7

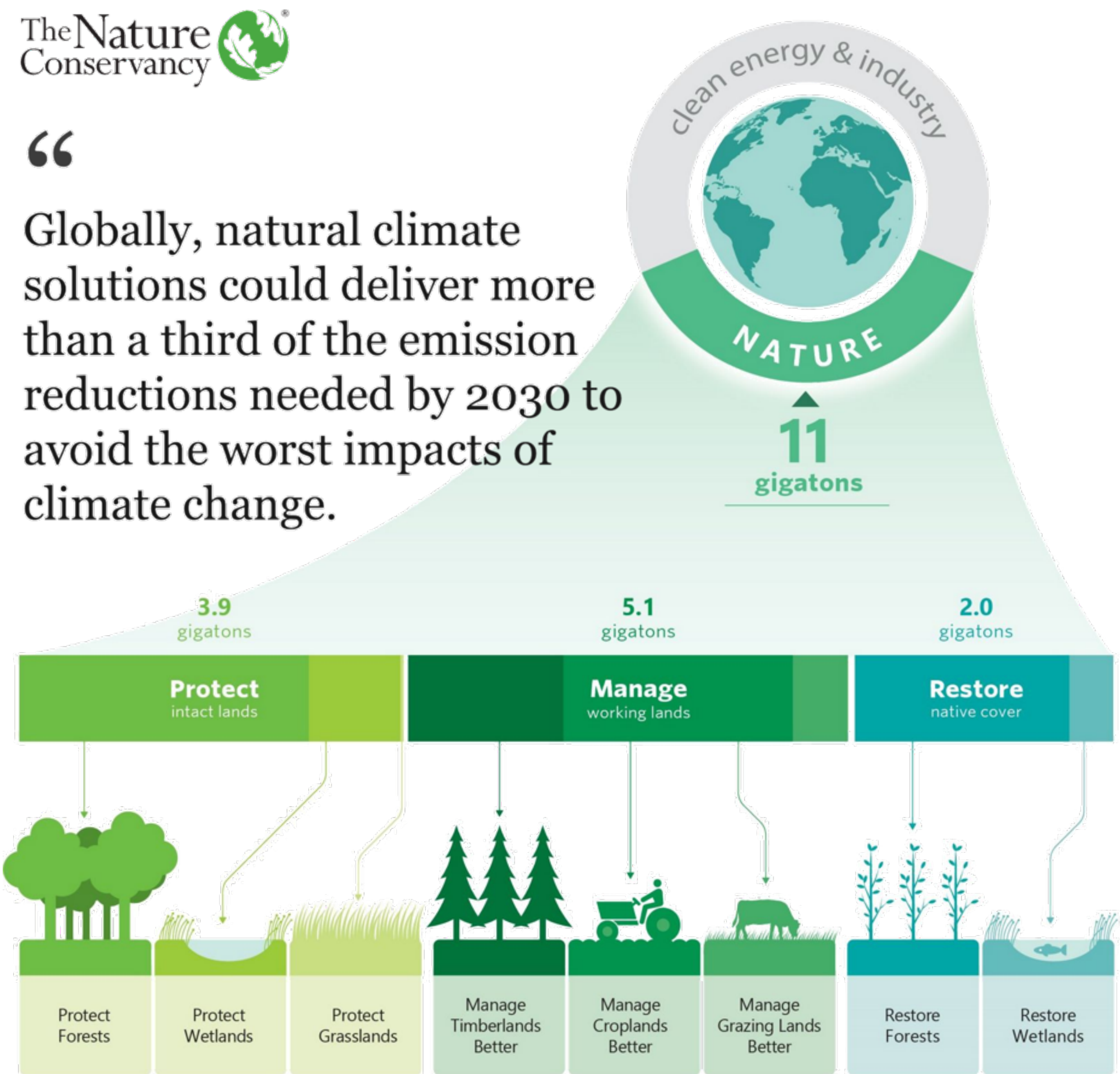
Estimating the Coupled Use of Water & Carbon Capture by Plants

Quick Links To Sections

Objectives:

1. Think about how the different components of evapotranspiration that ECOSTRESS reports can be used to describe unique properties of ecosystems.
2. Form a set of hypotheses to compare two ecosystems in the context of natural climate solutions and make a NASA worthy map to address your hypotheses.

