Urban Tree Shade Analysis: City of Austin, Texas

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Table of Contents

1. Introduction

1.1. Purpose and Objective:

The overall value of shade provided by a continuous tree canopy in a growing urban area is often undervalued and underappreciated by those who benefit from it. In the city of Austin, Texas however, the Urban Forestry Program and Board (UFP) is the driving force behind the maintenance and protection of the city's urban tree canopy. Continuous shade from a tree canopy in an urban area is an easily identifiable amenity and an important environmental feature that can have a great impact on the overall quality of life in a city. The purpose of this project is to utilize the analysis capabilities of Geographic Information Systems (GIS) to help identify the canopy coverage of the streets and trails of Austin and provide the UFP with a usable shade index for the city's street blocks and trail segments, as well as several averaged shade indices for the street blocks and trail segments that lie within the city's neighborhoods and watersheds. The UFP will take our results and use them to plan for future planting as well as apply them to related studies that are unique to the city's urban forest.

The objective of this project is to provide the UFP with efficient and effective tree shade indices that can be used to help determine the future location of trees and allow the UFP to focus the future planting of those trees in the areas of the city that have the least canopy coverage according to our findings. A joint study between members of the two consulting firms of Austin Urban Trails© (AUT) and Sustainable Solutions of Central Texas© (SSOCT) resulted in an extensive and collaborative research effort that provided the indices. The UFP will be able to use these indices to help them determine the density and distribution of the city's urban canopy.

They will also be able to conduct other side projects that will utilize the information we provide and relate it to the numerous impacts that trees have on an urban environment such as Austin.

1.2. Scope:

The scope of this project is limited to the streets and trails that fall within the city limits of Austin, Texas. While analysis was only conducted on the streets and trails of the city, the maps that display the average shade per watershed contain watershed boundaries that fall outside of the city limits. This was done intentionally to avoid any distortion in the maps of the watersheds as several of them extend beyond the city limits, but contain streets blocks and trail segments within the City of Austin.

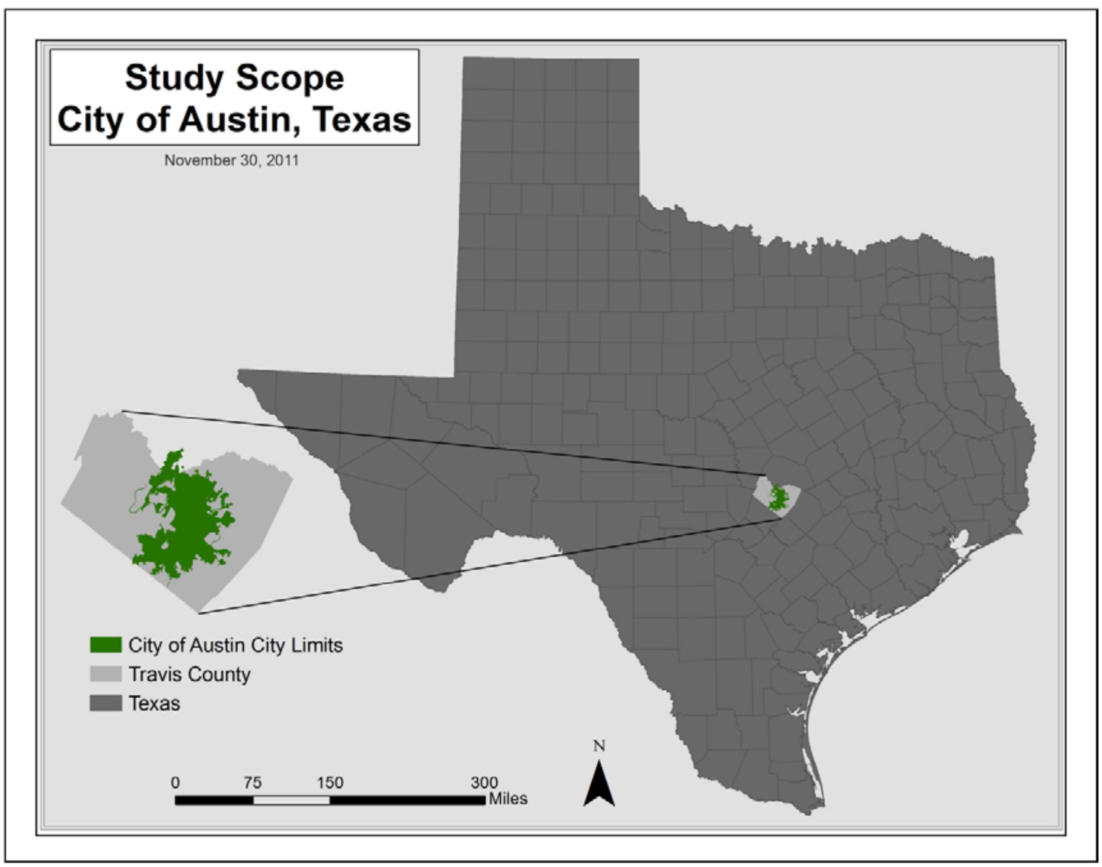


Figure 1: Study area of the project

1.3. Background and Literature Review:

Before analysis even began, the two groups expected to produce indices that would support widespread tree planting throughout the city, especially in the newer outlying parts of Austin. We also expected to produce results that support existing scientific literature that exemplifies the numerous benefits that trees can provide to a city, or anywhere for that matter. Relevant literature on the subject of tree benefits was compiled and examined by the groups.

When assessing the benefits that trees produce for an urban area, science shows that these benefits are both tangible and numerous. One very important benefit would be that urban trees help to maintain the air quality of a city by removing gaseous pollutants from the air by absorbing them. They absorb lingering CO_2 and other greenhouse gasses and in turn, replenish the atmosphere with oxygen (Bay Area Green 2009). In fact, planted Evergreen trees in rows can capture up to 85 percent of the particulate air pollution that blows through their branches by trapping the particulates and filtering them through the leaves, stems, and twigs of the tree (Bay Area Green 2009). The particulate pollution in a dense urban area can cause serious respiratory problems for humans, especially children.

Trees also help prevent global climate change. They act as a “carbon sink” by removing carbon from the CO_2 and then store it as cellulose, all while releasing carbon back into the air. A healthy green tree can absorb up to 40 pounds of CO_2 per year, which helps maintain a constant climate and improve air quality (Bay Area Green 2009). Also, in terms of maintaining a constant climate, trees help reduce the urban heat island effect, especially in places like Austin. The trees in a city can prevent heat islands from forming with their shade and can reduce the air temperature by as much as four degrees in these areas through transpiring (City of Austin, 1995).

In fact, by covering just 40 percent of our study area with trees, the shade provided would lower the peak summer temperatures by as much as two degrees (City of Austin, 1995).

Trees also help reduce household energy consumption, which saves money for anyone who pays the electric bill for a home or business. According to Dr. E. Greg McPherson, if you planted a tree today on the west side of your home, in five years your energy bill should cost three percent less than it currently does, and in 15 years the savings will equal nearly 12 percent of your current energy bill (Center for Forest Research, 2001). It is also stated that properly placing trees around a building can reduce air conditioning needs by 30 percent and can cut energy costs by 20 to 50 percent, in terms of the heating of a building (Center for Urban Forest Research, 2001). The more trees you have planted on the eastern and western sides of your home, especially if they are large and healthy, the more you will save in terms of money spent on your electric bill (Center for Urban Forest Research, 2001). These trees will help mitigate the amount of heat that enters a home through the walls and windows on eastern and western sides of a building, saving you the electric used for cooling and ultimately the money spent on it.

The urban forest in a city can also save the city money in terms of infrastructure repair. The more shade you have on a city street from a tree can mean more time between repaving sessions. With just 20 percent of a street under tree shade, the pavement condition of that street is improved by 11 percent which equals a 60 percent cut in repaving costs over a 30 year period (Bay Area Green, 2009). The money saved on repaving can be collected and spent on more trees to line city streets and save even more money on infrastructure repair.

Maybe the most important benefit that trees provide in terms of environmental assistance is the impact they have on local water quality by slowing storm water runoff. Trees can slow and even absorb storm water runoff, decreasing the amount of storm water storage needed and decreasing the amount of runoff that ends up in our streams and creeks. According to the experts at the USDA Forest Service, the planting of trees results in less runoff as well as less erosion found in local water bodies. This allows for better and more frequent recharging of groundwater. They also state that wooded areas help prevent the transport of sediment and chemicals into streams (USDA Forest Service, 2001). A study over tree benefits in the Greater San Antonio area showed that the existing tree canopy there reduces the need for storm water management and retention by 678 million cubic feet (American Forests, 2002). By using a $2 per cubic of foot storm water management cost system, trees currently save the San Antonio area $1.5 billion in one time construction costs (American Forests, 2002).

Other than the improvements to air quality, climate control, energy costs, infrastructure savings, and water quality, trees also provide aesthetic value to an urban area and allow for urban wildlife to prosper. The aesthetic quality that trees provide can improve home and building property values, as well as provide a much more pleasant atmosphere for those who frequent the area. In some cases, healthy trees can add up to a 15 percent increase in residential property value alone (Bay Area Green, 2009). They also block sound and noise from cars and pesky neighbors, reducing noise pollution by as much as 40 percent (Canopy, 2011). Also, having trees planted along the city streets and trails will increase the overall shade and thus invite more people to utilize the sidewalks and trails that cities provide. The members of the two groups of AUT and SSOCT are hoping that the scientific research, as well as the indices, will establish enough evidence to allow for the UFP to start planning for future tree planting in Austin.

2. Data

Between the two groups there were seven original sets of data used for the project. Each data set was provided by The City of Austin through the UFP for our use. These seven original data sets include: a City of Austin city limits polygon layer; a block-by-block streets line layer which extended beyond the city limits; a city parks polygon layer; a city trails line layer that extended beyond the city limits; a city watershed polygon layer which also extended beyond the city limits, a polygon layer of the neighborhood planning areas in the city; and a Lidar based tree canopy polygon layer from 2006. The seven layers we acquired already came projected in the Lambert Conformal Conic projection and used the NAD 1983 State Plane Texas Central FIPS 4203ft. coordinate system. Because they all came in the same projection and used the same coordinate system, there was no need to change projections or coordinate systems to match. They also all came in the form of vector data with every layer representing a polygon file. The only exceptions to this were the streets and trails layers, which were originally line files. In terms of usefulness for the tree shade analysis, the data was exactly what we needed to provide our shade indices. The combination of all theses layers gave a geographic representation of the problem the UFP wanted us to help them solve with our shade indices. The trails layer had to be segmented using X-Tools, which is a free extension for ESRI's ArcMap. This allowed the trails to be divided into smaller, equal sections for a more accurate representation of the tree shade within the desired trail segments the UFP wanted to see. The streets and trails layers, along with the overlay of the 2006 tree canopy, were the primary layers used in our analysis. The city limits layer was used as the general scope of the project, meaning the streets and trails that extended outside of the city limits were subsequently eliminated. The watershed and neighborhood layers were instrumental in the establishment of the averaged shade indices for the streets and trails of each individual watershed and neighborhood. The seven layers provided, allowed the teams to establish tree shade indices to be shown either as an average by the individual watersheds and neighborhoods, or by the overall shade percent for street blocks and trail segments.

Layer	Source
Streets	COA*
Tree Canopy (Lidar)	COA*
Watersheds	COA*
Planning Neighborhoods	COA*
Parks	COA*
Trails	COA*
City Limits	COA*

*Abbreviations: City of Austin (COA)

Figure 2: Original data sets used for the project

3. Analysis Methodologies

3.1. Shade Index of the Overall Street Blocks

The layers used to produce the shade index for the overall street blocks in Austin were the canopy and city limits polygons, as well as the street blocks line file. The first step in this analysis was buffering. We applied a 20ft. flat buffer to the street blocks layer. We used 20ft. as the width so that the canopy coverage could later be displayed throughout different times of the day, and we used the flat buffers because they create segments that have less overlap at intersections, as opposed to the rounded buffers. These flat 20ft. buffers are used in all the analysis methods for this project. A comparison between the two buffer types is displayed below.

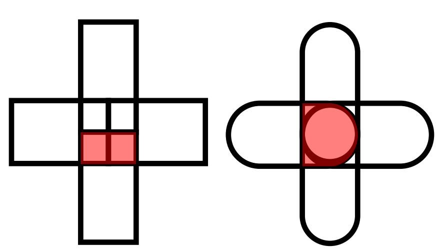


Figure 3: The flat buffer (left) and rounded buffer (right) intersection comparison

After the buffer was applied, we clipped the canopy layer to the newly buffered streets layer which provided us with a canopy layer that only fell within the city streets. Then we calculated the area of each street segment by square feet. To do this we created a new “double-type” field in our attribute table for the buffered streets layer and used the calculate geometry function to populate the new field. This gave us the area in square feet of each street segment in the city. This step was crucial in the eventual calculation of the shade indices. The next step taken was dissolving the previously clipped canopy layer into one multi-part polygon file and also calculating its geometry. We used the same calculate geometry method as earlier where we created a new double-type field and calculated the area in square feet. This step gave us a unique field that was used to identify polygons in the next step. After this dissolve, we preformed a union using the buffered streets layer and the dissolved canopy layer. We needed to show the area without shade in this new layer to continue the analysis process, so (in the attribute table) we deleted the polygon features that contained the same values as the dissolved polygon “area” field created earlier. This eliminated the canopy polygons, leaving only the un-shaded areas of the street blocks as we intended. We then calculated the area for this un-shaded layer using the same calculate geometry method used earlier. After this, we preformed a spatial join between the un-shaded layer and the original buffered streets layer that we first created. During the join process we were careful to choose “within” under the match option category, and set the original buffered streets layer as the target feature and the union layer as the join feature. After the join was complete, we were then able to subtract the un-shaded areas of streets from the buffered street layer by creating a new field and using the field calculator. This step resulted in a field in the attribute table that had the shaded area for each street segment in square feet. After this step was complete, we created a “percentage” field in the joined layer for the analysis to provide us with a shade index. After the percentage field was created, we used the field calculator to divide the shaded area of each street segment by the overall buffered area of each street segment. We took that output and multiplied it by 100 to populate the "percentage" field we had already created in the joined layer. We now had our shade percentages. For visual purposes, we preformed one last spatial join between the original line streets layer we started with (the target feature) and the buffer layer (the join feature) which would take the attributes of the buffered layer and essentially covert them back to a line file. The line file allowed us to adjust the thickness of the streets on the maps. After these steps, we were finally able to create a shade index by assigning the line file to a graduated color scheme with four equal intervals. This gave us a clearly defined shade index of the overall street blocks, ranging from 0% shaded to 100% shaded.

