An investigation of the hydration state of trees as a function of their proximity to urban and rural streams

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GEO 327G Spring 2022 with Dr. Mark Helper

May 6, 2022

[1] Problem formulation

A major area of investigation for Earth scientists as of late, especially those interested in the changing climate, is the phenomenon of urban overheating. This is the idea that human infrastructure such as buildings, roads, parking lots, etc. contributes to a heating effect that results in higher average surface temperatures in urbanized areas than in surrounding un-urbanized areas (Wei et al. 2021). Besides posing a threat to human health and wellbeing, urban overheating signifies a departure from typical ecosystem dynamics. Higher surface temperatures brought on by urban overheating contribute to a higher vapor pressure deficit, which is the ratio of the amount of moisture the air holds to the amount of moisture it could potentially hold at a given temperature and humidity, and therefore a higher evaporative demand on vegetation and soil. Especially during periods of drought, increased evaporative demands place vegetation under greater hydrologic stress as near-surface water becomes more difficult to access (Carriere et al. 2020) and plants attempt to transpire more.

The main goal of this project is to investigate whether trees in urban settings do experience greater hydraulic stress compared to those in non-urban settings, and more specifically how their proximity to a stream affects this dynamic. Leaf water potential acts as a proxy for the stress a plant experiences as it represents the pressure at which water is held in tension in the plant. The movement of water through a tree can be imagined as a string; the evaporative demand of the air packet surrounding the tree pulls the water from the subsurface into the roots, through the roots up through the trunk, from the trunk to smaller branches, and finally through the leaves where the water is returned to the atmosphere as water vapor. As evaporative demand increases so too does this pulling force, and if this force becomes too great, the string may break. Hydraulic failure is the term applied to this break in the column of water flowing through a tree, and if the tree is not able to restore the flow quickly enough it risks mortality (Pangle et al. 2015).

But the hydration state of a tree does not depend on just one factor. How easily a tree is able to access subsurface water through its roots also plays an important role in determining how stressed it is. Trees have a diverse array of strategies to access water in the subsurface, and in this project I investigated what role streams play in these water access strategies and in overall ecosystem health. The literature offers different perspectives on the role of streams supporting vegetation in their riparian zone, which is the area immediately surrounding the stream on either side. In 2015, Stromberg et al. suggested that the riparian zone of streams in semiarid environments support higher levels of biodiversity and more woody vegetation than do surrounding terrestrial areas, while Sun et al. in 2008 suggested that the Yangtze River of China did not play a dominant role in supporting the vegetation in its riparian zone.

The construction of this project assumes that a stream does play a role in the hydration of trees in its riparian zone, so the question instead is how big of a role does the stream play. At this point in time, the size of my dataset limits the integrity of any analysis performed, but I hope to lay the groundwork for a methodology I can use as my undergraduate research continues. With this project I attempt to assess trends in the leaf water potential of the trees as the distance of the trees from the stream varies and to compare these trends between the stream in an urban setting and the stream in a non-urban setting.

[2] Data collection

I collected leaf water potential (LWP) data for six Juniperus ashei at the White Ranch field site in Dripping Springs, Texas and for three trees at the Pease Park field site in Austin, Texas. For each tree, I measured three leaf bunches to obtain an average representative of the whole tree. Leaf water potentials are pressures reported in pounds per square inch (PSI). Because all water in a plant is held in tension, these pressure values are negative; a more negative value (larger magnitude) indicates that the water is being held more tightly in tension which in turn indicates that the plant is experiencing more hydraulic stress. I took other data for each tree such as the air temperature, wind conditions, sun conditions, and tree species, although all of the trees used in this project are of the same species. I have included a screen-capture of the digitized point features (Figures 1 and 3) alongside the value attribute table at the Onion Creek site (Figure 2).