Motivation For Today's Tutorial : Natural Climate Solutions



Combined with transitioning away from fossil fuels, natural climate solutions offer immediate and cost-effective ways to tackle the climate crisis—while also supporting healthy, thriving ecological communities and ecosystems. Natural climate solutions are actions that have been identified by scientists to protect, manage, and restore nature to reduce greenhouse gas emissions and store carbon.

Examples include reforestation, managing agriculture and timber, and protecting ecosystems known to capture and store large amounts of carbon. Less carbon in the atmosphere reduces the greenhouse effect which is needed to achieve the Paris Climate Agreement goal of holding warming to below 2 °C. Climate scientists utilize remote sensing data, like evapotranspiration and water use efficiency from ECOSTRESS, to assess the impact of natural climate solution actions.

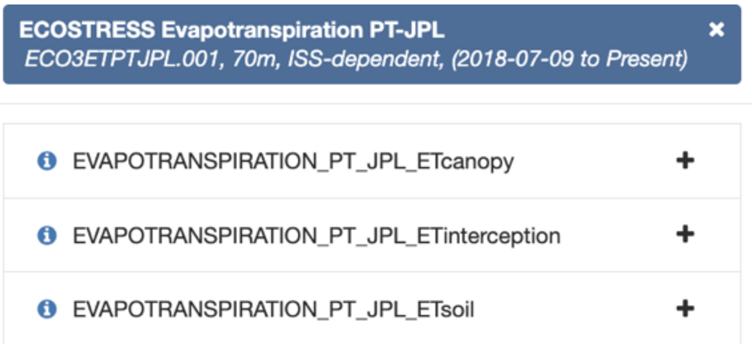
7.1 ACCESSING ECOSTRESS ET COMPONENT & WUE DATA THROUGH A$\rho\rho$EEARS

7.1.1 ECOSTRESS ET & WUE Data Variables

Data Product	Description	Pixel Size*	Temporal Resolution (days)
ECO1BRAD.001	Radiometric Calibration	70 x 70	Over continental United States and target areas**, every 1-7 days
ECO1BATT.001	Attitude and Ephemeris		
ECO1BMAPRAD.001	Radiometric Calibration		
ECO1BGEO.001	Geometric Calibration		
ECO2LSTE.001	Land Surface Temperature and Emissivity		
ECO2CLD.001	Cloud mask		
ECO3ETPTJPL.001	Evapotranspiration (PT-JPL model enhanced)		
ECO3ANCQA.001	Ancillary Data Quality		
ECO3ETALEXIU.001	Evapotranspiration (ALEXI model enhanced)	30 x 30***	
ECO4ESIPTJPL.001	Evaporative Stress Index derived from L3_ET_PT-JPL	70 x 70	
ECO4ESIALEXIU.001	Evaporative Stress Index derived from L3_ET_ALEXI	30 x 30***	
ECO4WUE.001	Water Use Efficiency	70 x 70	

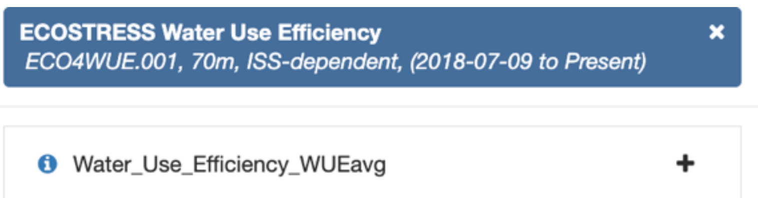
*More accurately referred to as pixel spacing resolution (m) because of dependencies on ISS altitude, which varies.
**For more info, please visit ECOSTRESS Gmap to see where data has been acquired
***70 x 70 is resampled to 30 x 30 (meters)