3.2. Shade Index of Neighborhood and Watershed Street Blocks

The following analysis method was used for the creation of the shade indices of the street blocks on both the neighborhood and watershed levels. We did not want to repeat the same analysis method later on in this document, so it is described below as the neighborhood analysis only, but was also used to establish the watershed index by simply using the watershed layer instead of the neighborhood layer.

The layers used to create the averaged shade index for the street blocks in each neighborhood were the canopy, city limits, and neighborhood polygons as well as the street block line file. First we buffered the streets layer using 20ft. flat buffers (just as we did in the last analysis). We then preformed a series of three clips. We clipped the neighborhoods to the city limits, then the buffered streets to the new neighborhoods, then the canopy to the new buffered streets. These clips gave us two new layers that represented the street buffers within neighborhoods within city limits, and the canopy within street buffers within neighborhoods within city limits. In order for the analysis to properly function, we then had to dissolve our two new layers we just created. After the dissolve, we preformed a union on each of these two newly dissolved layers. We union both layers with the neighborhoods within city limits polygon (created in the beginning by the first clip). We made sure to uncheck the "gaps" box during the unions, and after they were complete we opened the attribute tables for both new union layers and deleted the "-1s" in the field titled "FID." This step was needed in order for us to carry out the next step of obtaining the area in each of these layers. To do this we added a field in the attribute table of both layers and used the calculate geometry function to get the area of the layers in square feet. Now that we had the area for each layer, we needed to perform a regular join which would take the attributes of the two layers and convert them to the already existing neighborhoods within city limits polygon that we started with. We joined both layers to the neighborhoods within city limits polygon based on a unique id we created in their attribute tables. We now had the data from both layers (the buffered streets union layer and the canopy in the buffered streets union layer) in the attribute table of the neighborhoods within city limits polygon. The final step we preformed to get our index was the calculation of the percent of street shade in the neighborhoods within city limits polygon. To do this we created a new field and then populated the field by using the field calculator to divide the canopy area by the street area, and multiply the outcome by 100. This left us with the average shade percent of street blocks for each individual neighborhood in Austin.

3.3. Shade Index of the Overall Trail Segments

The layers used to produce the shade index of the overall trail segments were the canopy and city limits polygon files, as well as the city trails line file. The first thing we did was clip the trails layer by the city limits, which provided us with trails only in the city limits of Austin. We then dissolved this trails layer to create one entire continuous trail that was not split up into multi-parts. This was done because the UFP wanted to see the trails split into segments by 1/8th of a mile (660 ft.), which the dissolve function was not able to do. To successfully split the dissolved trail line, we downloaded a free extension toolkit for ESRI's ArcMap called X-Tools. We used the X-Tools extension to split the dissolved trail line by 1/8th of a mile (660ft.) by means of its "Feature Conversion" tool. After the split, we then created a new field in the trails layer and used the calculate geometry function to display the length of each trail segment. It is important to note that while the trails were split into 660ft. segments, not every entire trail was equally divisible by 1/8th of a mile, which gave us a remainder segment at the ends of some trails that are not to 1/8th of a mile. The next step was to buffer the newly segmented trails. We used a 20ft. flat buffer, just like the analysis for the street blocks. Then we calculated the area of these buffered segments in square feet by using the calculate geometry tool. This gave us the area of buffered trail segments (the non-shaded areas). We then took the canopy layer and clipped it by the buffered trails layer, which resulted in a new layer that contained the canopy within the buffered trails (the shaded areas). The next step we took was a union between the canopy within the trails layer and the buffered trails layer. We did this so we would have a new canopy layer within the buffered trails that was also split into 1/8th of a mile segments. We then used the calculate geometry function to obtain the area in square feet of the canopy segments in each trail segment. After the area was calculated, we opened the attribute table of this new layer and deleted the "-1s" in the field we just created for the area of the canopy segments. Now the union layer only had the area for the canopy within the buffered trails (the shaded areas). Now that we only had the area of the shaded parts of trail segments, we need to use the dissolve tool again to merge the separate shaded segments within each trail segment. This would give us the total area of shade per trail segment (instead of the area of each individual canopy per trail segment). We then preformed the dissolve to add the individual canopies per trail segment together. After the dissolve was complete, we calculated the area of the total shade per trail segment. After we had the total shaded area per trail segment, we needed to perform a regular join to combine the attribute data of the dissolved canopy layer to that of the previously unioned canopy layer we had prior to the dissolve. The join was preformed based on a unique identifier in the attribute table and we ended up with a canopy within the segmented trails layer that also represented the area of total canopy coverage for each different trail segment. After this step, we were ready to create a new field for the shade percent. After the percentage field was created, we used the field calculator to divide the total shaded area of each trail segment by the overall buffered area of each trail segment. We took that output and multiplied it by 100 to populate the "percentage" field we had already created in the joined layer. We now had our shade percentages. We then established our shade index by assigning the joined canopy within the segmented trails layer to a graduated color scheme with four equal intervals. This gave us a clearly defined shade index of the overall trail segments, ranging from 0% shaded to 100% shaded.

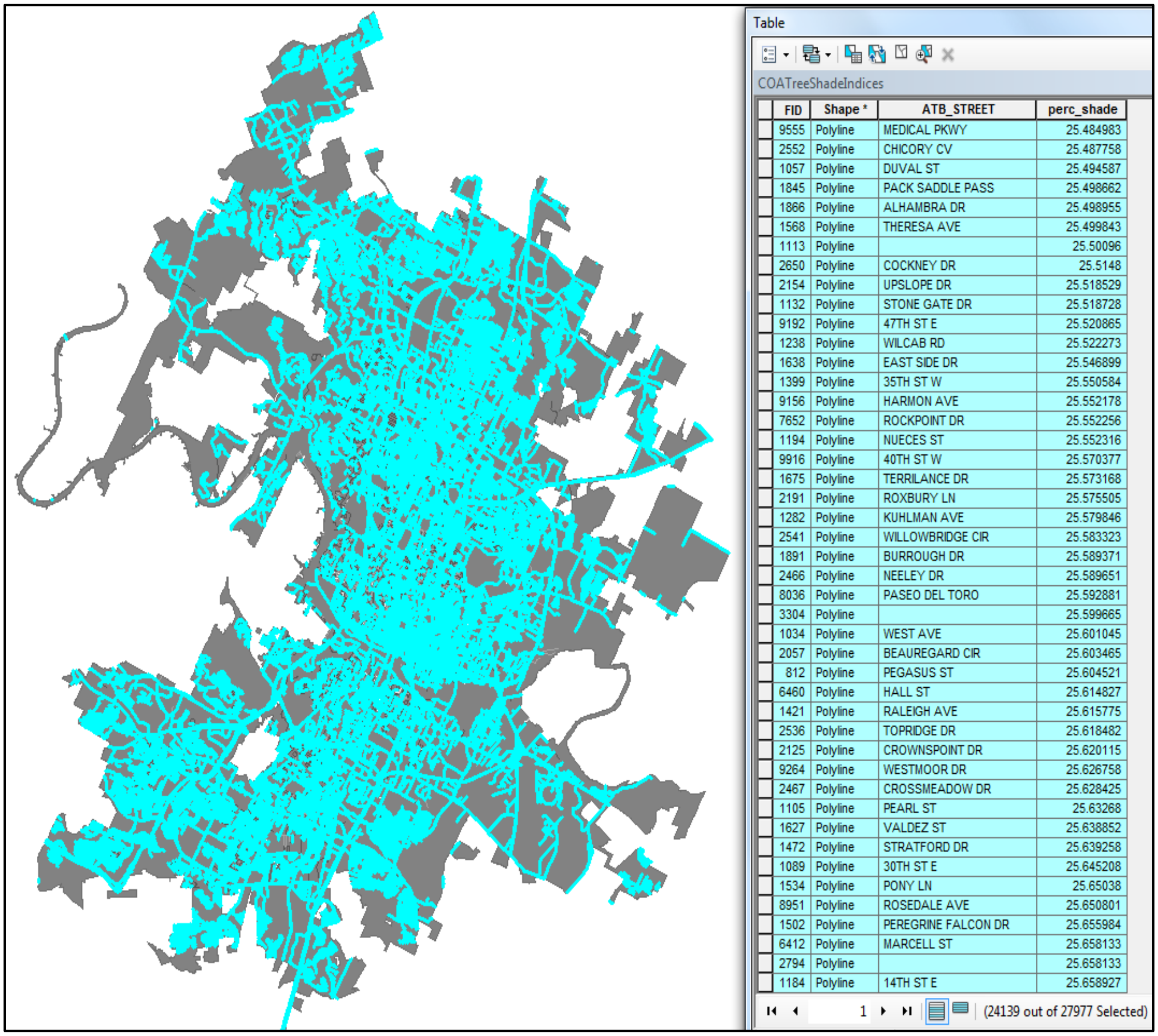
3.4. Shade Index of Neighborhood and Watershed Trail Segments

The following analysis method was used for the creation of the shade indices of the trail segments on both the neighborhood and watershed levels. We did not want to repeat the same analysis method later on in this document, so it is described below as the neighborhood analysis only, but was also used to establish the watershed index by simply using the watershed layer instead of the neighborhood layer.

The layers used to create the averaged shade index for the trail segments in each neighborhood were the canopy, city limits, and neighborhood polygons as well as the trail line file. First we clipped the trails by the neighborhood layer to give us only the trails within the neighborhoods. Then we dissolved the newly clipped trails and the neighborhoods layers to create one long continuous trail that is contained by the neighborhoods. Then we buffered the streets layer using 20ft. flat buffers (just as we did in the last analysis), and clipped out the tree canopy areas that were contained within that buffer. Then we dissolved the resulting canopy to the neighborhoods; this gave us one single canopy layer over the trails within the neighborhoods as a multi-layer file. We then preformed two unions, one between the continuous trail layer and the neighborhoods, and the other between the canopy and neighborhoods. This resulted in two new layers of the trails within individual neighborhoods, and the canopy coverage within individual neighborhoods. We then took the attribute table of the union trail layer and added two new fields (one for the trail area or non-shaded area, and one for the canopy or shaded area). We used the calculate geometry function to calculate the area in square feet for the amount of shaded and non-shaded areas in each individual neighborhood. Then we needed to get these area calculations over to the neighborhood layer so we preformed two joins based on unique identifiers. We join the trails to neighborhoods and also the canopy to neighborhoods. We now had the calculated area information displayed for both layers in the neighborhood attribute table. To create our percentages we had to create a new field in the neighborhood's attribute table and divide the area of the canopy coverage by the entire area of the trails, then multiply the outcome by 100 and populate the new field with that outcome. This left us with the average shade percent of trail segments for each individual neighborhood in Austin.