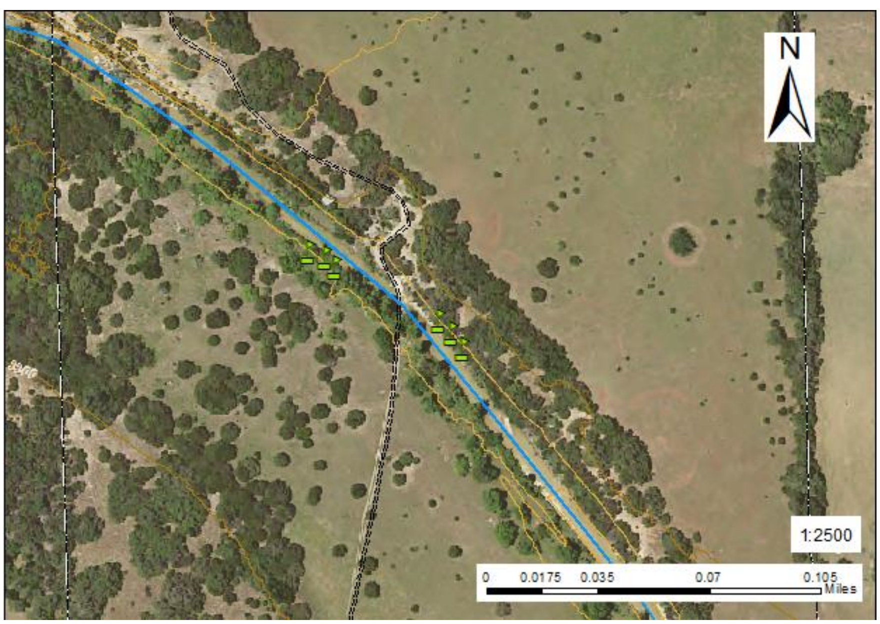
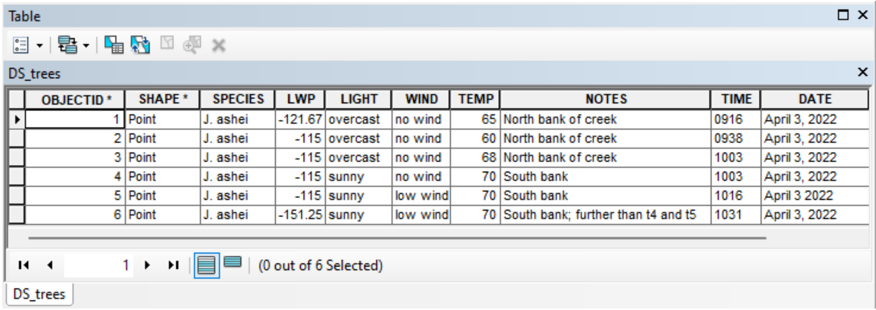


Figure 1: The six trees I sampled around South Onion Creek on the White Ranch property. I have included a scale bar to help understand the extent of the area I surveyed. In the future I plan to sample many more trees to cover more distance along the creek bed.



Table

DS_trees

OBJECTID *	SHAPE *	SPECIES	LWP	LIGHT	WIND	TEMP	NOTES	TIME	DATE
1	Point	J. ashei	-121.67	overcast	no wind	65	North bank of creek	0916	April 3, 2022
2	Point	J. ashei	-115	overcast	no wind	60	North bank of creek	0938	April 3, 2022
3	Point	J. ashei	-115	overcast	no wind	68	North bank of creek	1003	April 3, 2022
4	Point	J. ashei	-115	sunny	no wind	70	South bank	1003	April 3, 2022
5	Point	J. ashei	-115	sunny	low wind	70	South bank	1016	April 3 2022
6	Point	J. ashei	-151.25	sunny	low wind	70	South bank; further than t4 and t5	1031	April 3, 2022

1 (0 out of 6 Selected)

DS_trees

Figure 2: Value attribute table for the six trees at the Onion Creek site. For brevity's sake I did not include a figure for the VAT of the Shoal Creek trees, but all the fields are the same.

Figure 3: The three trees I sampled around Shoal Creek's extent in Pease Park. So far, I've only sampled Juniperus ashei, and only three trees were sampled because I was not able to find J.ashei on the west bank of the creek.

I sourced all other data for the White Ranch site (roads, streams, DEM, hillshade, etc.) from Dr. Mark Helper who very generously made available to me the data he collected when the university first acquired the White Property.

For the Pease Park site, I sourced elevation data and aerial imagery from the Texas Natural Resources Information System, and sourced all other various feature data from the publicly available data on ArcGIS Online. The table below contains more details about the data I used.

Description	Classification	Spatial Reference	Resolution (if raster)	Source and URL	Date of collection
Austin W QQuad image	Aerial image raster	WGS 1984 Datum; Mercator Auxiliary Sphere Projection	0.6 m x 0.6 m	TNRIS Data Hub http://www.glo.texas.gov/land/land-management/gis/	2020

Austin E QQuad image	Aerial image raster	WGS 1984 Datum; Mercator Auxiliary Sphere Projection	0.6 m x 0.6 m	TNRIS Data Hub http://www.glo.texas.gov/land/land-management/gis/	2020
DEM of north-east Shoal Creek area	DEM raster	NAD 1983 Texas Central (feet) Datum; unprojected	3 m x 3 m	TNRIS Data Hub http://www.glo.texas.gov/land/land-management/gis/	2016
DEM of south-east Shoal Creek area	DEM raster	NAD 1983 Texas Central (feet) Datum; unprojected	3 m x 3 m	TNRIS Data Hub http://www.glo.texas.gov/land/land-management/gis/	2016
DEM of north-west Shoal Creek area	DEM raster	NAD 1983 Texas Central (feet) Datum; unprojected	3 m x 3 m	TNRIS Data Hub http://www.glo.texas.gov/land/land-management/gis/	2016
DEM of south-west Shoal Creek area	DEM raster	NAD 1983 Texas Central (feet) Datum; unprojected	3 m x 3 m	TNRIS Data Hub http://www.glo.texas.gov/land/land-management/gis/	2016
Creeks of Austin	Line feature layer – vector	NAD 1983 Datum; UTM Zone 14N Projection	n/a	GEO 327G class data – Lab 6	2022
Pease Park Boundary	Polygon feature layer-vector	NAD 1983 Datum; UTM Zone 14N Projection	n/a	ArcGIS Online open source data BOUNDARIES_city_of_austin_parks - Overview (arcgis.com)	2015
DEM of Onion Creek's extent on the White Ranch	DEM raster	NAD 1983 Texas Central (feet) Datum; unprojected	3 m x 3 m	TNRIS Data Hub http://www.glo.texas.gov/land/land-management/gis/	2016
South Onion Creek	Line feature layer – vector	NAD 1983 Datum; UTM Zone 14N Projection	n/a	Dr. Helper's White Property map package	Unknown
White Ranch roads and fences	Line feature class – vector	WGS 1984 Datum; Geographic Coordinate System (unprojected)	n/a	Dr. Helper's White Property map package	Unknown
FM 194	Line feature layer - vector	NAD 1983 Datum; Geographic Coordinate System (unprojected)	n/a	Dr. Helper's White Property map package	Unknown
White Ranch Property Boundary	Polygon feature layer – vector	NAD 1983 Datum; UTM Zone 14N Projection	n/a	Dr. Helper's White Property map package	Unknown
White Ranch elevation contours	Line feature layer – vector	NAD 1983 – UTM Zone 14N Projection	n/a	Dr. Helper's White Property map package	Unknown
Dripping Springs WQQ image	Aerial image raster	WGS 1984 Datum; Mercator Auxiliary Sphere Projection	0.6 m x 0.6 m	TNRIS Data Hub http://www.glo.texas.gov/land/land-management/gis/	2020