In the last tutorial we learned that ECOSTRESS uses land surface temperatures to estimate evapotranspiration (ET), the sum of all processes that return water from the land surface to the atmosphere (evaporation + transpiration). The Level 3 (ECO3) ET data that we worked with last time (ET_{inst} & ET_{daily}) represent the total ET, but ECOSTRESS also has data allowing us to track the individual components of ET:



- ET_{canopy} = transpiration of water through the plants' stomata
- $ET_{interception}$ = evaporation of water off of the surface of the plants
- ET_{soil} = evaporation of water through the soil

Water use efficiency (WUE), or the amount of carbon plants capture per unit water used, is a Level 4 (ECO4) ECOSTRESS data product:



7.1.2 Today's Study Location : Southern Pine Forests

Southern Pine Forests

Table 1. Regional NCE (Tg C yr^{-1}, Mean ± Their Stand Deviation) for Land Covers of the Conterminous U.S. Over the Period of 2001 to 2005

Region	Croplands	Rangelands/Pasture	Urban	Forests	Shrublands	Grasslands	Other[a]	Total
Southeast	−9 ± 12	−2 ± 2	−1 ± 0	176 ± 26	0 ± 0	0 ± 1	−7 ± 1	156 ± 33
Midwest	−6 ± 17	−1 ± 3	0 ± 0	59 ± 11	0 ± 0	1 ± 4	12 ± 3	66 ± 35
Northeast	−2 ± 3	0 ± 0	−3 ± 1	43 ± 10	0 ± 0	0 ± 0	0 ± 1	39 ± 11
Northern Great Plains	13 ± 42	3 ± 25	0 ± 0	4 ± 2	0 ± 0	0 ± 1	0 ± 0	20 ± 65
Southwest	2 ± 11	0 ± 16	1 ± 1	7 ± 11	5 ± 22	1 ± 2	0 ± 1	15 ± 57
Northwest	3 ± 6	0 ± 1	0 ± 0	11 ± 5	0 ± 2	0 ± 0	0 ± 0	14 ± 12
Southern Great Plains	2 ± 29	−2 ± 32	0 ± 0	14 ± 4	0 ± 0	0 ± 1	0 ± 0	13 ± 65
Total	4 ± 80	−3 ± 60	−3 ± 2	313 ± 40	6 ± 22	1 ± 7	5 ± 3	323 ± 191

[a]Includes wetlands, mangrove, and bare lands.

- Longleaf pine (*Pinus palustris*) ecosystems once occupied 90 million acres in the Southeastern United States.
- Timber harvest, land conversion, and suppression of wildfires reduced longleaf pine ecosystems to only 3.2 million acres. Fire is a part of their natural life cycle.
- Characterized by a tall overstory and grassy meadow forest floor, there has been a recent movement to restore these forests.
- Scientists have discovered that longleaf can tolerate droughts and capture more carbon than other trees, which gives them a potential as a natural climate solution, especially since forests of the Southeast are already known to capture more carbon than any other forest region in the U.S.

Hypotheses

- Today we are going to compare two forests. One is a timber species, loblolly pine, the other is longleaf pine, a species researchers hope to restore to mitigate climate change.
- Given what you have just learned about longleaf pines (above), write a hypothesis on which species might have a higher WUE.
- The longleaf site we are observing is a wet coastal site. The loblolly site is a dry upland environment. Include a hypothesis as to how this might effect the components of transpiration. Maybe one site will have more evaporation rather than transpiration?

- Include an explanation to support each of your hypotheses. You will submit these as part of your "Map of the Week" assignment.