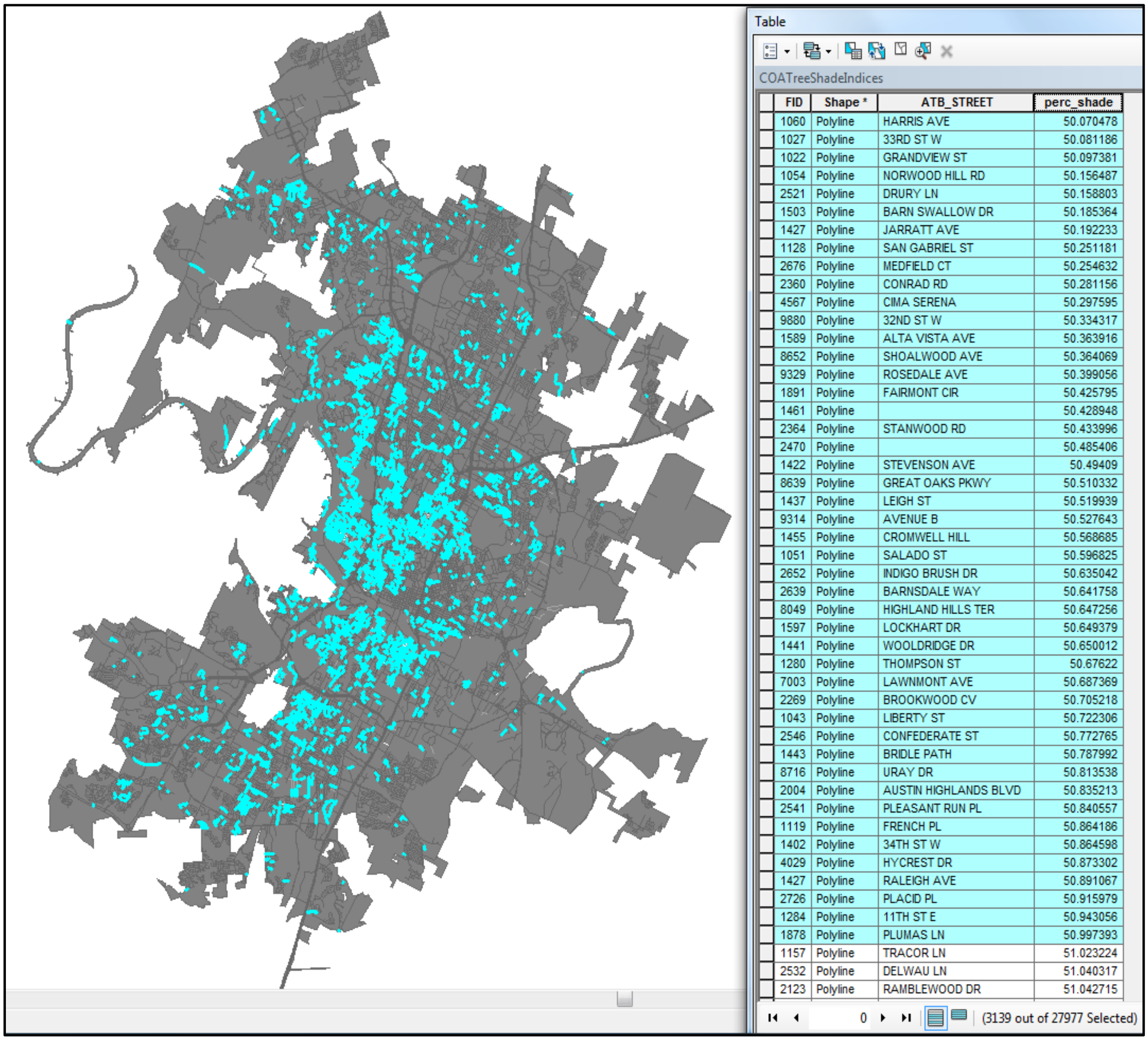
4. Results

4.1. Overall Street Block Shade Results



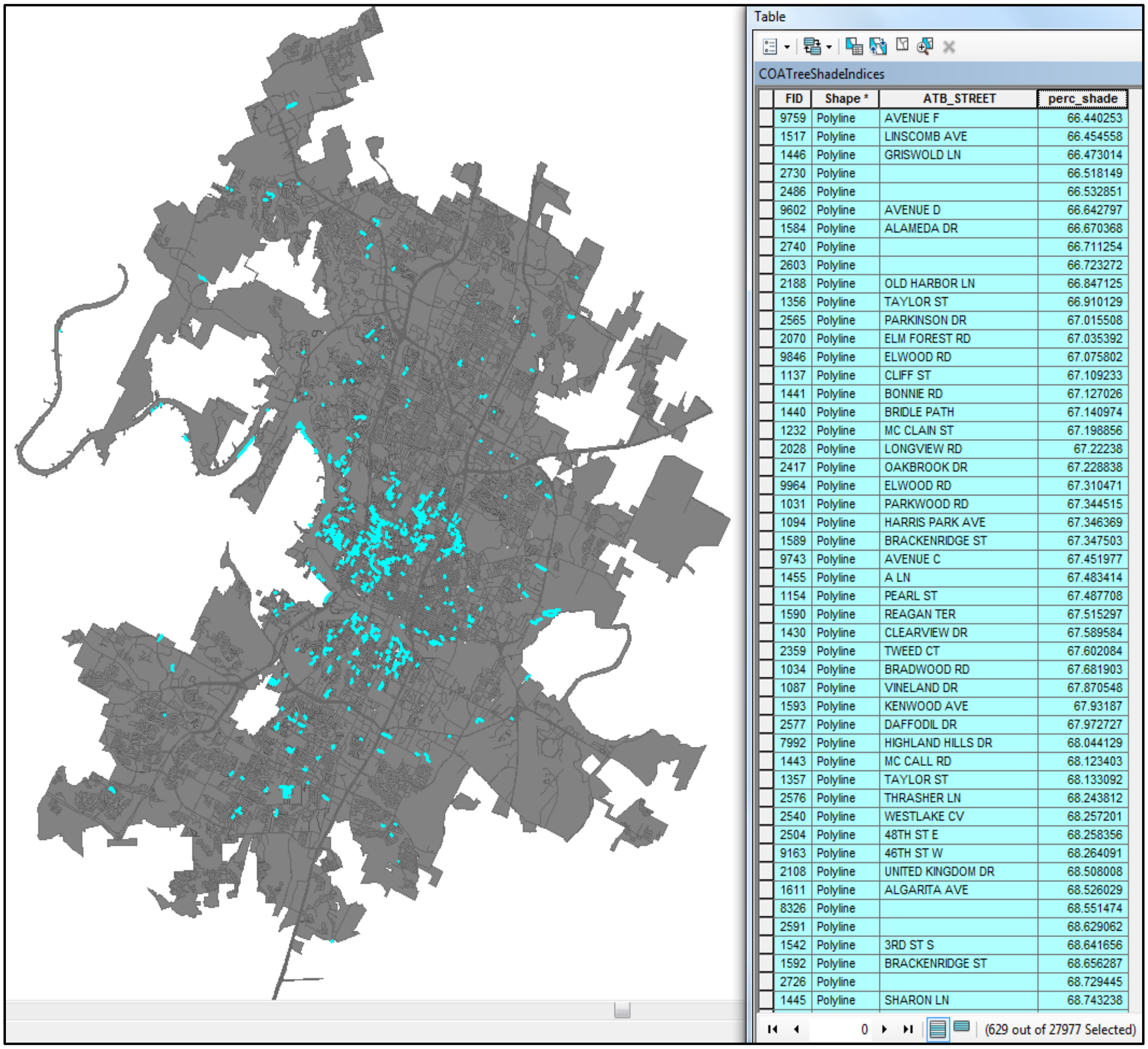
FID	Shape *	ATB_STREET	perc_shade
9555	Polyline	MEDICAL PKWY	25.484983
2552	Polyline	CHICORY CV	25.487758
1057	Polyline	DUVAL ST	25.494587
1845	Polyline	PACK SADDLE PASS	25.498662
1866	Polyline	ALHAMBRA DR	25.498955
1568	Polyline	THERESA AVE	25.499843
1113	Polyline		25.50096
2650	Polyline	COCKNEY DR	25.5148
2154	Polyline	UPSLOPE DR	25.518529
1132	Polyline	STONE GATE DR	25.518728
9192	Polyline	47TH ST E	25.520865
1238	Polyline	WILCAB RD	25.522273
1638	Polyline	EAST SIDE DR	25.546899
1399	Polyline	35TH ST W	25.550584
9156	Polyline	HARMON AVE	25.552178
7652	Polyline	ROCKPOINT DR	25.552256
1194	Polyline	NUECES ST	25.552316
9916	Polyline	40TH ST W	25.570377
1675	Polyline	TERRILANCE DR	25.573168
2191	Polyline	ROXBURY LN	25.575505
1282	Polyline	KUHLMAN AVE	25.579846
2541	Polyline	WILLOWBRIDGE CIR	25.583323
1891	Polyline	BURROUGH DR	25.589371
2466	Polyline	NEELEY DR	25.589651
8036	Polyline	PASEO DEL TORO	25.592881
3304	Polyline		25.599665
1034	Polyline	WEST AVE	25.601045
2057	Polyline	BEAUREGARD CIR	25.603465
812	Polyline	PEGASUS ST	25.604521
6460	Polyline	HALL ST	25.614827
1421	Polyline	RALEIGH AVE	25.615775
2536	Polyline	TOPRIDGE DR	25.618482
2125	Polyline	CROWNSPOINT DR	25.620115
9264	Polyline	WESTMOOR DR	25.626758
2467	Polyline	CROSSMEADOW DR	25.628425
1105	Polyline	PEARL ST	25.63268
1627	Polyline	VALDEZ ST	25.638852
1472	Polyline	STRATFORD DR	25.639258
1089	Polyline	30TH ST E	25.645208
1534	Polyline	PONY LN	25.65038
8951	Polyline	ROSEDALE AVE	25.650801
1502	Polyline	PEREGRINE FALCON DR	25.655984
6412	Polyline	MARCELL ST	25.658133
2794	Polyline		25.658133
1184	Polyline	14TH ST E	25.658927

Figure 4: 86.3% (2,4138 of 27,977) of Austin street blocks are in the 0-25% shade range of the total street block shade index



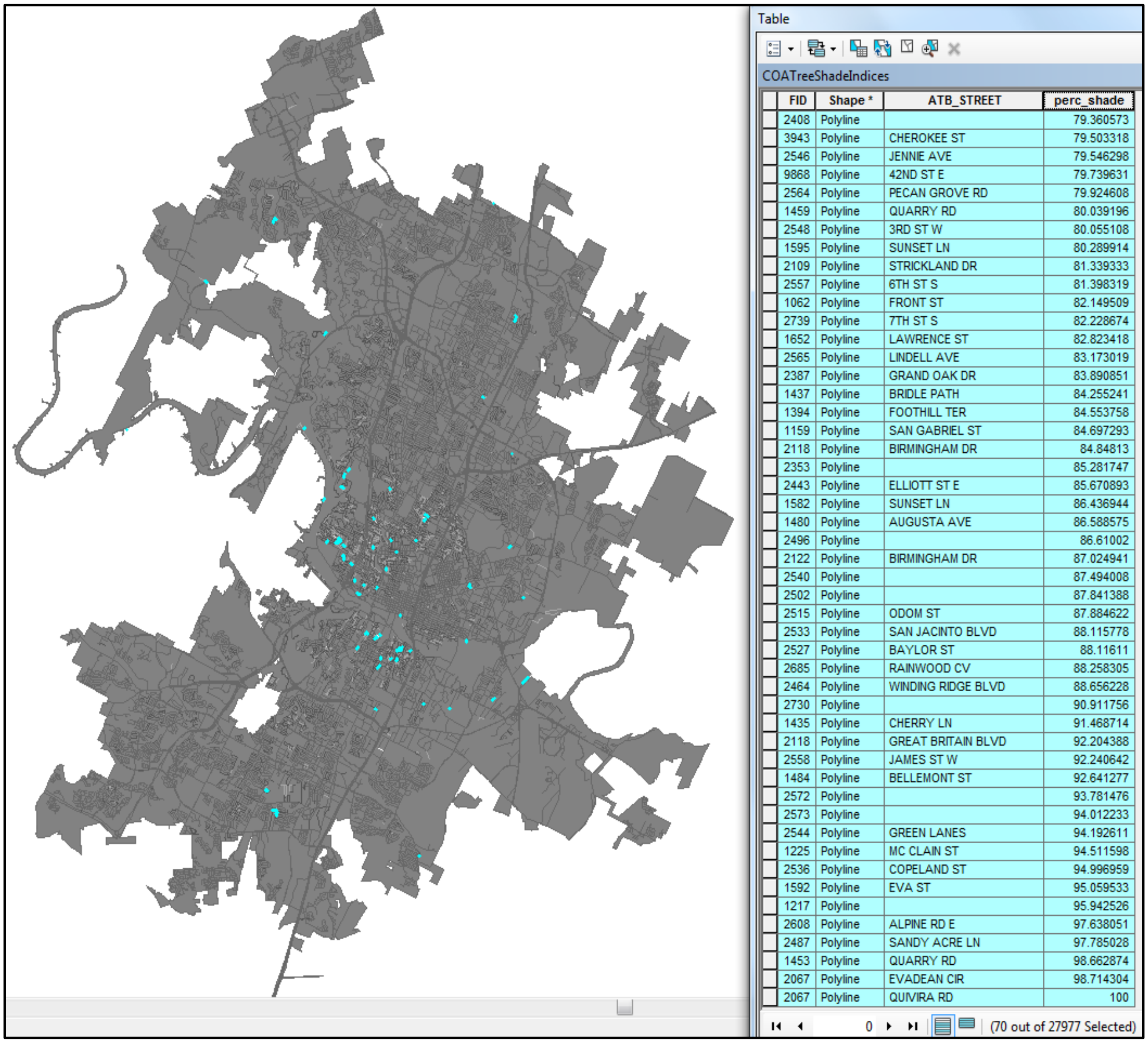
FID	Shape *	ATB_STREET	perc_shade
1060	Polyline	HARRIS AVE	50.070478
1027	Polyline	33RD ST W	50.081186
1022	Polyline	GRANDVIEW ST	50.097381
1054	Polyline	NORWOOD HILL RD	50.156487
2521	Polyline	DRURY LN	50.158803
1503	Polyline	BARN SWALLOW DR	50.185364
1427	Polyline	JARRATT AVE	50.192233
1128	Polyline	SAN GABRIEL ST	50.251181
2676	Polyline	MEDFIELD CT	50.254632
2360	Polyline	CONRAD RD	50.281156
4567	Polyline	CIMA SERENA	50.297595
9880	Polyline	32ND ST W	50.334317
1589	Polyline	ALTA VISTA AVE	50.363916
8652	Polyline	SHOALWOOD AVE	50.364069
9329	Polyline	ROSEDALE AVE	50.399056
1891	Polyline	FAIRMONT CIR	50.425795
1461	Polyline		50.428948
2364	Polyline	STANWOOD RD	50.433996
2470	Polyline		50.485406
1422	Polyline	STEVENSON AVE	50.49409
8639	Polyline	GREAT OAKS PKWY	50.510332
1437	Polyline	LEIGH ST	50.519939
9314	Polyline	AVENUE B	50.527643
1455	Polyline	CROMWELL HILL	50.568685
1051	Polyline	SALADO ST	50.596825
2652	Polyline	INDIGO BRUSH DR	50.635042
2639	Polyline	BARNSDALE WAY	50.641758
8049	Polyline	HIGHLAND HILLS TER	50.647256
1597	Polyline	LOCKHART DR	50.649379
1441	Polyline	WOOLDRIDGE DR	50.650012
1280	Polyline	THOMPSON ST	50.67622
7003	Polyline	LAWNMONT AVE	50.687369
2269	Polyline	BROOKWOOD CV	50.705218
1043	Polyline	LIBERTY ST	50.722306
2546	Polyline	CONFEDERATE ST	50.772765
1443	Polyline	BRIDLE PATH	50.787992
8716	Polyline	URAY DR	50.813538
2004	Polyline	AUSTIN HIGHLANDS BLVD	50.835213
2541	Polyline	PLEASANT RUN PL	50.840557
1119	Polyline	FRENCH PL	50.864186
1402	Polyline	34TH ST W	50.864598
4029	Polyline	HYCREST DR	50.873302
1427	Polyline	RALEIGH AVE	50.891067
2726	Polyline	PLACID PL	50.915979
1284	Polyline	11TH ST E	50.943056
1878	Polyline	PLUMAS LN	50.997393
1157	Polyline	TRACOR LN	51.023224
2532	Polyline	DELWAU LN	51.040317
2123	Polyline	RAMBLEWOOD DR	51.042715