[3] Data preprocessing

The spatial reference I chose to use is the North American Datum 1983 with the Universal Transverse Mercator Zone 14N coordinate system. As the table above shows, much of the data I used for my project did not originally match this coordinate system, so I had to go through the process of projecting both raster data and vector data. I have included an example of one of the DEM raster files at the Shoal Creek site.

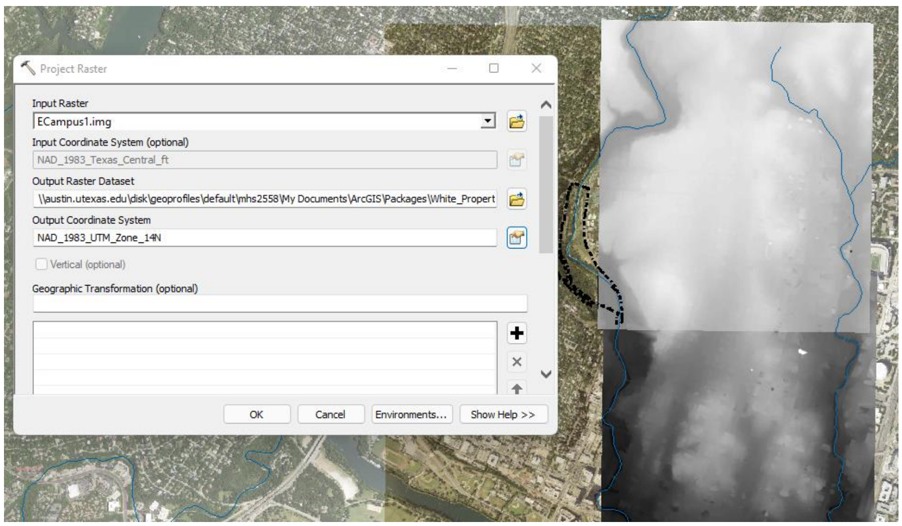


Figure 4: Projecting one of the DEM tiles into the spatial reference system I am using for the project. This screen capture was taken at a scale of

Next, I created hillshade layers from the DEM raster layers. Example below:

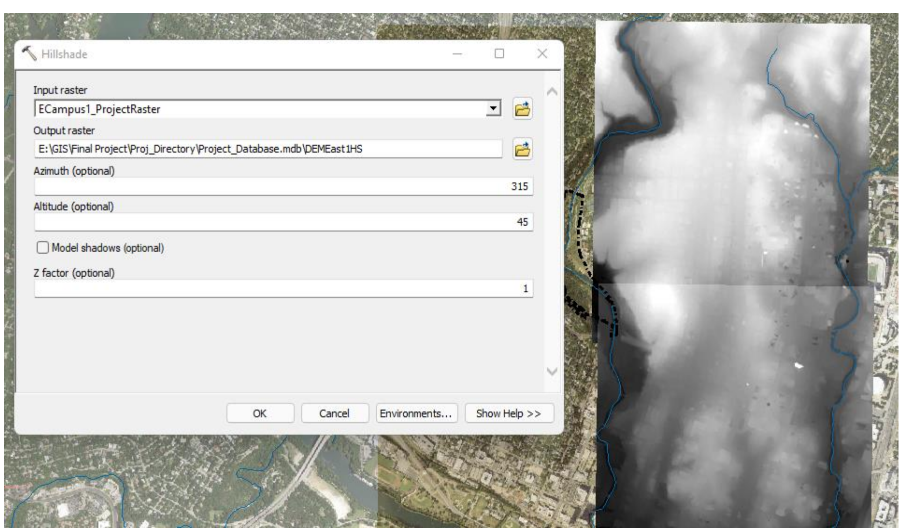


Figure 5: Creating a hillshade from the DEM raster. This process was repeated for each DEM file. This screen capture was taken at a scale of

Next, I clipped and re-symbolized the City of Austin Parks feature layer so that I was left with just the boundary of Pease Park, which is the park around the extent of Shoal Creek where I sampled trees. This process is documented below:

Figure 6: City of Austin Parks feature layer before clipping to just Pease Park. This screen capture was taken at a scale of 1:24,000.

