Walkability Measures for Florida

Estimating Walkability Metrics

Using Statewide Data

With Geographic Information Systems (GIS)

Prepared for
Bureau of Chronic Disease Prevention
Division of Community Health Promotion
Florida Department of Health
Tallahassee, FL

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In Partial Fulfillment of Contract #COHR9
June 2018

EXECUTIVE SUMMARY

This report was commissioned to examine, analyze, and evaluate walkability measures in current academic literature, assess the data available, develop a suitable walkability metric for Florida, and design online maps to visualize Florida's walkability using this devised formula. A broader wish for the Department of Health is that the results of this study are useful to local planners for designing more walkable communities with the long-term goal of increasing physical activity.

The academic fields of transportation, urban design, and public health each identify differing explanations as to why people walk and suggest different characteristics to affect one's choice to walk. Reviewing academic journals and charting the data used for studies revealed a finite set of data inputs in spite of the diverging theories on walking motivation.

Examination into the data available for Florida revealed several commonly used quantifiable data inputs that are readily available. Road compactness, population estimates, proximity to destinations, and presence of parks and trails are available statewide at favorable resolutions. Much data affecting urban design and pedestrian aesthetics such as sidewalk data, lighting, and cleanliness is not available at a state level. Further, elements such as visual design, human scale, unblocked vision, and perceived safety-- also not available at a state level-- are nebulous as these characteristics could be considered subjective measures.

This research seeks to accommodate both transportation and recreation walking motivations. The final results are presented visually as a composite based upon multiple criteria at a 1-kilometer grid cell scale. Multiple map visualizations are used to convey information about the various input data so that users can understand the positive and negative factors in an area instead of a single metric. An area's score can be assessed from multiple perspectives, thus revealing the reason(s) why an area might have received a particular score. While much local and subjective data cannot be included in this study, it is hoped that the results of this research could be helpful to local planners and designers looking to increase walking motivation in their communities.

The interactive map is located at: http://hermes.freac.fsu.edu/che/walk/

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INTRODUCTION

This research is commissioned by the Florida Department of Health in hopes of quantifying environmental factors in Florida for the purpose of assisting local planners and designers with information potentially useful for increasing walkability in their communities. The specific tasks involve writing a report of findings from assessing existing walkability formulae in the academic literature, examining the data available in Florida, and devising a new formula for the state. A second task is to develop a statewide online map using the devised formula via an online map available to the general public.

It is commonly recognized that physical activity plays an important role in human health. Walking is the first thing an infant wants to do and the last thing an elder wants to give up (Butcher 1999). Walking is one method to increase physical activity that is generally considered accessible to most without special training or equipment. Walking is "the forgotten transportation" (Cochoy et al 2015) as automobiles and other modes of transit have encroached upon humans' simplest mobility. One out of two adults lives with a chronic disease that contributes to disability, premature death, and health care costs. Physical activity is recognized as one of the most important steps that people can take to improve their health. The Surgeon General has issued a Call to Action that addresses goals to make walking a national priority (United States, U.S. Department of Health and Human Services, Surgeon General 2015).

While the scope of this project is limited to assessing walkability and developing tangible statewide maps, it is hoped by the Department that the maps produced here would be of value to local planners for increasing walk motivation in their communities. The Department would like for local officials to be able to use this information to design environmental changes such as lighting, sidewalks, or greenways to increase walking motivation. However, this project initially serves as a gathering of baseline statewide data considered to be related to walkability. This research could be extended in the future to include more detailed information through localized Geographic Information Systems (GIS) data and perceptions gathered from local walkers. The combination of these datasets holds promise for fully understanding the environmental details and how areas are viewed by the community. Combining quantifiable GIS data with audits of the pedestrian experience help ensure a more realistic view of neighborhoods.

Definition of Research Topic

The concept of walkability began in 1993 in Ottawa, Canada following a proposed property tax increase related to road infrastructure improvements. Some land and shop owners argued that most in their neighborhood traveled by foot for their daily trips, and as such, did not need road improvements and should not be required to pay increased taxes. The city planner proposed an index to rate the "walkability" of neighborhoods to be used to calculate the new tax rates (Ghidini 2011, Bradshaw 1993). The original definition of walkability was a "quality of place" with four basic characteristics: "foot-friendly" environment with sidewalks, intersections, good lighting; a range of useful active destinations; a natural environment that moderates weather extremes without excessive noise, dirt, and grime of motor traffic; and a social and diverse culture that could increase contact between people. The final qualitative assessments included questions on population density, number of parking spaces, the chance of meeting someone while walking, the age at which a child would be allowed to walk alone, women's rating of neighborhood safety, responsiveness of the transit service, the number of "places of significance", and the area covered with sidewalks and parks (Bradshaw 1993, Cambra 2012).