Figure 5: 11.2% (3,139 out of 27,977) of Austin street blocks are in the 26-50% shade range of the total street block shade index



FID	Shape *	ATB_STREET	perc_shade
9759	Polyline	AVENUE F	66.440253
1517	Polyline	LINSCOMB AVE	66.454558
1446	Polyline	GRISWOLD LN	66.473014
2730	Polyline		66.518149
2486	Polyline		66.532851
9602	Polyline	AVENUE D	66.642797
1584	Polyline	ALAMEDA DR	66.670368
2740	Polyline		66.711254
2603	Polyline		66.723272
2188	Polyline	OLD HARBOR LN	66.847125
1356	Polyline	TAYLOR ST	66.910129
2565	Polyline	PARKINSON DR	67.015508
2070	Polyline	ELM FOREST RD	67.035392
9846	Polyline	ELWOOD RD	67.075802
1137	Polyline	CLIFF ST	67.109233
1441	Polyline	BONNIE RD	67.127026
1440	Polyline	BRIDLE PATH	67.140974
1232	Polyline	MC CLAIN ST	67.198856
2028	Polyline	LONGVIEW RD	67.22238
2417	Polyline	OAKBROOK DR	67.228838
9964	Polyline	ELWOOD RD	67.310471
1031	Polyline	PARKWOOD RD	67.344515
1094	Polyline	HARRIS PARK AVE	67.346369
1589	Polyline	BRACKENRIDGE ST	67.347503
9743	Polyline	AVENUE C	67.451977
1455	Polyline	A LN	67.483414
1154	Polyline	PEARL ST	67.487708
1590	Polyline	REAGAN TER	67.515297
1430	Polyline	CLEARVIEW DR	67.589584
2359	Polyline	TWEED CT	67.602084
1034	Polyline	BRADWOOD RD	67.681903
1087	Polyline	VINELAND DR	67.870548
1593	Polyline	KENWOOD AVE	67.93187
2577	Polyline	DAFFODIL DR	67.972727
7992	Polyline	HIGHLAND HILLS DR	68.044129
1443	Polyline	MC CALL RD	68.123403
1357	Polyline	TAYLOR ST	68.133092
2576	Polyline	THRASHER LN	68.243812
2540	Polyline	WESTLAKE CV	68.257201
2504	Polyline	48TH ST E	68.258356
9163	Polyline	46TH ST W	68.264091
2108	Polyline	UNITED KINGDOM DR	68.508008
1611	Polyline	ALGARITA AVE	68.526029
8326	Polyline		68.551474
2591	Polyline		68.629062
1542	Polyline	3RD ST S	68.641656
1592	Polyline	BRACKENRIDGE ST	68.656287
2726	Polyline		68.729445
1445	Polyline	SHARON LN	68.743238

Figure 6: 2.2% (629 out of 27,977) of Austin street blocks are in the 51-75% shade range of the total street block shade index

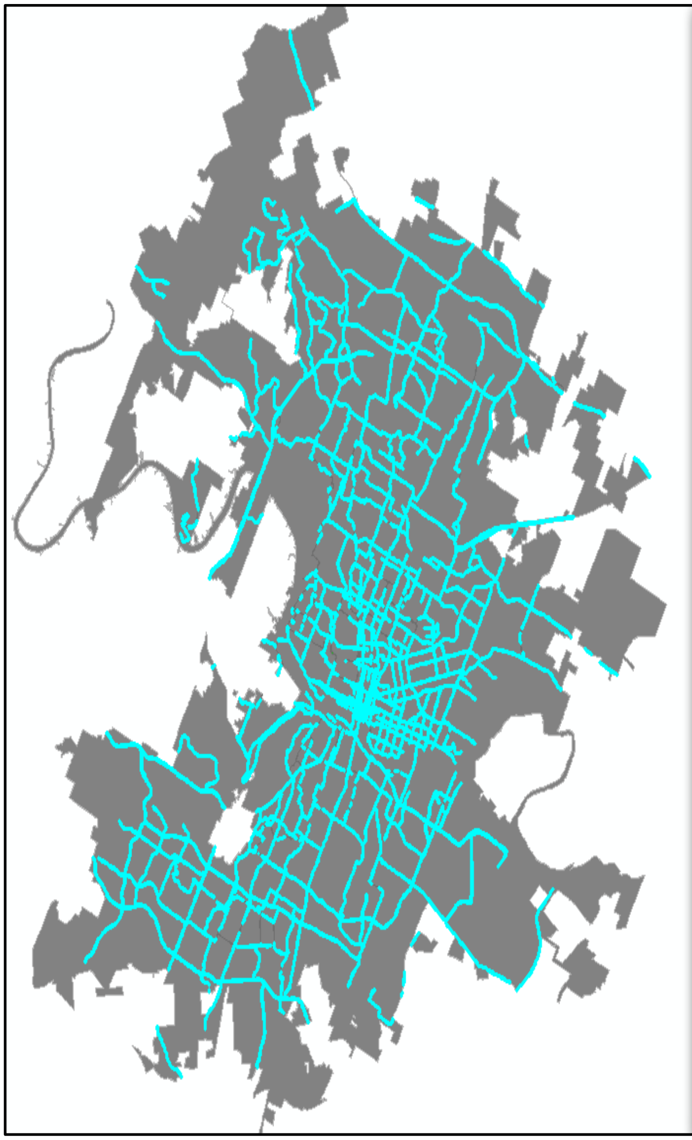


FID	Shape *	ATB_STREET	perc_shade
2408	Polyline		79.360573
3943	Polyline	CHEROKEE ST	79.503318
2546	Polyline	JENNIE AVE	79.546298
9868	Polyline	42ND ST E	79.739631
2564	Polyline	PECAN GROVE RD	79.924608
1459	Polyline	QUARRY RD	80.039196
2548	Polyline	3RD ST W	80.055108
1595	Polyline	SUNSET LN	80.289914
2109	Polyline	STRICKLAND DR	81.339333
2557	Polyline	6TH ST S	81.398319
1062	Polyline	FRONT ST	82.149509
2739	Polyline	7TH ST S	82.228674
1652	Polyline	LAWRENCE ST	82.823418
2565	Polyline	LINDELL AVE	83.173019
2387	Polyline	GRAND OAK DR	83.890851
1437	Polyline	BRIDLE PATH	84.255241
1394	Polyline	FOOTHILL TER	84.553758
1159	Polyline	SAN GABRIEL ST	84.697293
2118	Polyline	BIRMINGHAM DR	84.84813
2353	Polyline		85.281747
2443	Polyline	ELLIOTT ST E	85.670893
1582	Polyline	SUNSET LN	86.436944
1480	Polyline	AUGUSTA AVE	86.588575
2496	Polyline		86.61002
2122	Polyline	BIRMINGHAM DR	87.024941
2540	Polyline		87.494008
2502	Polyline		87.841388
2515	Polyline	ODOM ST	87.884622
2533	Polyline	SAN JACINTO BLVD	88.115778
2527	Polyline	BAYLOR ST	88.11611
2685	Polyline	RAINWOOD CV	88.258305
2464	Polyline	WINDING RIDGE BLVD	88.656228
2730	Polyline		90.911756
1435	Polyline	CHERRY LN	91.468714
2118	Polyline	GREAT BRITAIN BLVD	92.204388
2558	Polyline	JAMES ST W	92.240642
1484	Polyline	BELLEMONT ST	92.641277
2572	Polyline		93.781476
2573	Polyline		94.012233
2544	Polyline	GREEN LANES	94.192611
1225	Polyline	MC CLAIN ST	94.511598
2536	Polyline	COPELAND ST	94.996959
1592	Polyline	EVA ST	95.059533
1217	Polyline		95.942526
2608	Polyline	ALPINE RD E	97.638051
2487	Polyline	SANDY ACRE LN	97.785028
1453	Polyline	QUARRY RD	98.662874
2067	Polyline	EVADEAN CIR	98.714304
2067	Polyline	QUIVIRA RD	100

Figure 7: 0.25% (70 out of 27,977) of Austin street blocks are in the 76-100% shade range of the total street block shade index

4.2. Overall Trail Segment Shade Results

Figure 8 (below): 95.2% (5,857 of 6,149) of Austin trail segments are in the 0-25% shade range of the total trail segment shade index



Table

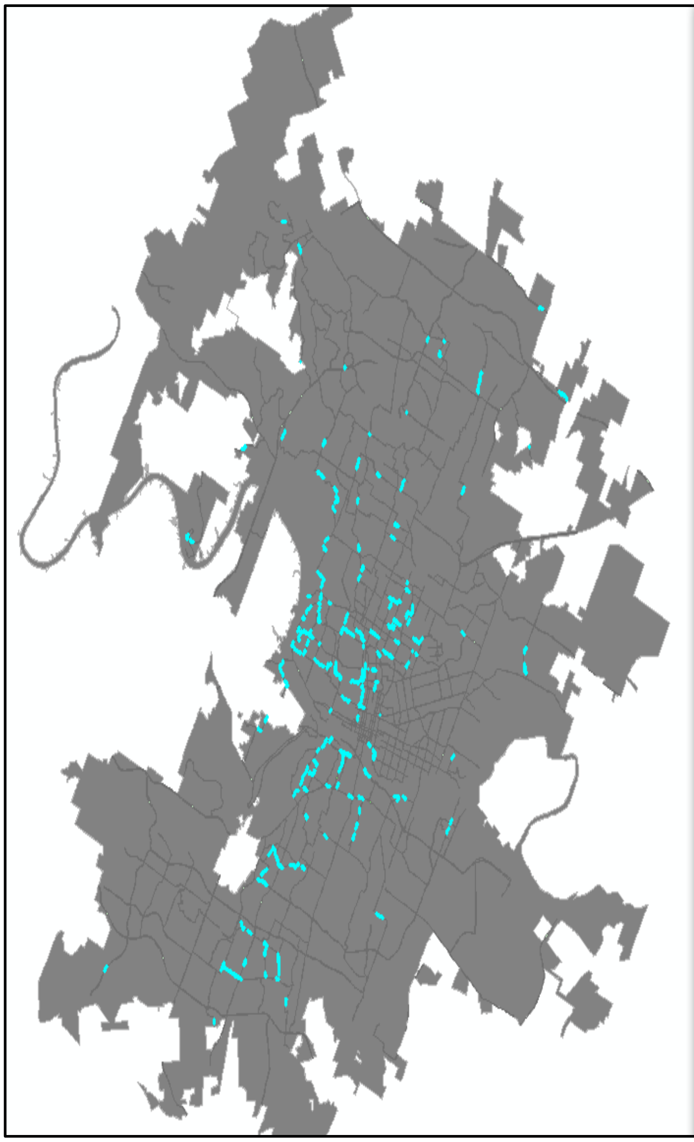
Trail_Percent_Final_Layer

FID	Shape *	length	OBJECTID_1	Seg_ID	BUFF_DIST	Seg_AREA	PercentSha
205	Polygon	660	2435	205	20	26396.646188	24.086845
4360	Polygon	660	1033	4360	20	26331.26527	24.104663
1995	Polygon	236	2283	1995	20	9449.841153	24.195437
3548	Polygon	115	1062	3548	20	4585.729713	24.430894
3367	Polygon	359	745	3367	20	14357.807522	24.507134
2782	Polygon	469	1956	2782	20	18755.986621	24.573185
3806	Polygon	300	3575	3806	20	12006.253129	24.602544
3866	Polygon	660	1371	3866	20	26399.938872	24.611308
2320	Polygon	660	3757	2320	20	26399.999993	24.622881
2153	Polygon	660	2549	2153	20	26399.572175	24.64569
3363	Polygon	660	93	3363	20	26399.998624	24.676809
4242	Polygon	660	16	4242	20	26387.371135	24.678967
2865	Polygon	660	2470	2865	20	26399.987692	24.692387
3964	Polygon	660	29	3964	20	26396.78114	24.707258
2014	Polygon	660	72	2014	20	26399.827864	24.732108
3606	Polygon	660	1387	3606	20	26399.998657	24.742047
4056	Polygon	632	49	4056	20	25297.2487	24.76311
4062	Polygon	660	1278	4062	20	26330.707169	24.856266
5848	Polygon	660	4094	5848	20	26390.959568	24.863592
6048	Polygon	660	3524	6048	20	26399.069411	24.919574
4239	Polygon	660	16	4239	20	26399.94622	24.994505
2151	Polygon	264	1160	2151	20	10558.472895	25.099003
3067	Polygon	238	81	3067	20	9514.573299	25.176848
393	Polygon	660	112	393	20	26305.916602	25.222981
3956	Polygon	660	1045	3956	20	26399.970112	25.314992
2236	Polygon	660	2545	2236	20	26399.365196	25.346051
3576	Polygon	660	31	3576	20	26399.998217	25.384931
5131	Polygon	660	982	5131	20	26399.928635	25.426144
4358	Polygon	660	1031	4358	20	26391.319533	25.441438
2581	Polygon	660	3615	2581	20	26399.996848	25.462126
4002	Polygon	660	1	4002	20	26399.802186	25.670481
2997	Polygon	660	65	2997	20	26399.997606	25.762112
1612	Polygon	517	640	1612	20	20680.474266	25.791547
4703	Polygon	660	898	4703	20	26059.56934	25.836988
411	Polygon	660	1783	411	20	26400.000007	25.84608
5130	Polygon	660	980	5130	20	26399.997887	25.85918
1693	Polygon	660	1182	1693	20	26394.85916	25.924077
3360	Polygon	660	93	3360	20	26399.999995	25.988005
2013	Polygon	660	72	2013	20	26390.648256	26.002113
2035	Polygon	243	72	2035	20	9706.942046	26.070135
3361	Polygon	154	27	3361	20	6143.835141	26.08686
2558	Polygon	342	3291	2558	20	13674.492788	26.201839