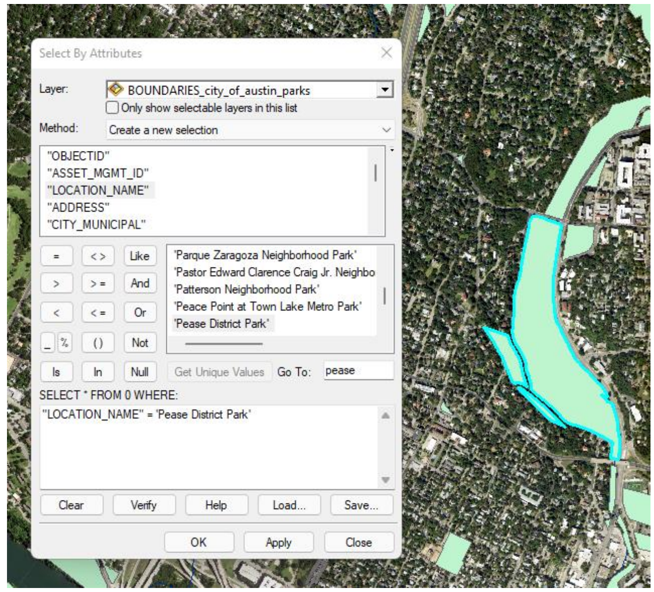


Figure 7: Using SQL to select Pease Park in order to make a layer from just the selection. This screen capture was taken at a scale of 1:15,000.

Figure 8: The new polygon feature layer containing just Pease Park now re-symbolized to only represent the boundary of the park. This screen capture was taken at a scale of 1:8,000.

Because I am working at such a small scale (often just 1:2,500 suffices for what I need to visualize), I decided to make edits to the South Onion Creek and Austin Creeks feature layers. I re-digitized the streams to more closely match the aerial images, which are the most current data sets I use in the project. An example from Pease Park is shown below.

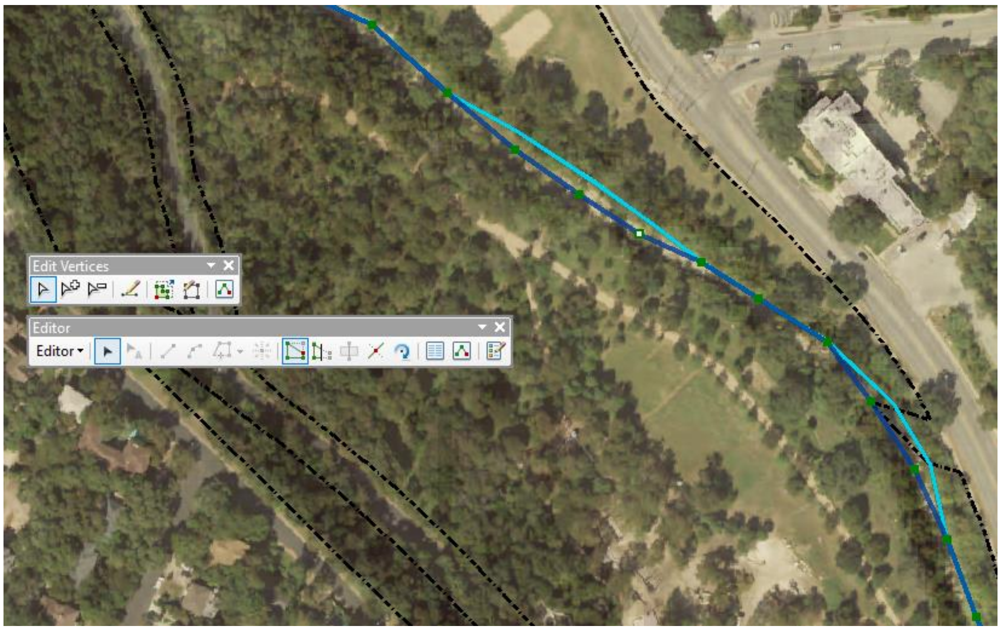


Figure 9: Editing the extent of Shoal Creek that runs through Pease Park. The light blue represents the stream before edits, the dark blue after. I made edits by dragging vertices and sometimes creating new vertices so that the stream would more closely coincide with the stream in the aerial image. This screen capture was taken at a scale of 1:2,500.

[4] ArcGIS processing

One of the questions I aim to answer in this project is if a tree becomes more hydraulically stressed as its distance from a stream increases. If there is a correlation between hydration state and distance from a stream, the next question I am to answer is how this trend may differ between streams in an urban, developed setting and streams in a non-urban, undeveloped setting due to the effects of urban overheating. I have chosen to construct a series of buffer rasters that represent a distance away from the stream feature on either side. I have constructed a 5-meter buffer, a 10-meter buffer, and 15-meter buffer. I intend to adjust these distance bins as I continue to take data for this project in the future.