7.1.3 Requesting loblolly ET & WUE data from AρρEEARS

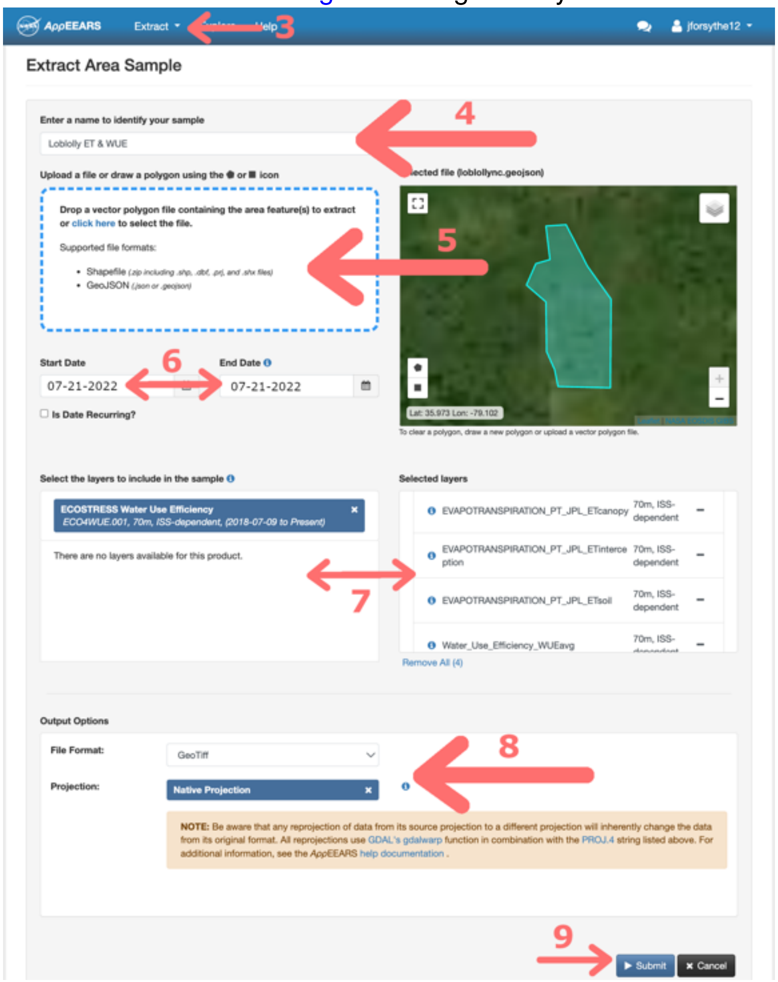
The procedure for downloading ET component and WUE data through the AρρEEARS interface is the same as the previous tutorials on land surface temperature.
1. First, begin by downloading two GeoJSON files, saving them somewhere you can remember (as always we suggest creating a folder for each tutorial):

1. Longleaf Pine (South Carolina Wet Coastal Environment): LongleafSC.geojson
2. Loblolly Pine (North Carolina Dry Upland Environment): LoblollyNC.geojson

and saving it somewhere you can remember. We recommend a folder containing all of the files for this tutorial.

NOTE: Depending on your web browser you may need to right click and select *Save as*. Some web browsers may even display the contents of the GeoJSON file instead of prompting you to save it. If this happens you can select the *File* dropdown menu and click on *Save as*.

2. Go to https://appeears.earthdatacloud.nasa.gov/ and login with your credentials.



3. Use the *Extract* dropdown menu to select *Area*. Next select *Start a New Request*.
4. Enter a useful name for the request you are going to submit, maybe something like “Loblolly ET and WUE”.

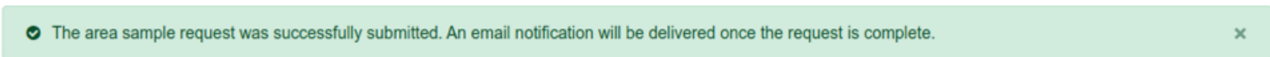
5. Drag and drop (or use the *click here to select the file* link) to upload the GeoJSON file *LoblollyNC.geojson*. The map should be updated with a polygon in a North Carolina forest.
6. Update the *Start* and *End* Date Fields for our preselected date of interest: 07/21/2022 to 07/21/2022.
7. Under *Select the layers to include in the sample* type the words “ECOSTRESS” and “Evapotranspiration.” Select *ECOSTRESS Evapotranspiration PT-JPL*. Click on the “+” signs to add the following layers to your cart:

- *EVAPORTRANSPIRATION_PT_JPL_ETcanopy*
- *EVAPORTRANSPIRATION_PT_JPL_ETinterception*
- *EVAPORTRANSPIRATION_PT_JPL_ETsoil*

Next, clear the selection of the current category using the small “x” to the right of the *ECOSTRESS Evapotranspiration PT-JPL* box.
Then under *Select the layers to include in the sample* type the words “ECOSTRESS” and “WUE.” Select *ECOSTRESS Water Use Efficiency* box.Click on the “+” signs to add the following layers to your cart:

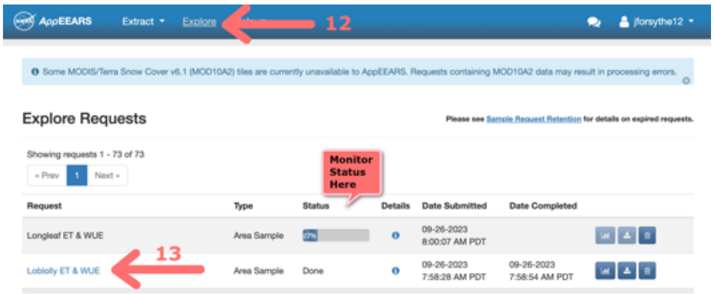
- *Water_Use_Efficiency_WUEavg*

Clear the selection of the current category using the small “x” to the right of the *ECOSTRESS Water Use Efficiency* box.
8. Under *Output Options*, we want to use GeoTIFF (Geographic Tagged Image File Format; essentially an image file where the corresponding geographic information is embedded in the file) and *Native Projection* for projection.
9. Click *Submit* to complete the data request. At the top, you should see a green banner:



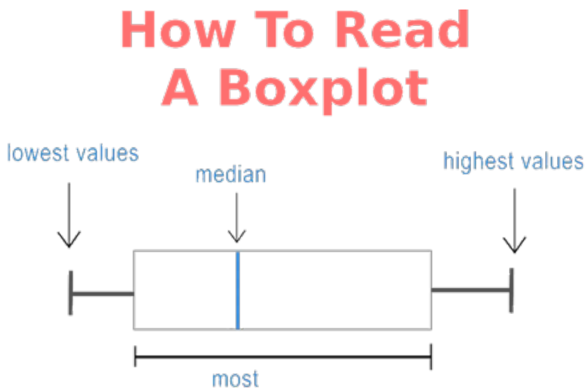
7.1.4 Requesting longleaf ET & WUE data from A$\rho\rho$EEARS

10. In the meantime, we are going to create a second request for this tutorial, as we need data for the longleaf pines to compare to the established loblolly. Use the *Extract* dropdown menu to select *Area*. Next select *Start a New Request*. Enter a useful name to distinguish this request from the other, maybe something like “Longleaf ET and WUE”. Drag and drop (or use the *click here to select the file* link) to upload the GeoJSON file *LongleafSC.geojson*. The map should be updated with a polygon on the coast of South Carolina.
11. Repeat steps 6 - 9 above to retrieve the ET component and WUE data for the longleaf pine site on 7/26/2022.
12. Use the *Explore* drop-down at the top to monitor the status of your request. The requests will likely go quickly, given that it is only one day’s worth of data.