0 (5857 out of 6149 Selected)

Trail_Percent_Final_Layer

Figure 9 (below): 4.1% (254 of 6,149) of Austin trail segments are in the26-50% shade range of the total trail segment shade index



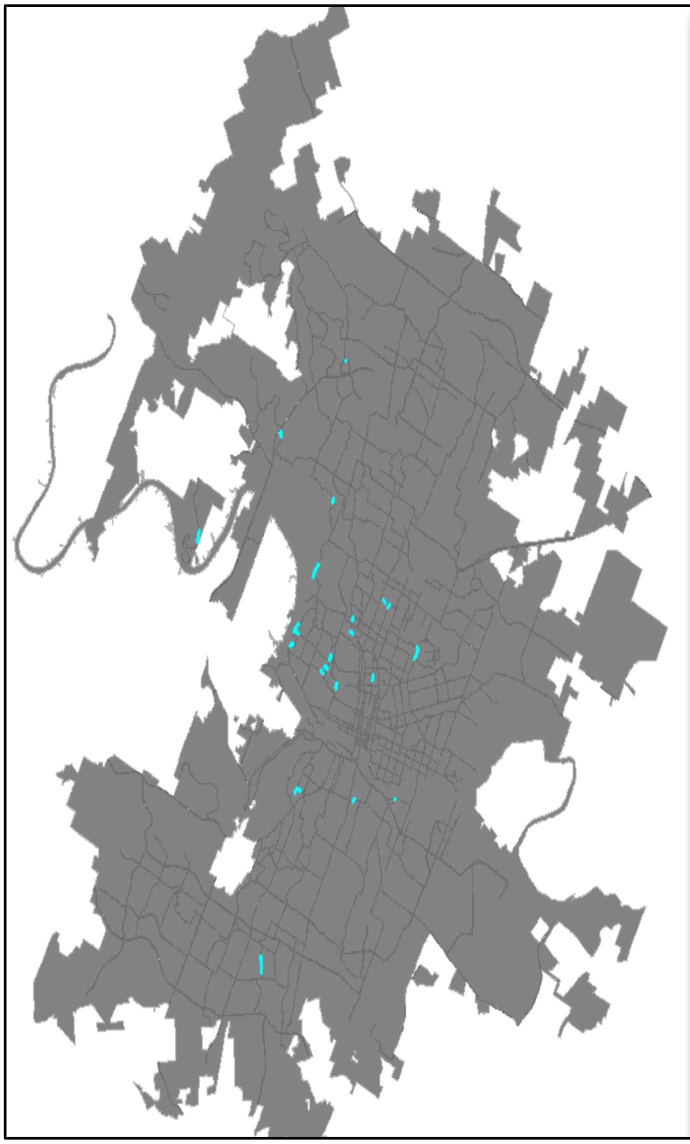
Table

Trail_Percent_Final_Layer

FID	Shape *	length	OBJECTID_1	Seg_ID	BUFF_DIST	Seg_AREA	PercentSha
3742	Polygon	660	22	3742	20	26399.82132	42.777171
3541	Polygon	230	4	3541	20	9217.888742	43.006165
3686	Polygon	581	4	3686	20	23237.954621	43.135276
3568	Polygon	660	2238	3568	20	26396.857863	43.137325
3228	Polygon	660	1413	3228	20	26398.690097	43.265698
2915	Polygon	460	6	2915	20	18407.344726	43.292446
3317	Polygon	660	1608	3317	20	26398.989054	43.600589
3593	Polygon	660	1062	3593	20	26399.904511	43.614291
3530	Polygon	660	80	3530	20	26397.252444	43.678026
3025	Polygon	660	2083	3025	20	26399.932924	43.828608
3404	Polygon	660	81	3404	20	26385.628796	43.95558
3485	Polygon	660	3610	3485	20	26399.425506	44.088971
2632	Polygon	660	587	2632	20	26399.317908	44.266484
3544	Polygon	660	39	3544	20	26398.570627	44.519869
2047	Polygon	660	97	2047	20	26400.000013	45.101838
4699	Polygon	660	897	4699	20	26397.557803	45.208307
3807	Polygon	660	3575	3807	20	26399.999984	45.364349
3225	Polygon	495	1415	3225	20	19789.492614	45.511322
4264	Polygon	660	1117	4264	20	26399.999996	46.043253
2036	Polygon	660	2554	2036	20	26399.995873	46.068221
2631	Polygon	660	587	2631	20	26399.023724	46.129258
3381	Polygon	660	3598	3381	20	26397.188396	46.210329
3946	Polygon	546	25	3946	20	21838.605837	46.491045
3962	Polygon	660	1050	3962	20	26398.009543	46.707095
3677	Polygon	660	1653	3677	20	26230.82257	47.029953
3573	Polygon	660	32	3573	20	26399.707492	47.18633
260	Polygon	660	3356	260	20	26399.098948	47.279962
3486	Polygon	660	3610	3486	20	26399.839271	47.831938
3275	Polygon	192	93	3275	20	7686.480179	47.994192
3963	Polygon	660	1050	3963	20	26394.704869	48.282376
3689	Polygon	155	21	3689	20	6215.88736	48.382969
3961	Polygon	660	1050	3961	20	26397.704529	48.453051
3379	Polygon	660	3599	3379	20	26399.734561	49.394021
3908	Polygon	660	1920	3908	20	26399.189935	49.864912
3256	Polygon	660	102	3256	20	26400.000006	50.227248
4409	Polygon	115	2195	4409	20	4606.931208	50.474315
4698	Polygon	660	897	4698	20	26398.096432	51.184009
3653	Polygon	659	1673	3653	20	26363.256909	52.101345
2037	Polygon	660	2552	2037	20	26233.262617	52.364434
2145	Polygon	660	616	2145	20	26399.821327	52.681262
3602	Polygon	660	1386	3602	20	26395.960642	52.703623
636	Polygon	660	1547	636	20	26399.970239	52.761314

0 (254 out of 6149 Selected)

Figure 10 (below): 0.54% (33 of 6,149) of Austin trail segments are in the 51-75% shade range of the total trail segment shade index



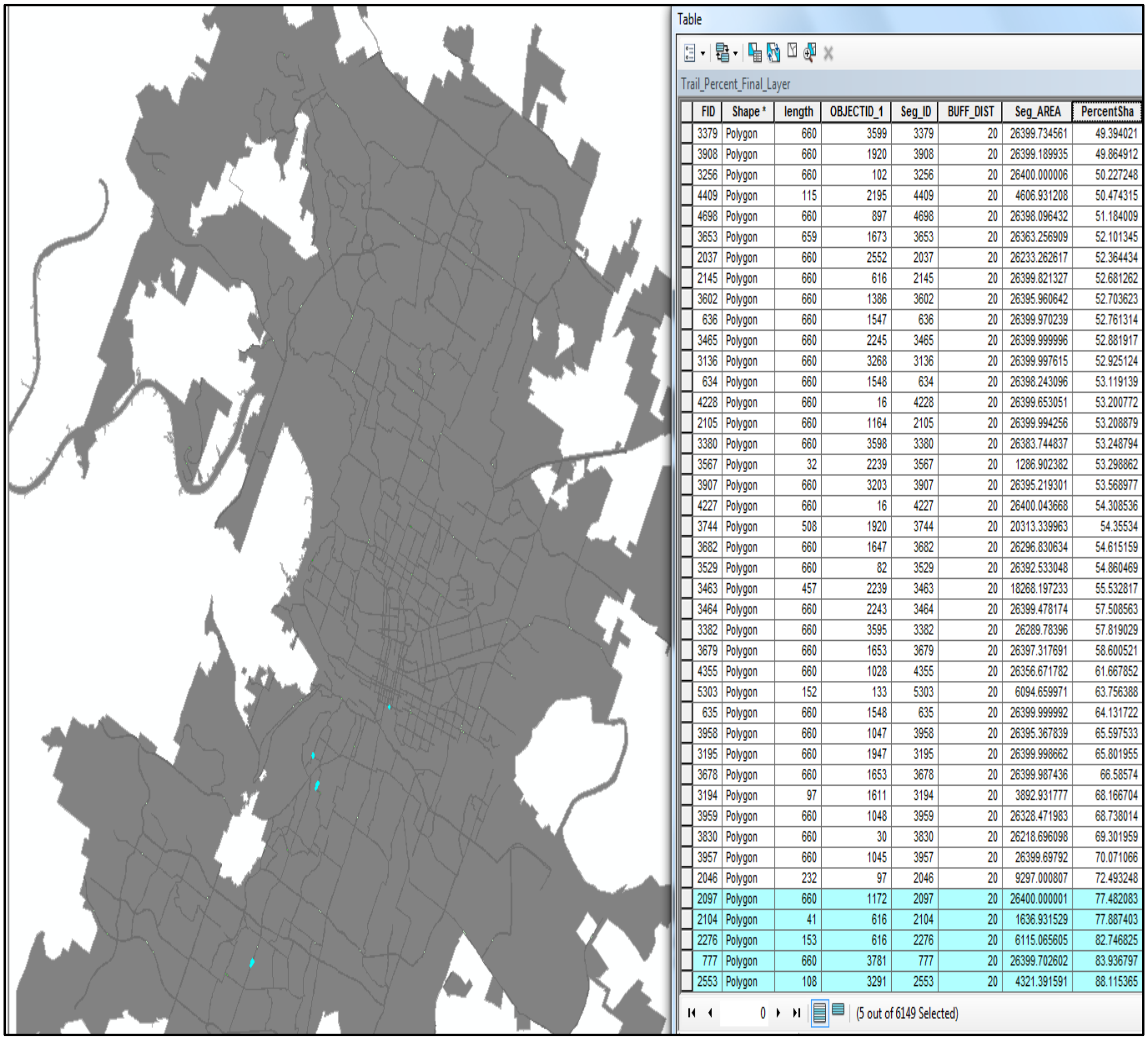
Table

Trail_Percent_Final_Layer

FID	Shape *	length	OBJECTID_1	Seg_ID	BUFF_DIST	Seg_AREA	PercentSha
3379	Polygon	660	3599	3379	20	26399.734561	49.394021
3908	Polygon	660	1920	3908	20	26399.189935	49.864912
3256	Polygon	660	102	3256	20	26400.000006	50.227248
4409	Polygon	115	2195	4409	20	4606.931208	50.474315
4698	Polygon	660	897	4698	20	26398.096432	51.184009
3653	Polygon	659	1673	3653	20	26363.256909	52.101345
2037	Polygon	660	2552	2037	20	26233.262617	52.364434
2145	Polygon	660	616	2145	20	26399.821327	52.681262
3602	Polygon	660	1386	3602	20	26395.960642	52.703623
636	Polygon	660	1547	636	20	26399.970239	52.761314
3465	Polygon	660	2245	3465	20	26399.999996	52.881917
3136	Polygon	660	3268	3136	20	26399.997615	52.925124
634	Polygon	660	1548	634	20	26398.243096	53.119139
4228	Polygon	660	16	4228	20	26399.653051	53.200772
2105	Polygon	660	1164	2105	20	26399.994256	53.208879
3380	Polygon	660	3598	3380	20	26383.744837	53.248794
3567	Polygon	32	2239	3567	20	1286.902382	53.298862
3907	Polygon	660	3203	3907	20	26395.219301	53.568977
4227	Polygon	660	16	4227	20	26400.043668	54.308536
3744	Polygon	508	1920	3744	20	20313.339963	54.35534
3682	Polygon	660	1647	3682	20	26296.830634	54.615159
3529	Polygon	660	82	3529	20	26392.533048	54.860469
3463	Polygon	457	2239	3463	20	18268.197233	55.532817
3464	Polygon	660	2243	3464	20	26399.478174	57.508563
3382	Polygon	660	3595	3382	20	26289.78396	57.819029
3679	Polygon	660	1653	3679	20	26397.317691	58.600521
4355	Polygon	660	1028	4355	20	26356.671782	61.667852
5303	Polygon	152	133	5303	20	6094.659971	63.756388
635	Polygon	660	1548	635	20	26399.999992	64.131722
3958	Polygon	660	1047	3958	20	26395.367839	65.597533
3195	Polygon	660	1947	3195	20	26399.998662	65.801955
3678	Polygon	660	1653	3678	20	26399.987436	66.58574
3194	Polygon	97	1611	3194	20	3892.931777	68.166704
3959	Polygon	660	1048	3959	20	26328.471983	68.738014
3830	Polygon	660	30	3830	20	26218.696098	69.301959
3957	Polygon	660	1045	3957	20	26399.69792	70.071066
2046	Polygon	232	97	2046	20	9297.000807	72.493248
2097	Polygon	660	1172	2097	20	26400.000001	77.482083
2104	Polygon	41	616	2104	20	1636.931529	77.887403
2276	Polygon	153	616	2276	20	6115.065605	82.746825
777	Polygon	660	3781	777	20	26399.702602	83.936797
2553	Polygon	108	3291	2553	20	4321.391591	88.115365