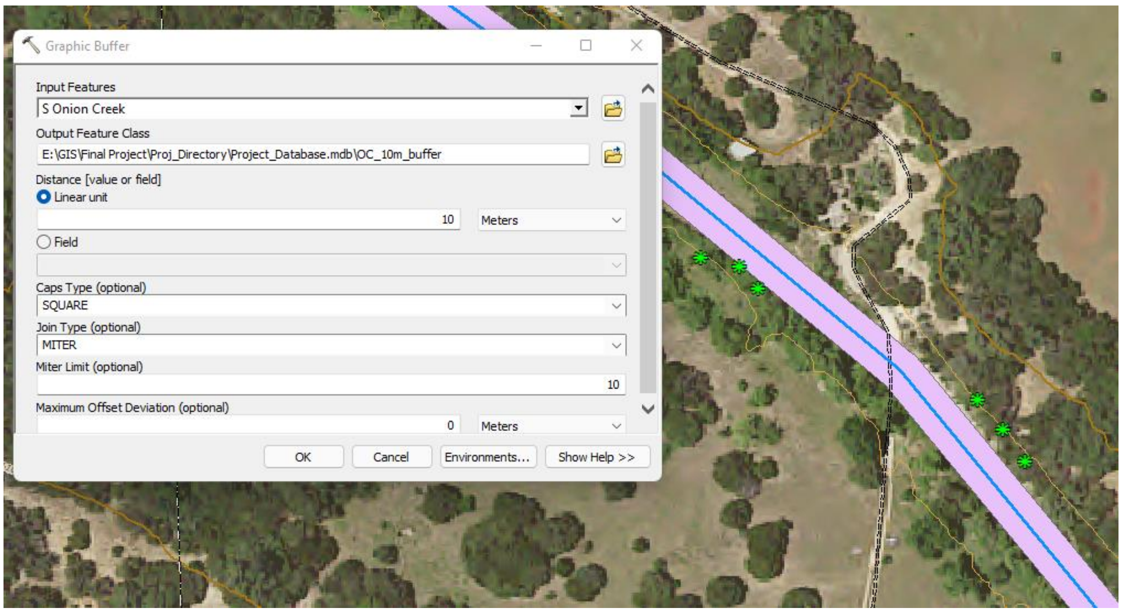


Figure 10: Creating a buffer raster for a distance of 10m on either side of the creek. In this image, the 5m buffer is already being displayed, and I am in the process of creating the 10m raster. This screen-capture was taken at a scale of 1:1,250

*note I use a different symbology for the tree point features, I will explain more as I continue the process of creating the buffers

Figure 11: The 5m, 10m, and 15m buffer rasters have all been created and are stacked in the order stated.

I created this same set of three buffer rasters for the Shoal Creek site and symbolized them in the same way. The trees I sampled are relatively close together and because of this it is difficult to tell which trees fall into which buffer distance.

To determine which trees fell into which buffer using a more rigorous method than just looking, I used the geoprocessing intersect tool. This tool allows you to input feature layers and will return only features in locations where the inputted layers intersect. I used this tool a total of three times at each field site, intersecting the tree point feature layer with each of the three buffer distance layers. Figure 12 below shows the product of the tree feature class and 5m buffer raster intersection.

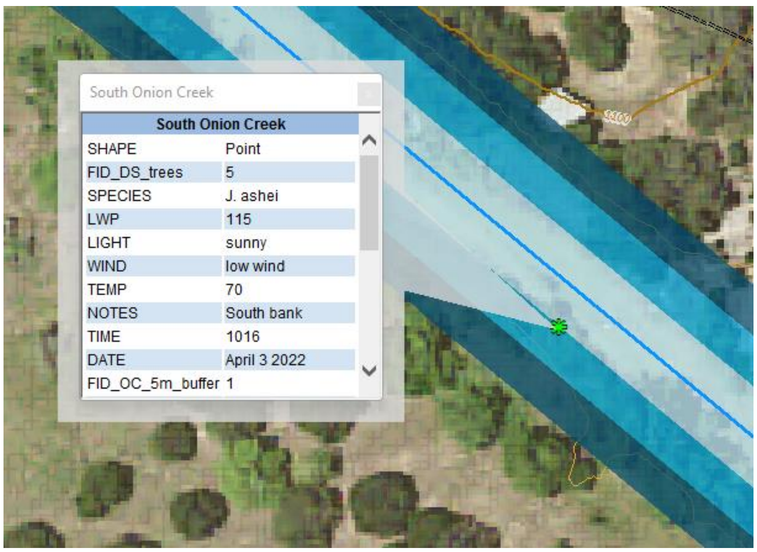


Figure 12: The new feature layer created by the intersection only has one tree (tree 5) i.e., only one of the six trees I sampled at this site fell within 5 meters of the stream. This screen capture was taken at a scale of 1:800.

After creating the intersection feature layers, I re-symbolized the trees to represent which distance bin they lie within. The green asterisks represent trees within the 5m buffer, yellow asterisks represent trees within the 10m buffer, and red asterisks represent trees within the 15m rasters.

