000 square km do NOT check this option – it will take forever to generate. If you notice ArcGIS crashing after this, your watershed may be too big for the HRU feature class*

Click Overlay > OK

7. Save project and back up project if desired.
8. If you checked the HRU Feature Class option a new layer called “Full HRU Layer” will be added to the map > open Attribute Table to see info
9. HRU Analysis > HRU Definition > Multiple HRUs
 - a. Land use percentage (%) over subbasin area = 10%
 - b. Soil class percentage (%) over land use area = 10%
 - c. Slope class percentage (%) over soil area = 10%
 - d. Create HRUs > OK

You can restrict the number of HRUs by modifying these parameters. You can “protect” land classes so that they are preserved in the HRUs. In the post-fire model “protect” all burned area land cover classes, except any Open Water Low/Moderate/High Burn (LBWA, MBWA, HBWA) land cover classes.

10. Save project and back up project if desired.
11. To see full list of HRUs created > HRU Analysis > HRU Analysis Reports > Final HRU Distribution
12. Prepare temperature and precipitation text files:
 - Precipitation header file: XXXpcp.txt
 - Temperature header file: XXXtmp.txt
 - Precipitation station data files: __stationname__.txt
 - Temperature station data files: __stationname__.txt

See ExInputs folder in SWAT installation folder for examples of correct formatting for the weather files. Once you have your weather text files ready, copy and paste them into your project folder.

13. Write Input Tables > Weather Stations

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Weather Generator Data must be set first > WGEN_US_FirstOrder

As long as you're in the US you can choose any of the WGEN options, WGEN_user is for watersheds outside the US that the user must define.

Rainfall Data tab > Raingages > Locations Table folder icon > navigate to where the precipitation header file is and select it

Temperature Data tab > Climate Stations > Locations Table folder icon > navigate to where the temperature header file is and select it

Solar Radiation tab > Simulation

Relative Humidity Data tab > Simulation

Wind Speed Data tab > Simulation

Weather Data Definition box > OK

14. Save project and back up project if desired.
15. Write Input Tables > Write SWAT Input Tables > Select All > Create Tables > pop-up about heat units > Yes if watershed is in US > OK
16. Save project and back up project if desired.
17. Post-fire model setup (if setting up pre-fire model continue to next step): Save and close ArcSWAT model. At this point the project database (aka. proj_name.mdb in the project folder) has a .sol and .mgt1 tabs that need to be modified as described below. Save all database changes and close database when done.

.sol file – Modify USLE_K for the burned land cover classes. *USLE_K – Add to initial value +0.014 for low burn / +0.015 for moderate burn / +0.016 for high burn then divide values by 0.1317*

.mgt1 file – Modify LAI_INT for the burned land cover classes. *LAI_INT – Set to 0.1*

Do not make any parameter changes to Open Water Low/Moderate/High Burn (LBWA, MBWA, HBWA) land cover classes! Leave the original Open Water parameter values as is.

18. For post-fire model only (if setting up pre-fire model continue to next step): Re-open ArcSWAT project by double clicking the ArcGIS ArcMap Document in the project folder. Re-write the modified files (.sol and .mgt) before running the model by completing the following steps.

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Edit SWAT Input > Rewrite SWAT Input Files > Select the files you edited (in this case .Sol and .Mgt) > Write Files > Click OK on pop-up > Close window

19. Now the model is set up and ready to be run > **SWAT Simulation** > Run SWAT

Period of Simulation = 01/01/2000 to 12/31/2020 *Modify this for your study period.*

Printout Settings = monthly *Modify timestep as desired daily, yearly, etc.*

NYSKIP = 3 *This represents the model warm-up period in which the model is running but no output is generated. It is meant to give the model time to equilibrate. Modify this for your study.*

Output file variables = All

Rainfall Distribution = Skewed normal

SWAT .exe Version = 64-bit, release version *Modify as desired for your study.*

Setup SWAT Run > OK

Click Run SWAT > (you will see a command line interface pop-up showing the model running) OK > Cancel out of SWAT Simulation window

You can make changes on the SWAT Simulation window after you run a model, for example you could run the model using the 64bit release then run it again with the 32-bit release. But note, you always have to click Setup SWAT Run before Run SWAT.

20. Save project and back up project if desired.

21. There are 2 options for reviewing the model output.

Option A navigate to project folder > Scenarios > Default > TxtInOut folder contains all model input and output files

Option B (Step 22) ArcSWAT interface > SWAT Simulation > Read SWAT Output

22. SWAT Simulation > Read SWAT Output

Read SWAT Output

Check the boxes of the output files you'd like to see > Import Files to Database > OK > Open SWATOutput.mdb

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This step reads the output text files back into a database file. This may take a while depending on your model so be patient. The output.rch, output.sub, and output.hru files are the most common output files to look at.