0 (33 out of 6149 Selected)

Figure 11 (below): 0.08% (5 of 6,149) of Austin trail segments are in the 76-100% shade range of the total trail segment shade index



FID	Shape *	length	OBJECTID_1	Seg_ID	BUFF_DIST	Seg_AREA	PercentSha
3379	Polygon	660	3599	3379	20	26399.734561	49.394021
3908	Polygon	660	1920	3908	20	26399.189935	49.864912
3256	Polygon	660	102	3256	20	26400.000006	50.227248
4409	Polygon	115	2195	4409	20	4606.931208	50.474315
4698	Polygon	660	897	4698	20	26398.096432	51.184009
3653	Polygon	659	1673	3653	20	26363.256909	52.101345
2037	Polygon	660	2552	2037	20	26233.262617	52.364434
2145	Polygon	660	616	2145	20	26399.821327	52.681262
3602	Polygon	660	1386	3602	20	26395.960642	52.703623
636	Polygon	660	1547	636	20	26399.970239	52.761314
3465	Polygon	660	2245	3465	20	26399.999996	52.881917
3136	Polygon	660	3268	3136	20	26399.997615	52.925124
634	Polygon	660	1548	634	20	26398.243096	53.119139
4228	Polygon	660	16	4228	20	26399.653051	53.200772
2105	Polygon	660	1164	2105	20	26399.994256	53.208879
3380	Polygon	660	3598	3380	20	26383.744837	53.248794
3567	Polygon	32	2239	3567	20	1286.902382	53.298862
3907	Polygon	660	3203	3907	20	26395.219301	53.568977
4227	Polygon	660	16	4227	20	26400.043668	54.308536
3744	Polygon	508	1920	3744	20	20313.339963	54.35534
3682	Polygon	660	1647	3682	20	26296.830634	54.615159
3529	Polygon	660	82	3529	20	26392.533048	54.860469
3463	Polygon	457	2239	3463	20	18268.197233	55.532817
3464	Polygon	660	2243	3464	20	26399.478174	57.508563
3382	Polygon	660	3595	3382	20	26289.78396	57.819029
3679	Polygon	660	1653	3679	20	26397.317691	58.600521
4355	Polygon	660	1028	4355	20	26356.671782	61.667852
5303	Polygon	152	133	5303	20	6094.659971	63.756388
635	Polygon	660	1548	635	20	26399.999992	64.131722
3958	Polygon	660	1047	3958	20	26395.367839	65.597533
3195	Polygon	660	1947	3195	20	26399.998662	65.801955
3678	Polygon	660	1653	3678	20	26399.987436	66.58574
3194	Polygon	97	1611	3194	20	3892.931777	68.166704
3959	Polygon	660	1048	3959	20	26328.471983	68.738014
3830	Polygon	660	30	3830	20	26218.696098	69.301959
3957	Polygon	660	1045	3957	20	26399.69792	70.071066
2046	Polygon	232	97	2046	20	9297.000807	72.493248
2097	Polygon	660	1172	2097	20	26400.000001	77.482083
2104	Polygon	41	616	2104	20	1636.931529	77.887403
2276	Polygon	153	616	2276	20	6115.065605	82.746825
777	Polygon	660	3781	777	20	26399.702602	83.936797
2553	Polygon	108	3291	2553	20	4321.391591	88.115365

5. Discussion and Considerations

In general, the members of both groups are very satisfied with the various shade indices and overall results of our tree shade analysis. There is a unanimous feeling among the group members that we now have more knowledge and a better understanding of spatial analysis techniques and GIS management skills used by current GIS professionals, than we did prior to the start of the project.

While both of the groups feel confident and comfortable with our output, we also feel that our analysis results should only be taken for what they represent. This is not a ground breaking study, nor is it a funded one, nevertheless our GIS analysis yielded high quality results that describe the density and distribution of Austin's urban forest. The UFP will be able to take our results and use them however they see fit.

During the course of the project, we did encounter some analysis limitations that would affect our results and therefore should be mentioned. One of those limitations we encountered was that our canopy layer of over one million polygons dated back to 2006, creating a five year gap in the canopy coverage of Austin. While five years is not an overly extensive amount of time, the canopy of the city will almost certainly have some differences between now and 2006. Another limitation we encountered was the buffering issue. Using the flat buffers for all the analysis study methods certainly reduced the overlap of street blocks and trail segments at intersections, but it did not completely eliminate them, creating room for a small amount of distortion in the canopy coverage at intersections. Finally, when observing the averaged shade indices for the street blocks and trail segments of the watersheds, you will notice that some of the watershed boundaries stretch well beyond the city limits. While this is true, the shade analysis was only conducted for the street blocks and trail segments that fall within the city limits even though the corresponding watershed might only have a few blocks or segments that fall within the city. This creates maps that might lead the person interpreting them to think that the indices represent the entire watershed, when it only includes the city's portion of street block and trail segment shade within those watersheds.

The results (and maps later in the document) of the analysis clearly show a direct correlation between the lack of tree cover of the streets and trails, and the outlying areas of Austin. Before the start of the analysis, both teams predicted that this might be the case. We noticed that the majority of the 75-100% shaded blocks and segments are all located within miles of the central business district (CBA) of Austin. Considering that only 0.08% of the trail segments and 0.25% of the street blocks are in the 75-100% shade range, it is extremely tough to have a street block or trail segment shaded at least three quarters of the way. Even so, it was hard to come by a street block or trail segment that was far away from the CBD and shaded in this range or the 50-75% shade range. The UFP can use the map outputs and table results to locate the heavily shaded blocks and segments to plan for future trees to be placed either: near or around the already heavily shaded areas to create corridors of streets and trails with heavy tree shade; or do just the opposite and plan for more trees to be placed in locations that have a higher percentage of very low shaded street blocks and trail segments. The results of the analysis can also be used in future studies to display a direct relationship with urban tree coverage and: energy consumption; crime rate; walk-ability and bike-ability; air quality; water quality; climate control; aesthetics and property value; and a number of other benefits that urban trees can provide. Whatever the case, we are confident that our results will be able to help the UFP make decisions on where to locate future trees to strengthen the urban canopy of Austin.

6. Conclusion

The urban tree canopy of a city like Austin may be considered by many to be one of the most important features of the city in terms of the aesthetic and environmental qualities that it provides. The shade indices provided by the two groups not only show a breakdown of the number of streets and trails that are heavily shaded, somewhat shaded, and poorly shaded, but they also show the average percent of shade of the streets and trails by the individual neighborhoods and watersheds of the city. These indices will be of great use to any group or individual interested in the in shade distribution of Austin, as well the numerous benefits an urban tree canopy can provide. The members of both groups enjoyed working on such a neat project and truly worked as a team to accomplish our goals that we set at the beginning of the project. While our results may not be extensive enough to convince political leaders to provide funding for future tree planting in Austin, they will at least provide some groundwork for future studies on tree benefits that have more research behind them. The group members of both AUT and SSOCT are proud of the work we've accomplished and we wish the UFP and the City of Austin well on any future research conducted with our findings.

7. References

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Appendix I: Participation

Sustainable Solutions of Central Texas team members:

Brooks Andrews: Project Manager

As the project the main project manager, Brooks made sure all five combined group members were contributing to the project. He assigned deadlines, scheduled all group meetings, and delegated equal amounts of work to all group members. He was also responsible for the writing and formatting of all three word documents, various portions of GIS analysis and resulting maps, and the professional poster.

Chaz Armijo: Assistant Manager and Webmaster

Chaz contributed more to the project than any other member. He served as an assistant manager and also made sure the analysis methodologies were correct. He designed and constructed the team logo and website, assembled two of the three power point presentations, and was the lead contributor of the GIS analysis and map design portions of the project.

Lori Beabout: GIS Analyst and Data Technician

Lori worked as the data technician and contributed to the GIS analysis as well. She helped with the creation of the data dictionary and the compilation of metadata for the final layers, and also wrote sections and provided sources for the literature review in two of the three documents.

Austin Urban Trails team members:

Jason Hinojosa: Project Manager

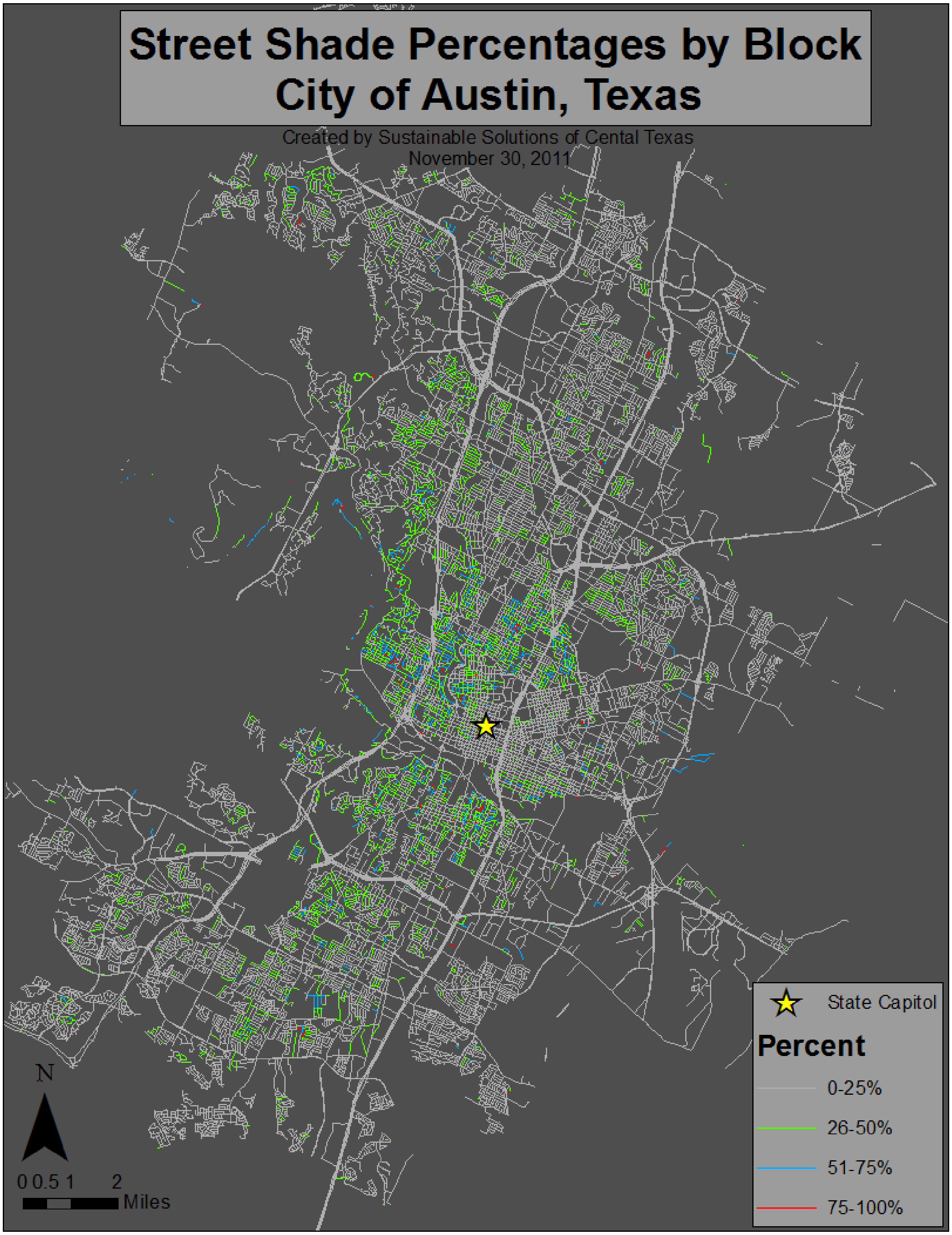
Jason served as the replacement project manager for the trails group. He made sure the analysis methodology for all trails layers were correct. He delegated work among the trails team until the time of the final report. He also helped write the AUT proposal, designed the power point presentation for the final report, and was responsible for half of the GIS analysis for the trail layers and the production of the professional poster.