The following two figures depict each site after the intersection feature layers have been created and the trees have been re-symbolized.

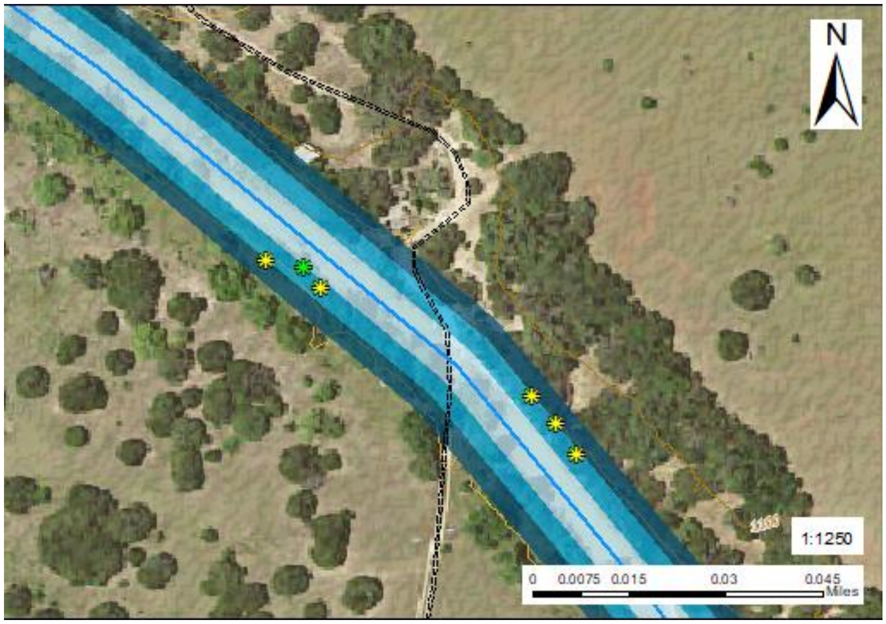


Figure 13: The Onion Creek site with buffer rasters depicted and trees re-symbolized to represent the distance bin they lie within. Trees 1,2,3,4, and 6 lie in the 10m buffer, tree 5 lies in the 5m buffer.

Figure 14: The Shoal Creek site with buffer rasters depicted and trees re-symbolized to represent the distance bin they lie within. Trees 2 lies in the 10m buffer, while trees 1 and 3 lie in the 15m buffer.

As I mentioned in the introduction, my analysis is severely limited by the size of my data set. I have elected to not perform any sort of geostatistical analysis for this reason. However, in the final map products to follow, I display the leaf water potential value for each tree so that at least a visual comparison can be made between trees in the different buffer layers. I have made a map for each site which I will submit separately as PDF files, but I will briefly comment on them here.

[5] Data presentation

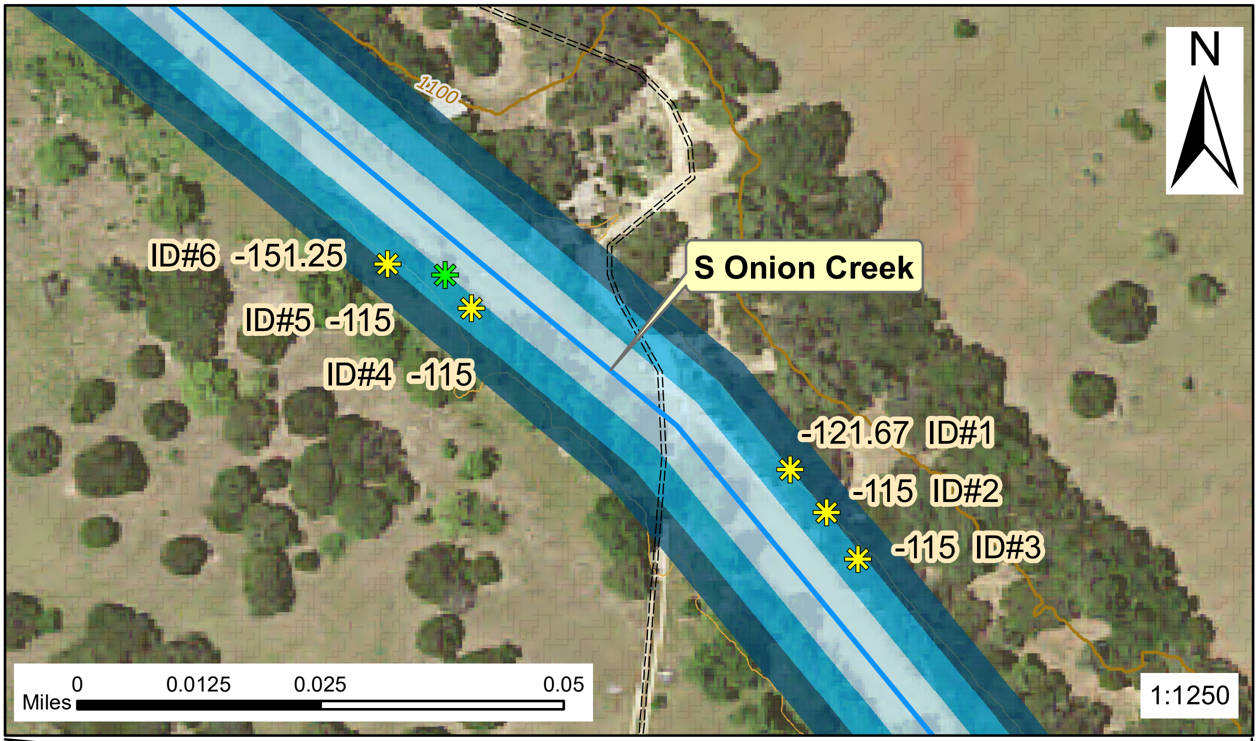
Map 1 shows the leaf water potentials of six trees lying within 5, 10, and 15 meters of South Onion Creek. Of the six trees sampled, five of them fell within 10m of the creek (Tree ID#s 1,2,3,4, and 6), while only one fell within 5 m of the creek (Tree ID# 5). Overall, the leaf water potentials for these trees were remarkably consistent, with four of the trees sampled having an average LWP of -115 PSI and one other tree having an average LWP of -121.67 PSI. The last tree (ID#6) sampled had a lower average LWP at -151.25 PSI, meaning this was the most hydraulically stressed, or dehydrated, tree sampled. While this tree still falls within 10m of the stream, it does sit just along the border between the 10m buffer and 15m buffer. Again, the size of this dataset limits me from being able to determine if this is a statistically significant difference.