SWATOutput.mdb is a Microsoft Access file containing output details that you can export to Excel, graph, etc. There are tables with keys for the column headings in case you need clarification. HRUGIS is column that you can use to link to ArcGIS for creating maps.

Review SWAT Output

Run SWATCheck > a new interface will open up (the path to the input and output files will be shown) > Examine Model Output

Simulation Details section will list an overview of your model.

It is NOT a calibration tool, it is a diagnostic tool to assess if there is anything wrong with your inputs. It is a large-scale overview of your watershed.

Save SWAT Simulation

Save current simulation as: > (enter name of your choice) > Save Simulation > OK > Close window

This step saves the model conditions used in the run you just completed. You are able to go back and tinker with the ArcSWAT model parameters and re-run the model, than save as a new simulation.

23. Save project and back up project if desired.

24. Close ArcSWAT project.

D. Run Land Use Update Tool to simulate wildfire in your watershed

1. For both the pre-fire and post-fire models: Open the project database > Open each hru tab > Copy and paste the SUBBASIN, HRU, LANDUSE, SOIL, SLOPE_CD, and HRU_FR columns from the hru tab to a new text file and save in the SWAT project folder.

Note: be careful of the formatting of these text files! R script does not work properly if the text files are not formatted into neat, clearly aligned tabs. See image from L.D. Nguyen below for example of what the text file formatting needs to look like. (In order to get to spacings correct, I edit in Excel then copy and paste data into new text file and save).

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1	SUBBASIN	HRU	LANDUSE	SOIL	SLOPE_CD	HRU_FR
2	1	1	URML	B129N21	5-9999	7.51834440969959E-04
3	1	2	URML	B129N21	0-5	4.74659113215851E-03
4	1	3	URML	B161N21	5-9999	1.85413716099942E-03
5	1	4	URML	B161N21	0-5	0.018744963141398
6	1	5	URML	B198N23	0-5	2.23368994454518E-03
7	1	6	URML	B198N23	5-9999	1.96320405282291E-04
8	1	7	AGRL	B128N21	5-9999	1.1401125758616E-03
9	1	8	AGRL	B128N21	0-5	1.23376468030738E-02
10	1	9	AGRL	B129N21	0-5	0.298747304731572
11	1	10	AGRL	B129N21	5-9999	1.56183789091245E-02

1	SUBBASIN	HRU	LANDUSE	SOIL	SLOPE_CD	HRU_FR
2	1	1	URML	B128N31	0-5	1.04762385159528E-02
3	1	2	URML	B128N31	5-9999	1.43241184594857E-03
4	1	3	URML	B129N21	0-5	8.87077386831094E-05
5	1	4	URML	B129N31	0-5	7.54452046373723E-03
6	1	5	URML	B129N31	5-9999	7.00936558118995E-04
7	1	6	URML	B156N21	0-5	3.63556306078317E-04
8	1	7	URML	B165N31	5-9999	4.10673203346067E-02
9	1	8	URML	B165N31	0-5	0.11779078894415
10	1	9	AGRL	B128N21	5-9999	1.1401125758616E-03
11	1	10	AGRL	B128N21	0-5	1.23376468030738E-02

2. Open R script name "hru_all_landuse" and modify the user defined parameter lines within the code shown in the L.D. Nguyen image below.

Malibu Creek example:

```
hru_landuse[1] <- INSERT PATH TO hru_prefire.txt
```

```
hru_landuse[2] <- INSERT PATH TO hru_postfire.txt
```

```
output_file <- INSERT PATH TO WHERE YOU WANT TO SAVE THE OUTPUT FILE THAT THIS  
CODE MAKES & SPECIFY file name "hru_pre_post_fire.txt"
```

3. After modifying the user defined parameters, run the hru_all_landuse R script.

Navigate to the output_file location and check that the hru_pre_post_fire.txt file was created. The HRU and HRU fraction are assigned a value of 0 if that particular land use does not exist in that land use scenario.

Note: be careful of the formatting of these text files! R script does not work properly if the text files are not formatted correctly. See image from L.D. Nguyen below for example of what the text file formatting needs to look like. (In order to get to spacings correct, I edit in Excel then copy and paste data into new text file and save).