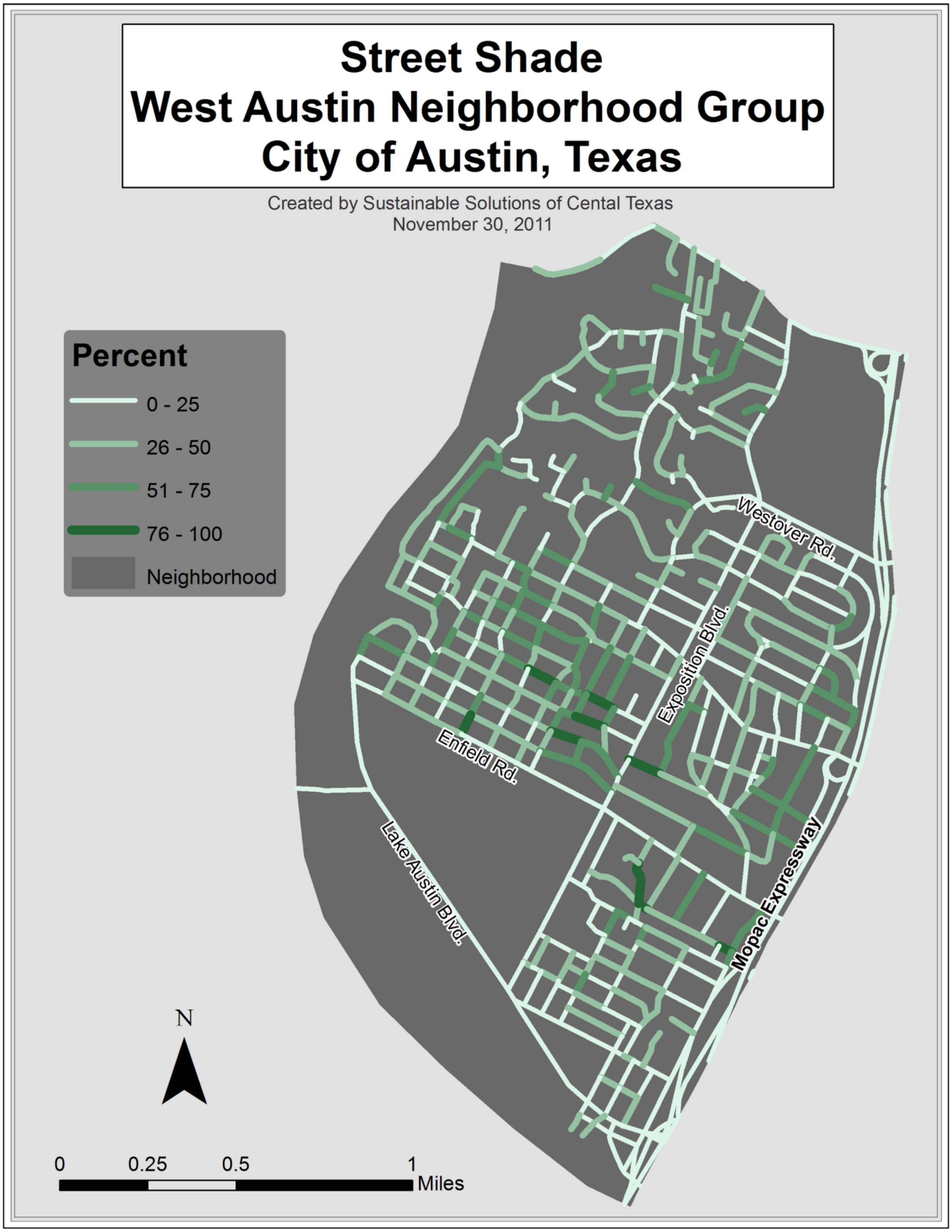
Neliralda de Silva: GIS Analyst and Cartographer

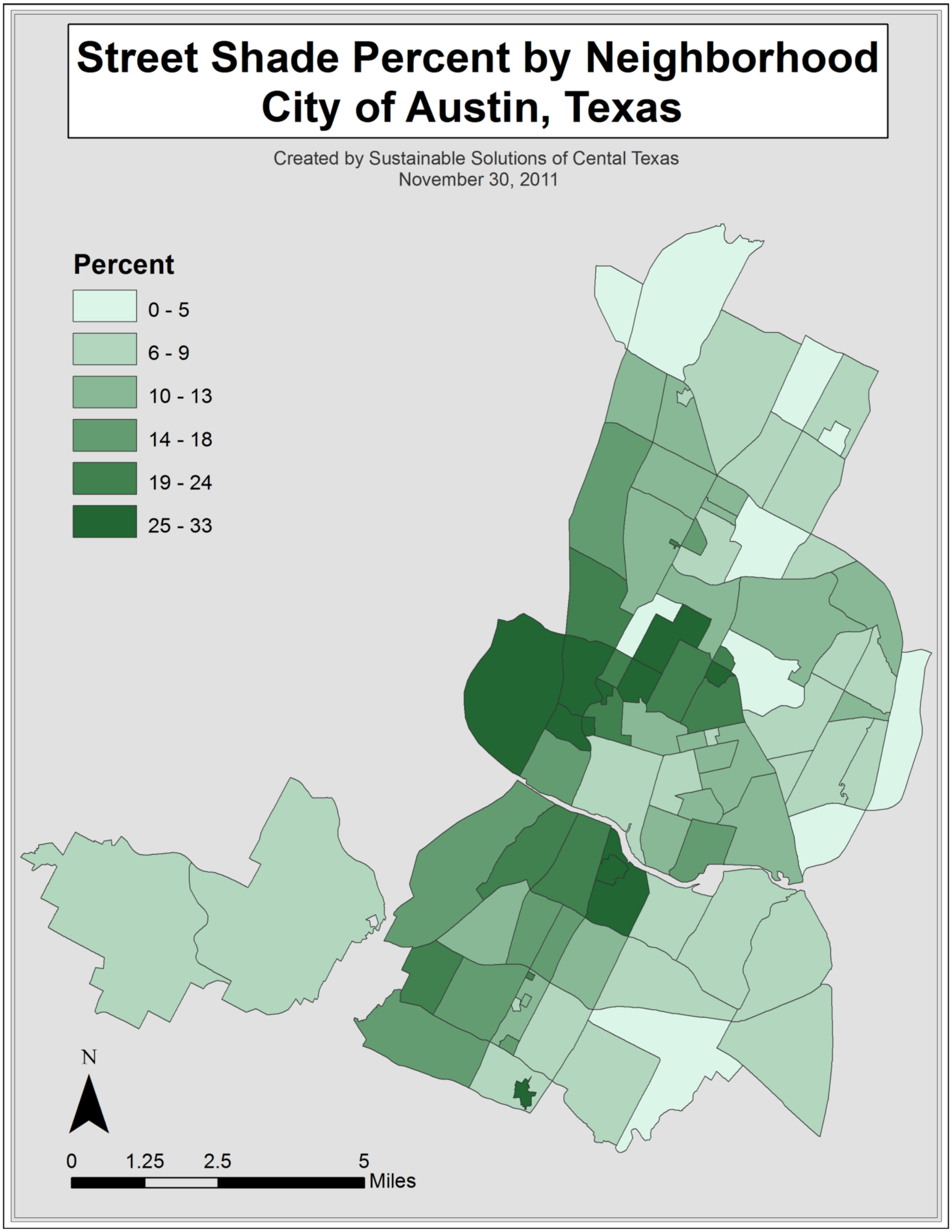
Neliralda served as the lead map maker as well as a skilled GIS analyst. She designed most of the maps for the trails layers and helped with the writing of the metadata for all final layers. She also was responsible for the team logo and power point presentations for the AUT proposal and progress reports.