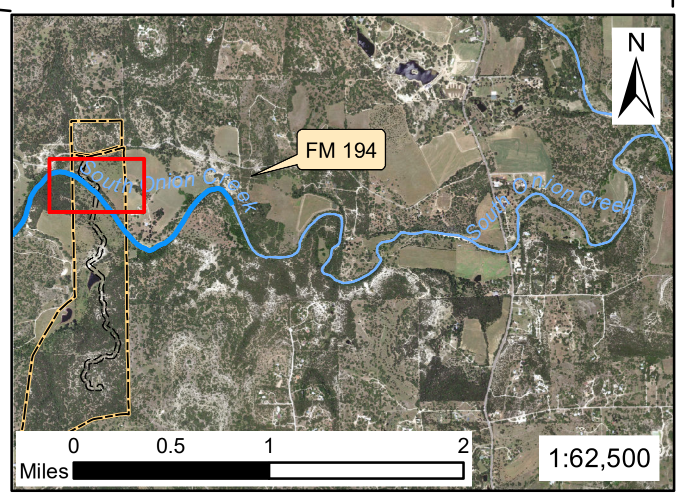
Map 2 shows the leaf water potentials of three trees lying within 5, 10, and 15 meters of Shoal Creek. I sampled only three trees at this site because as I mentioned earlier, I only sampled Juniperus ashei. Two of the three trees sampled at this site (Tree ID#s 1 and 2) had very similar LWP at -257.5 PSI and -260 PSI respectively. Of these, tree 1 fell within 15m of the stream, while tree 2 fell within 10m of the stream. Again, the amount of data I have makes it difficult to reasonably determine if distance from the stream actually has no correlation with a tree's hydration state. The third tree (ID#3) has a higher average LWP than the previous two at -206.67 PSI, meaning it is less hydraulically stressed, or less dehydrated, than the others. This tree also falls within 15m of the stream, so some sort of local heterogeneity in incoming radiation or temperature could explain this difference. I would like to note however, that the leaves on this tree were morphologically different from the J. ashei I sampled, leading me to believe that it might be a different species of juniper than the other trees I sampled. This could be a possible explanation for the difference in this tree's LWP from the others.

As for differences between the two sites, the trees sampled at Shoal Creek in general had much more negative leaf water potentials, meaning that these trees were under more hydraulic stress relative to the tree sampled at Onion Creek. This does answer one of the motivating questions of this project as it shows that trees around urban streams (Shoal Creek) do experience greater hydraulic stress than trees around rural streams (Onion Creek). My instinct of course is to attribute this difference to urban overheating, but the other data I have taken do not necessarily agree. I took the data at each site on different days but at the same time of day, from around 9:00 AM to 11:00 AM. Interestingly, the temperature at this time of day at both sites was in the range of 65-70 degrees F, so it is unlikely that the difference in average LWP between the two sites can be attributed to differences in temperature. This is a rather incomplete project, so my future work includes not only taking much more data, but also investigating other properties of this system such as stream dynamics. Still, this report lays the groundwork for an investigation I will continue with my undergraduate research.