7.1.5 Visualizing loblolly ET Component Data in A$\rho\rho$EEARS

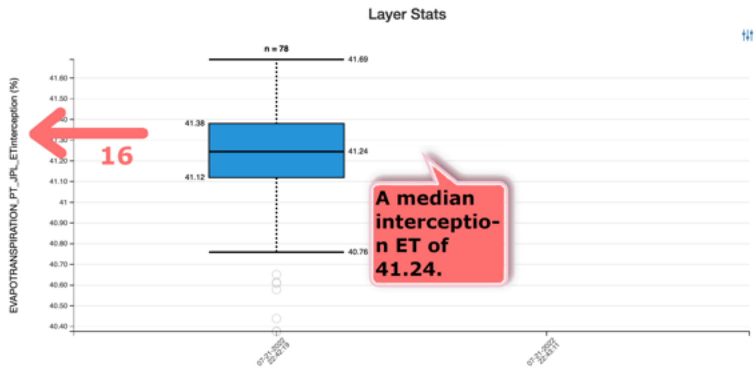
13. When your first request ("Loblolly ET and WUE") is complete, use the link on the *Explore* page to access the details. Let's check out the data... but first a quick review of boxplots:



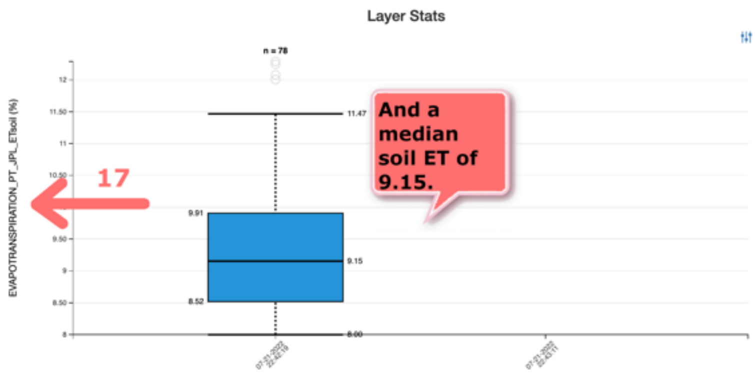
14. Our goal for the evapotranspiration component analysis is not to visualize the data in space, but rather to compare the differences of the two ecosystems (loblolly vs longleaf) as a whole. As a result there is no need to download the GeoTIFF files and import the layers into QGIS. We can explore the data with the A$\rho\rho$EEARS interface to get the information we need.

15. First, select the *EVAPORTRANSPIRATION_PT_JPL_ETcanopy* layer:

Notice the median value for the canopy component of evapotranspiration is 49.57. This means that the median value for the pixels in our area of interest is 49.57, which we can take to mean that 49.57% of the total evapotranspiration (the "EVAPOTRANSPIRATION_PT_JPL_ETinst" variable) is coming from the transpiration of the canopy. While the overall distribution of the data is skewed towards higher values, there is no need to worry as the range of the data (minimum to maximum observed value) is about 3%. Since our analysis is mostly concerned with the relative percentages of the different components (canopy vs interception vs soil), it is reasonable to simply use the median value.
16. Next, select the *EVAPORTRANSPIRATION_PT_JPL_ETinterception* layer.



Here we can say that 41.24% of transpiration is coming from interception.
17. Lastly, select the *EVAPORTRANSPIRATION_PT_JPL_ETsoil* layer.



So the overall breakdown for the components of evapotranspiration are 49.57% canopy transpiration, 41.24% interception evaporation, and 9.15% soil evaporation. You will report this in the write-up that accompanies your "Map of the Week" assignment alongside data for longleaf pine that you will do on your own.

7.1.6 Downloading loblolly WUE Data

18. From the *Layer* dropdown menu, choose "Water_Use_Efficiency_WUEavg", then expand the *Request* box above by clicking on the caret. Click the download button to continue.
Select the following filename: ECO4WUE.001_Water_Use_Efficiency_WUEavg_doy2022202224219_aid0001.tif
19. Download the files using the *Download* button that for some reason does not look much like a button on the top right corner of the screen. Save the files somewhere you can remember.

7.2 VISUALIZING ECOSTRESS WUE DATA IN QGIS

7.2.1 Adding a Google Satellite Basemap

20. Open QGIS and start a new project by selecting the *Project* menu, then *New*.
21. To add a basemap, find the *HCMGIS* menu bar, select *Basemap*, then pick your preferred map. For today's map, we will use *Google Satellite*. Note that clicking on a basemap type automatically adds a new layer to your map, as seen in the layer browser window.