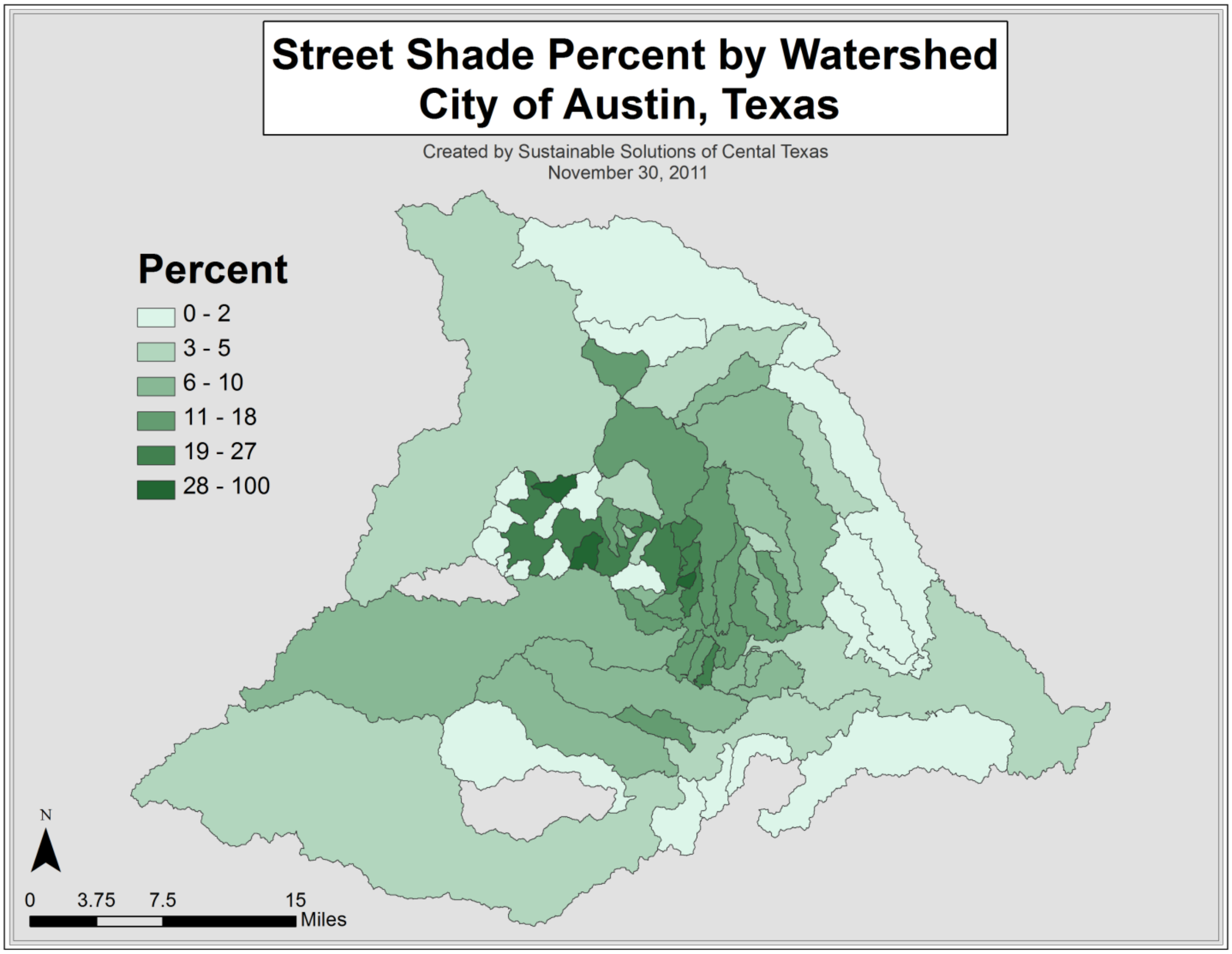
Appendix II: Maps

<u>Sustainable Solutions of Central Texas maps:</u>

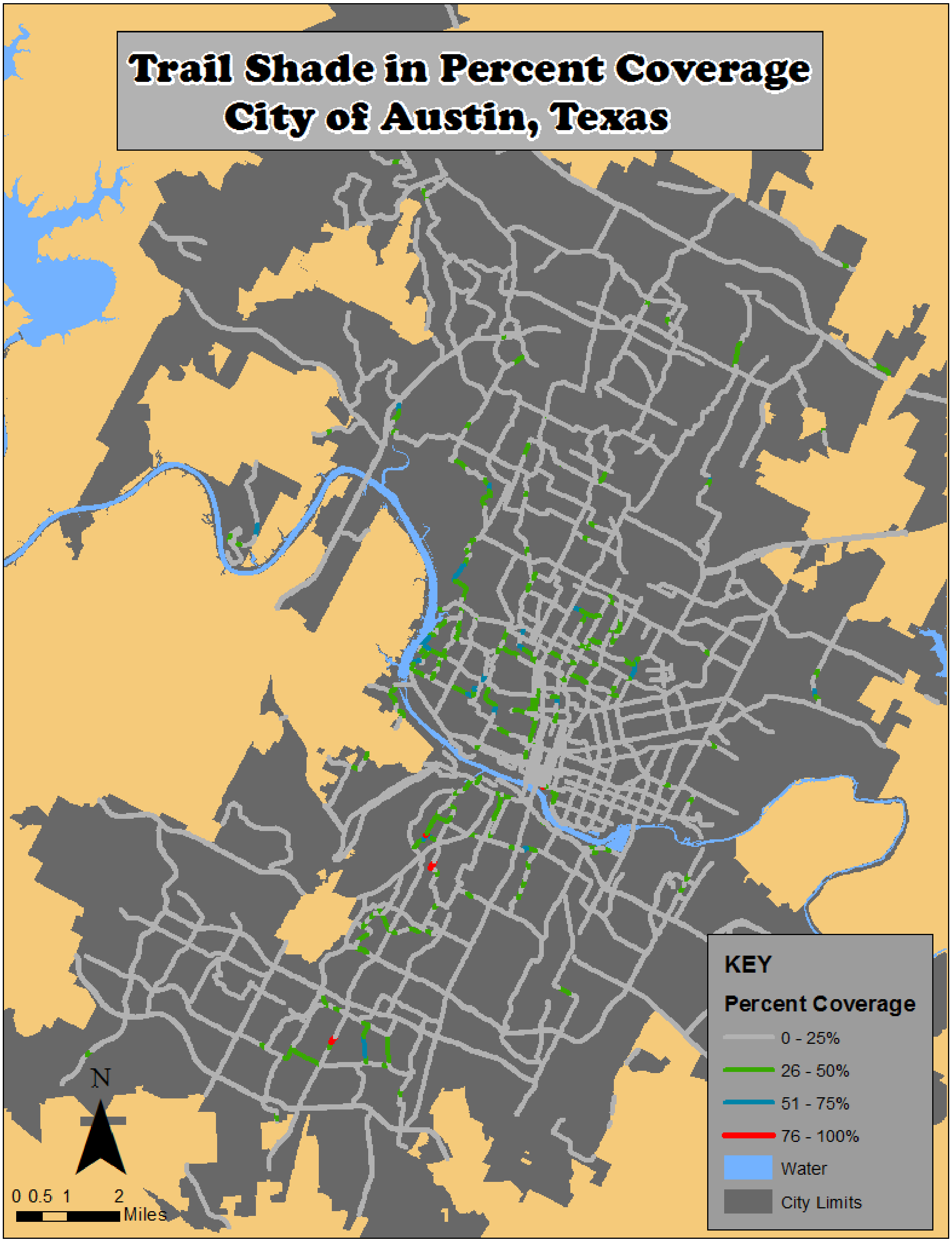


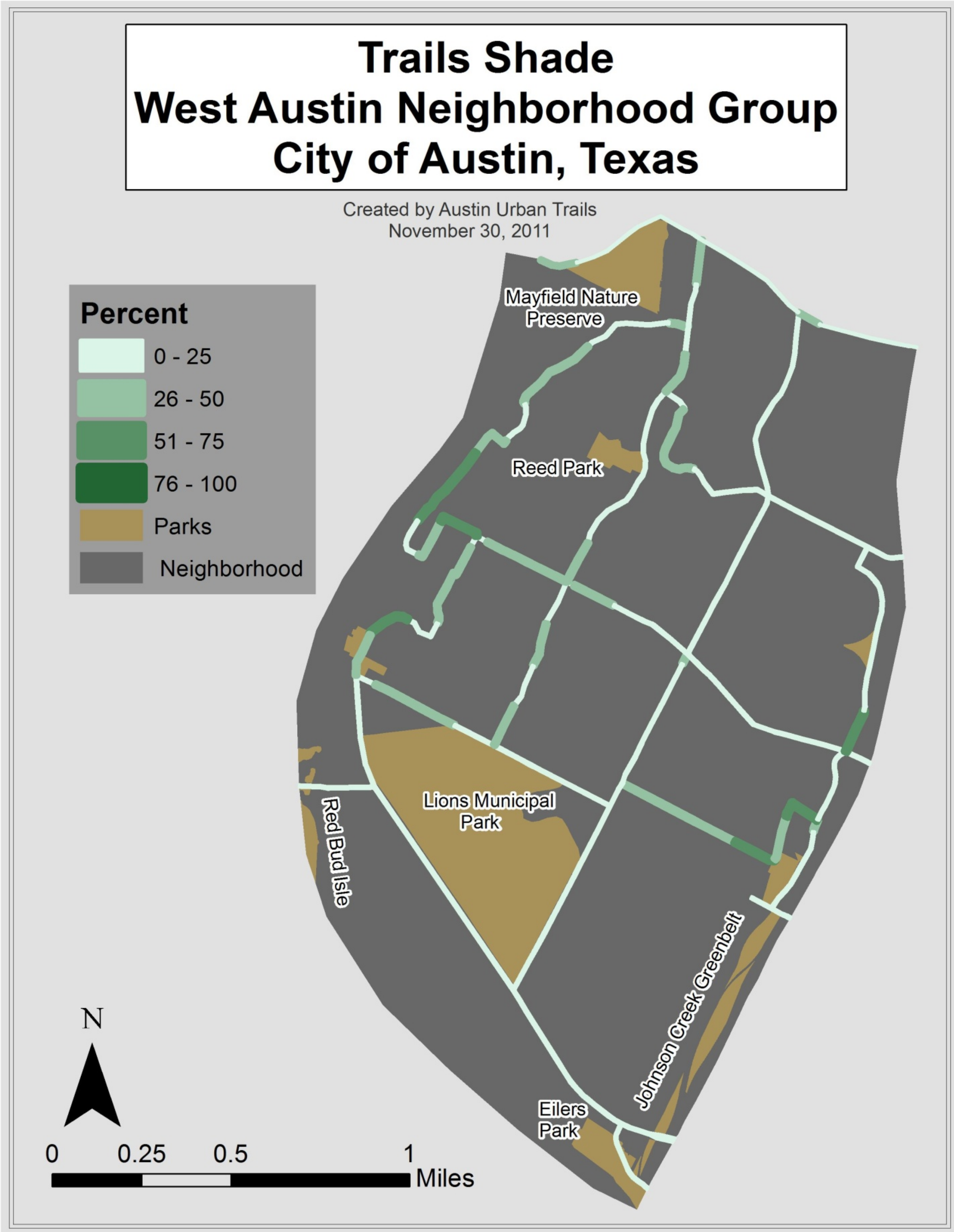

Street Shade
West Austin Neighborhood Group
City of Austin, Texas
Created by Sustainable Solutions of Cental Texas
November 30, 2011
Percent
0 - 25
26 - 50
51 - 75
76 - 100
Neighborhood
Westover Rd.
Exposition Blvd.
Enfield Rd.
Lake Austin Blvd.
Mopac Expressway
N
0
0.25
0.5
1
Miles

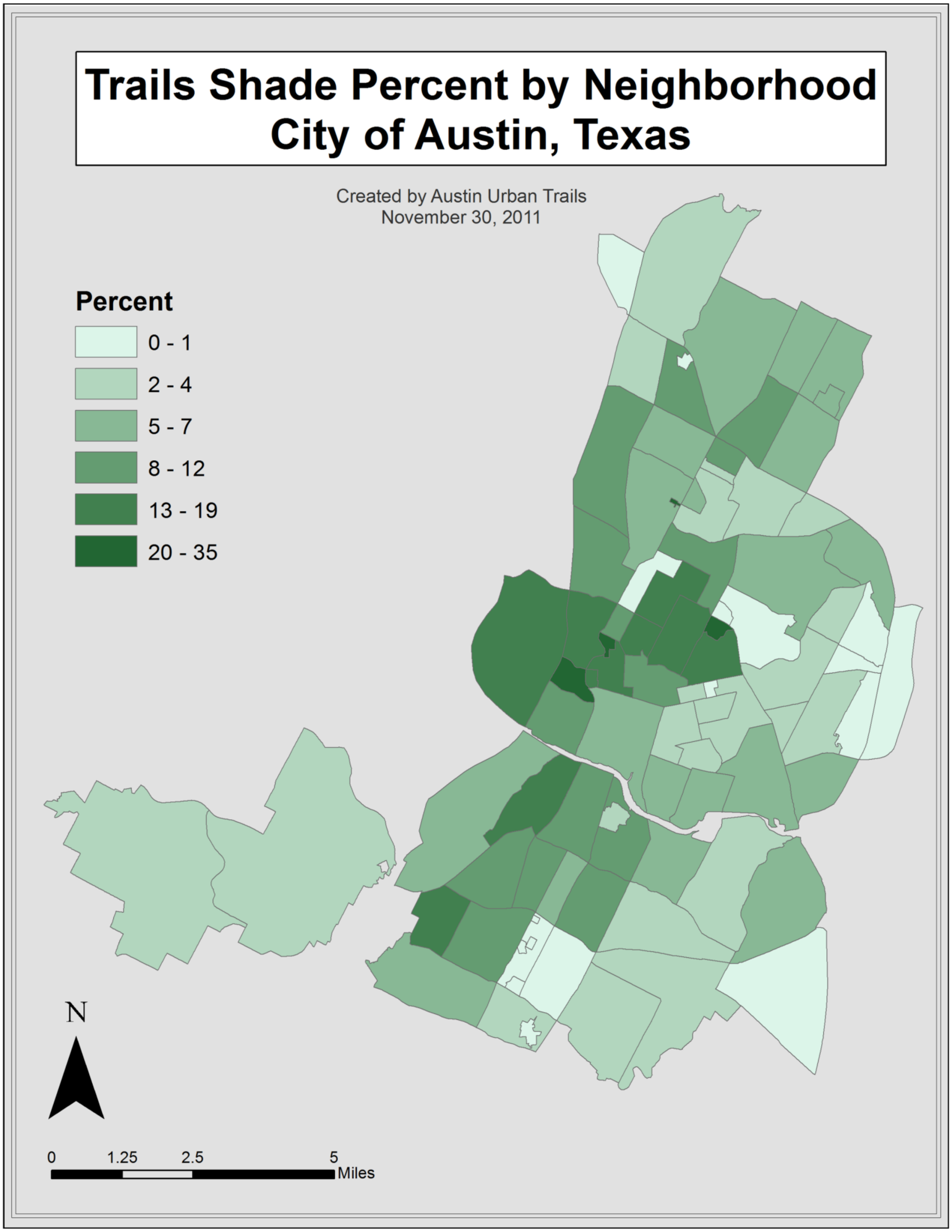

Street Shade Percent by Neighborhood
City of Austin, Texas
Created by Sustainable Solutions of Cental Texas
November 30, 2011
Percent
0 - 5
6 - 9
10 - 13
14 - 18
19 - 24
25 - 33
N
0
1.25
2.5
5
Miles


Street Shade Percent by Watershed
City of Austin, Texas
Created by Sustainable Solutions of Cental Texas
November 30, 2011
Percent
0 - 2
3 - 5
6 - 10
11 - 18
19 - 27
28 - 100
N
0
3.75
7.5
15
Miles

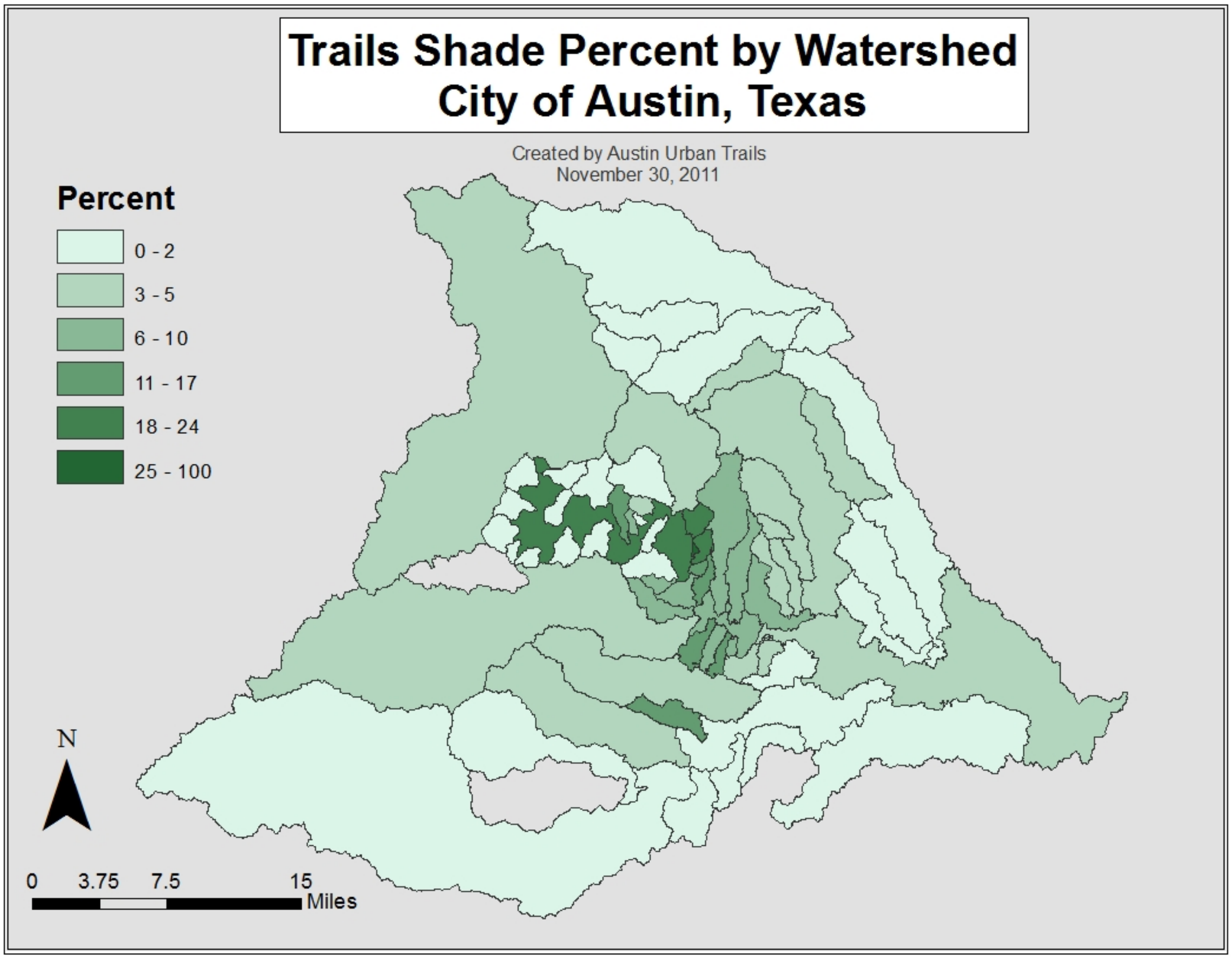
Austin Urban Trails maps:




Trails Shade
West Austin Neighborhood Group
City of Austin, Texas
Created by Austin Urban Trails
November 30, 2011
Percent
0 - 25
26 - 50
51 - 75
76 - 100
Parks
Neighborhood
Mayfield Nature Preserve
Reed Park
Lions Municipal Park
Red Bud Isle
Johnson Creek Greenbelt
Eilers Park
N
0
0.25
0.5
1
Miles



Trails Shade Percent by Neighborhood
City of Austin, Texas
Created by Austin Urban Trails
November 30, 2011
Percent
0 - 1
2 - 4
5 - 7
8 - 12
13 - 19
20 - 35
N
0
1.25
2.5
5
Miles


Trails Shade Percent by Watershed
City of Austin, Texas
Created by Austin Urban Trails
November 30, 2011
Percent
0 - 2
3 - 5
6 - 10
11 - 17
18 - 24
25 - 100
N
0
3.75
7.5
15
Miles

Appendix II: Metadata

(all metadata is located on the disk)