Map 1: Leaf Water Potentials of Trees in the Riparian Zone of South Onion Creek

Michael Snook
May 5, 2022





Explanation

Trees within 5m of stream

- 5

Trees within 10m of stream

- 1
- 2
- 3
- 4
- 6

S Onion Creek

====== Main S Ranch Road

5m buffer

10m buffer

15m buffer

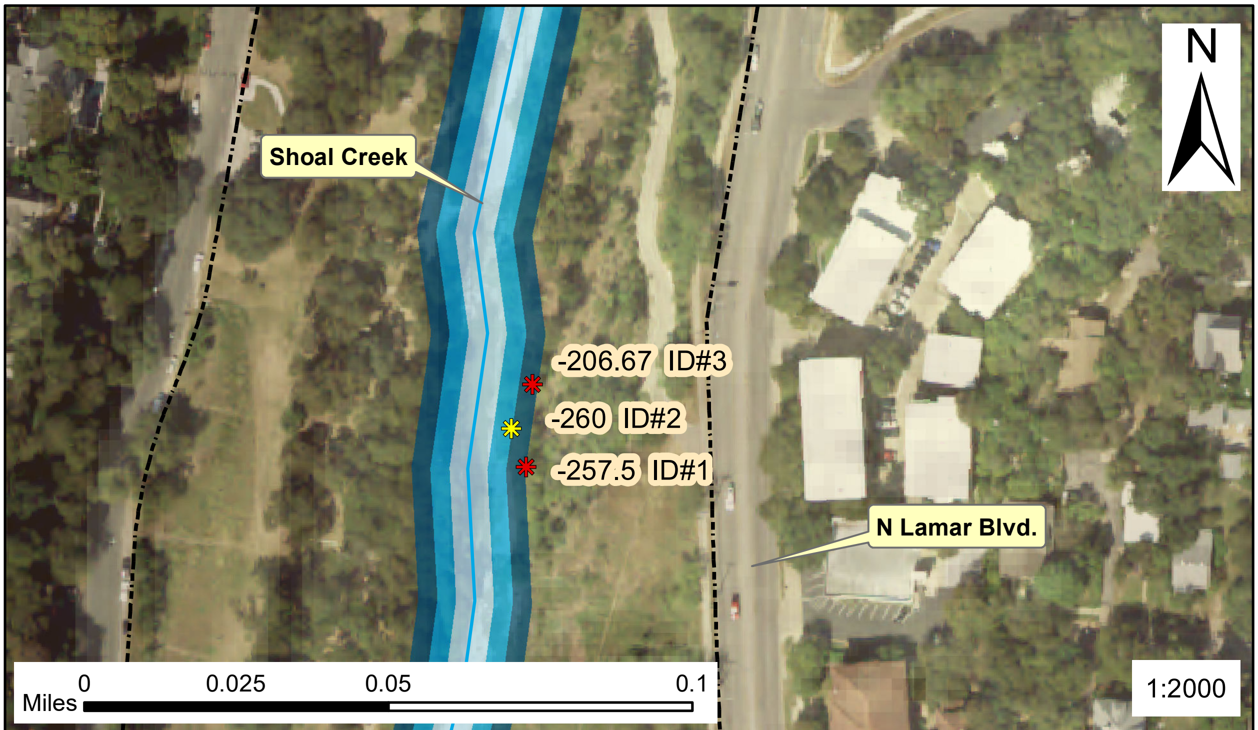
*the explanation tree labels are their specimen ID numbers

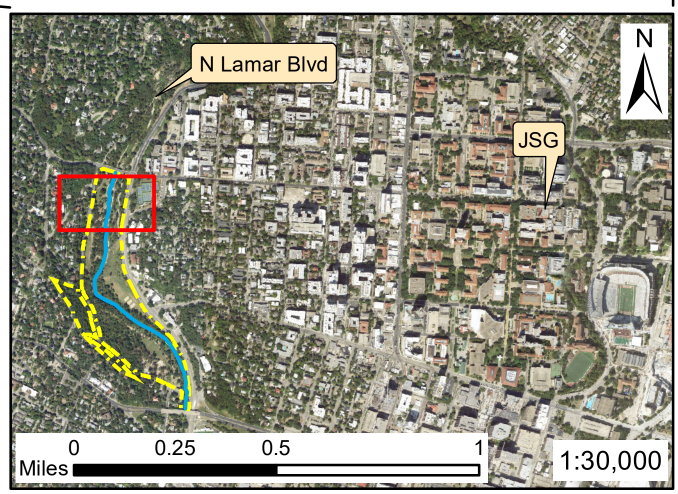
For all data frames:
Datum: NAD 1983
Coordinate System: UTM Zone 14N

This map displays the measured leaf water potential (LWP) of six Juniperus ashei on the North and South banks of Shoal Creek. Leaf water potential acts as a proxy for the hydration state of the tree, where a larger magnitude for LWP indicates a more dehydrated tree. Three buffer distances from the stream are also displayed.

Map 2: Leaf Water Potentials of Trees in the Riparian Zone of Shoal Creek

Michael Snook
May 5, 2022





Explanation

Trees within 10m of stream

2

Trees within 15m of stream

1

3

Shoal Creek

Pease Park boundary

5m buffer

10m buffer

15m buffer

*the explanation tree labels are their specimen ID numbers

For all data frames:
Datum: NAD 1983
Coordinate System: UTM Zone 14N

This map displays the measured leaf water potential (LWP) of three Juniperus ashei on the East bank of Shoal Creek. Leaf water potential acts as a proxy for the hydration state of the tree, where a larger magnitude for LWP indicates a more dehydrated tree. Three buffer distances from the stream are also displayed.