7.2.2 Add in WUE layer

22. Use the *browser* window to find the folder where you saved the WUE file:
ECO4WUE.001_Water_Use_Efficiency_WUEavg_doy2022202224219_aid0001.tif
23. Double-click the ECO4WUE.001_Water_Use_Efficiency_WUEavg_doy2022202224219_aid0001.tif file to add it to your map. Again, notice that they are now also listed in the *Layers* window.

NOTE: Our loblolly data is at a pretty fine scale and might be hard to see if your basemap is zoomed out at the global scale. Qgis can automatically zoom to your layer's area of interest by right clicking (ctrl-click on Mac) on the layer and selecting *Zoom to Layer(s).*

24. Now you have ECOSTRESS WUE data on your map but we need to change it from grayscale. Right-click (ctrl-click on Mac) on the layer name in the *Layers* window and select *Layer Properties*.
25. On the menu bar to the left, select *Symbology* and change *Render type* to Singleband pseudocolor.
26. QGIS has automatically determined the minimum and maximum values from the datafiles; however, we are going to want to compare two ecosystems types and need to match them. Specify 0.35 as the minimum and 1 as the maximum. Click apply.
27. Change the color ramp to something that you feel communicates WUE. I selected the "Blues" option.
28. Finally, add the border from the LoblollyNC.geojso by double clicking on it in the *Browser* window. Right-click (ctrl-click on Mac) on the layer in the *Layers* window and change the symbology to *outline red*.

7.3 ADD MAP ELEMENTS

29. Following the procedure described in Tutorial #5 : Adding Elements To Maps, make a professional map complete with scalebars, labels, a legend, titles, and a North arrow. Include an inset showcasing the study region (North Carolina, USA) with this WUE as a basemap. This map will be your part of your map of the week assignment.

7.4 MAKE THE SAME MAP FOR LONGLEAF PINES

30. Follow the same procedure (steps 13 - 29) for our other request, "Longleaf ET & WUE":

1. Explore the ET component data for the longleaf pine ecosystem in the A$\rho\rho$EEARS interface to determine the relative contributions of the canopy, interception, and soil to evaportranspiration. Note the differences between longleaf and loblolly. Submit this as part of your write-up for the "Map of the Week" assignment.

2. Download the water use efficiency GeoTIFF for longleaf pines.
3. Visualize this WUE data in QGIS.
4. Make a second professional map with the same color ramp scale for the WUE of the longleaf pine complete with scalebars, labels, a legend, titles, and a North arrow.
5. Submit these two maps (one for longleaf, one for loblolly) as part of your "Map of the Week" assignment along with the write-up described below.

Map of the Week Assignments

1. Make a WUE map for longleaf pine of the same format as the loblolly pine map we made in the tutorial. It should include a basemap of water use efficiency with an inset showcasing the geographic region. The map should be complete with scalebars(s), north arrow(s), legend(s), title(s), and label(s). Submit this longleaf map alonside the loblolly we made in the tutorial today.
2. Provide a 1-2 paragraph description of your maps and ET component data that includes your hypotheses on which tree species would be better suited to mitigate climate change. Does your map support your hypotheses? Would you recommend foresters plant longleaf pine trees instead of loblolly? Will it maximize growth while minimizing water loss? Address the limitations of your analysis.

Submit these assignments via Canvas before Monday's class.

Datafiles

In case you encountered any issues with the A$\rho\rho$EEARS database, here are copies of the ECOSTRESS GeoTIFF file for the loblolly WUE:

1. ECO4WUE.001_Water_Use_Efficiency_WUEavg_doy2022202224219_aid0001.tif

And longleaf WUE:

1. ECO4WUE.001_Water_Use_Efficiency_WUEavg_doy2022207201636_aid0001.tif

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