1	SUBBASIN	HRU	LANDUSE	SOIL	SLOPE_CD	HRU_FR	V7	V8	V9	V10
2	1	1	URML	B129N21	5-9999	0.000751	0	0	1	0.00075183444096996
3	1	2	URML	B129N21	0-5	0.004746	3	8.8707e-05	2	0.00474659113215851
4	1	3	URML	B161N21	5-9999	0.001854	0	0	3	0.00185413716099942
5	1	4	URML	B161N21	0-5	0.018744	0	0	4	0.018744963141398
6	1	5	URML	B198N23	0-5	0.002233	0	0	5	0.00223368994454518
7	1	6	URML	B198N23	5-9999	0.000196	0	0	6	0.000196320405282291
8	1	7	AGRL	B128N21	5-9999	0.001140	9	0.001140	0	0
9	1	8	AGRL	B128N21	0-5	0.012337	10	0.012337	0	0
10	1	9	AGRL	B129N21	0-5	0.298747	11	0.298747	9	8.87077386831094e-05
11	1	10	AGRL	B129N21	5-9999	0.015618	12	0.015618	0	0
...										
...										
1		0	FRSE	B165N21	5-9999	0	0	0	35	0.027880406000534
1		0	FRSE	B198N21	0-5	0	0	0	36	0.0545799811189256
1		0	FRSE	B198N21	5-9999	0	0	0	37	0.00257252442181017
2		1	AGRL	B129N21	5-9999	0.00266	8	0.002665	0	0
2		2	AGRL	B129N21	0-5	0.053428	9	0.053428	0	0
2		3	AGRL	B129N31	0-5	0.000411	10	0.000411	2	0.00946027035637853
2		4	AGRL	B129N31	5-9999	0.000179	11	0.000179	1	0.00290185441914833

This info is as in the file "hru_lu_1990.txt"

HRU number in the second land use scenario "hru_lu_1995.txt"

HRU fraction in the second land use scenario "hru_lu_1995.txt"

HRU number in the third land used

HRU fraction in the third land used scenario

4. Create a folder named "newTxtInOut" on your computer in the location of your choice.
5. Copy and paste a dummy DAT file named "lup" into the newTxtInOut folder.

There are real DAT files in the project folder > Scenarios > Default > TxtInOut folder. Copy and paste one of these DAT files into the newTxtInOut folder and change the name to "lup". Open the DAT file (open as a text file) and erase all contents. Then fill in dummy information for your study.

6. Fill in information in the lup DAT file pertaining to the date of the wildfire. Malibu Creek dummy DAT file example (keep spacing shown here!):

```
1 11 8 2018 11082018.dat
```

7. Open the "writeTxtInOut.R" and modify the user defined parameters as relevant to your study.

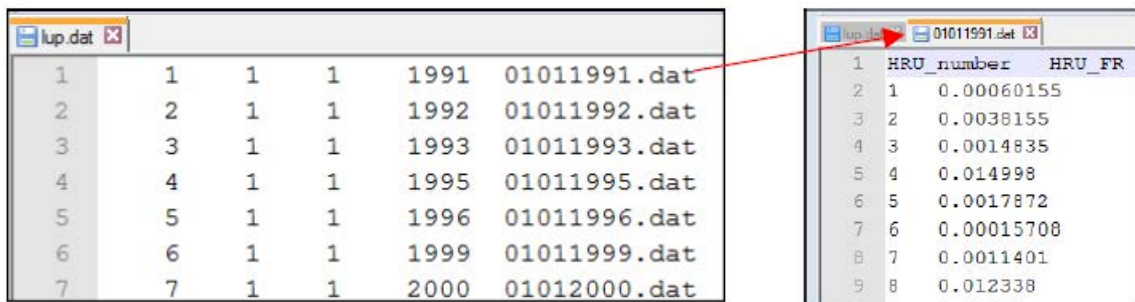
Malibu Creek example:

```
Lu[1] <- INSERT PATH TO arset_prefire project TxtInOut folder
Lu[2] <- INSERT PATH TO arset_postfire project TxtInOut folder
date <- c("01012000", "11082018")
inter_date[[1]] <- c("NA") no interpolation needed for Malibu Creek example
ofolder <- INSERT PATH TO newTxtInOut folder you made
```


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hru_lu_all <- INSERT PATH TO hru_pre_post_fire.txt file you made using the
hru_all_landuse R script

8. After modifying the user defined parameters, run the writeTxtInOut R script.
9. Navigate to the newTxtInOut folder and confirm that the files you want were created. Specifically, check to see that a new lup DAT file was made – the new lup DAT file will have the land use change date as the file name. See image from L.D. Nguyen below for reference.



Row	LU	LU	LU	Year	Filename
1	1	1	1	1991	01011991.dat
2	2	1	1	1992	01011992.dat
3	3	1	1	1993	01011993.dat
4	4	1	1	1995	01011995.dat
5	5	1	1	1996	01011996.dat
6	6	1	1	1999	01011999.dat
7	7	1	1	2000	01012000.dat

HRU	HRU	HRU
number	number	FR
1	1	0.00060155
2	2	0.0038155
3	3	0.0014835
4	4	0.014998
5	5	0.0017872
6	6	0.00015708
7	7	0.0011401
8	8	0.012338

Malibu Creek example:

11082018.dat file was created by the writeTxtInOut R script

10. Copy and paste the SWAT application file of version of SWAT that you ran your models with (64 bit) from the SWAT installation folder into the newTxtInOut folder.
11. Double click on the SWAT application file in the newTxtInOut folder to run a new SWAT model that will use the LUU tool apply land use changes during the model simulation. Results of this model run will populate into the newTxtInOut folder.
12. Use the newTxtInOut folder to load the project into SWATCUP where you can visualize the model outputs and work on calibration-validation.

E. Learn about SWATCUP and decide how to subset in situ (observational) data into calibration and validation periods

1. Watch the SWATCUP Youtube tutorials by Dr. Karim Abbaspour before starting model calibration-validation using SWATCUP
<https://www.youtube.com/playlist?list=PLjDkjZqbf4OtJ36tToupeMAbBCY9ffu00>.
2. I also highly recommend watching the SWAT Advanced Workshop videos by Dr. Srinu before starting calibration-validation in SWATCUP.
3. Recommended reading list:

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- Abbaspour et al. 2007 Modelling hydrology and water quality in the pre-alpine/alpine Thur watershed using SWAT
- Abbaspour et al. 2015 A continental-scale hydrology and water quality model for Europe: Calibration and uncertainty of a high-resolution large-scale SWAT model
- Abbaspour et al. 2018 A Guideline for Successful Calibration and Uncertainty Analysis for Soil and Water Assessment: A Review of Papers from the 2016 International SWAT Conference
- Arnold et al. 2012 *SWAT: Model use, calibration, and validation*
- Brighenti et al. 2019 Two calibration methods for modeling streamflow and suspended sediment with the swat model
- Moriasi et al. 2007 Model evaluation guidelines for systematic quantification of accuracy in watershed simulations

4. In order to calibrate and validate a SWAT model, you need in situ observations of **daily continuous** discharge in units of cubic meters per second at monitoring gage locations within your watershed over the course of your model period.
5. First, calibrate and validate the SWAT model for hydrology using the in situ discharge observations. After you are confident that your model is adequately capturing the hydrological conditions in your watershed, you can calibrate-validate for other water quality parameters like sediment, nitrogen, etc.
6. Decide what time step you will be calibrating-validating your model with (daily, monthly, yearly). Monthly timesteps are recommended as daily variability can be tricky to accurately capture by the model and yearly variations may be too broad in scope to reflect on-the-ground changes.
7. Create hydrographs of the in situ discharge versus time for each monitoring gage in your watershed to visualize the wet/dry seasonality in the watershed.
8. Adding precipitation as another line/axis on each hydrograph is also recommended to visualize if the observed discharge correlates to rainfall (or other precipitation types) events in the watershed. If the discharge and precipitation do not correlate, there is something off with the data and further investigation is warranted before continuing.
9. Based on your model period, availability in situ discharge data, and the wet/dry seasonality you need to decide how to subsets the observational data into chunks that will be used for calibration, validation, and interpretation. As a rule of thumb, the average discharge and standard deviation of discharge should be similar between the calibration and validation periods.

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- a. Arnold et al. 2012 *SWAT: Model use, calibration, and validation* has further guidance on how to subdivide observational data into calibration-validation periods.
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F. Prepare in situ (observational) data for use in SWATCUP model calibration and validation

1. After you decide on what observational data will be used for calibration and validation, proceed with formatting the observational data for integration into SWATCUP.
2. A drainage area correction may need to be applied to the observational data depending on the location of the outlets and monitoring gages in your SWAT delineated watershed.
3. For calibrating water quality variables such as sediment or nitrogen: in most cases you will not find daily continuous in situ observations so you will need to use a rating curve to estimate a continuous record of the variable that can be used for calibration-validation.
 - a. I recommend using the USGS LOADEST program, which is a rating curve calculator that can generate sediment load, nitrogen load, etc. estimates that are usable for calibration-validation in SWATCUP. There is an online interface called LOADEST WEB <https://engineering.purdue.edu/mapserve/LOADEST/>. The webpage has instructions for how to use the tool. Essentially, you need to prepare 2 input files (txt or csv format) and the tool will do the rest. Contact Youn Shik Park parkyounshik@gmail.com for assistance or troubleshooting.
4. SWAT model outputs for monthly and yearly timesteps are sums not averages. For example, the January 2000 SWAT model output is a total monthly sum of discharge, sediment load, etc. (not a monthly averaged estimate). Consequently, you need to sum the daily observed discharges for each day in January 2000 and compare that value to the SWAT modeled value.