Since the initial introduction of the concept, walkability has become a common focus in several academic fields. People walk for either transportation or recreation. The academic fields of transportation, urban design, and public health each identify differing explanations as to why people walk and suggest different characteristics to affect one's choice to walk. Transportation theory focuses upon the built transportation system designed for automotive transport, and, although this is currently changing to include pedestrians, the field remains focused on walking for utilitarian purposes. Urban design focuses on aesthetics and pedestrian infrastructure in relation to functionality. Public health stresses the importance of physical activity because of the positive health benefits. The role of nature and pleasant environments is increasingly being included in some academic fields but currently remains a fringe consideration.

This research seeks to understand the data components of these three academic fields in order to develop a formula broad enough to encompass those walking for transportation as well as recreation.

Structure of this Report

This report is structured as follows:

Definitions, Expectations, Limitations, and Scale

This section provides a general overview of walkability measures.

Method

Gathering Formulae and Potential Data Inputs

- A broad overview of prior walkability studies reveals a finite set of data commonly used for walkability measures.

Refining Potential Data Inputs

- Refining the set of data inputs in the previous section into categories clarifies data that is more appropriate for this research.

Identifying Statewide Data Availability

- Examining the selected datasets from the prior section and identifying those available at the state level provides a compact list of potential data inputs.

Data Preparation

- Data inputs are normalized for easy comparison with other inputs.

Exploring Data and Potential Combinations

- Statewide maps of each dataset convey spatial location and intensity as a means of preliminary data exploration.

Developing the Formula

- Preliminary exploratory measures provide guidance on the final formula.

Results

Walkability metrics are visualized on a map. Multiple map visualizations are used to convey the various components used to determine the final walkability metric to explain the reasoning behind the metric.

Case Study: Sidewalks of Leon County, Florida

Localized data has potential to add another perspective to statewide walkability data. Sidewalk data for Leon County is overlaid on the walkability results as an exploratory measure.

Conclusions

The formula and final map accurately identify geographic areas with sufficiently high measures of quantifiable data inputs commonly used for walkability studies.

Recommendations for Future Work

This research serves as a first step in assessing features associated with walking. Assessment can be furthered by including local data and opinions of local pedestrians.

Acknowledgements

We would like to acknowledge the consultancy provided by Dr. Christopher Coutts of the Florida State University, Department of Urban and Regional Planning. Dr. Coutts is a leading expert in walkability and urban form with publications in both planning and public health literature. He was instrumental in explaining the nuances of the various walkability definitions and their interpretations, highlighting important if not irrefutable studies in the field, adding his input to the final formula, and offering other helpful advice along the way.

BACKGROUND

Definitions, Expectations, Limitations, and Scale

DEFINITIONS

What is walkability? There is a lack of consensus on what walkability means and several definitions abound. What is important seems to depend upon who is asking (Lo 2009). Walkability is the extent that characteristics of the built environment and land use may or may not be conducive to residents walking for leisure, errands, or travel to work (Leslie et al 2007). Walkability is the "extent to which the built environment is friendly" (Abley and Turner 2011). Walkability is a "match" between a resident's expectation for a type of destination, their willingness to walk a given distance, and the quality of the walking path. Does someone walk because their neighborhood is walkable or because they have no other option? (Manaugh & El-Geneidy 2011). Walkability is "the extent to which the built environment supports and encourages walking by providing for pedestrian comfort and safety, connecting people with varied destinations within a reasonable amount of time and effort and offering visual interest in journeys throughout the network" (Southworth, 2005, p.205). "If a space cannot be 'read' by a pedestrian as walkable, then perhaps it is not in fact walkable – even if quantitative models show that it should be" (Riggs 2017). An alternative measure of a walkable area could be an assessment of the number of people walking in the area.

Grasser (2013) notes that the concept of walkability has two fundamental aspects: proximity to destinations and connectivity. Proximity is defined as density plus land use mix, where density can be defined as people, houses, or jobs in an area. Land use mix complements density and serves as a measure of how many types of activities are in an area. Areas with high mixed land use are assumed to have destinations nearby. Connectivity is based on street design (Grasser et al 2013). Glazier (2014) determined that proximity to destinations and high population densities are associated with the highest levels of alternative transportation (Glazier et al 2014).

The built environment is thought to contribute positively or negatively to one's decision to engage in walking. Several characteristics are associated with high walkability such as population density, mixed land use, proximity to destinations, compactness of transportation system, pedestrian experience (lighting, sidewalks, etc.), safety, and other factors. The use of a composite index as a measure of walkability combines various characteristics into a single simple metric to easily convey information about an area's walkability.

In Florida, the Department of Transportation has updated the design manual used by planners and transportation engineers to incorporate the ideals in a program known as *Complete Streets*. *Complete Streets* emphasizes considering the transportation needs of all users of all ages and abilities when developing transportations systems. This includes pedestrians, bicyclists, transit users, and motorists. The FDOT Design Manual uses these principles to promote safety, development, and quality of life. The goal is accomplished by including consideration of the community context (urban, rural, suburban) in transportation design. This approach allows engineers to design for speed, sidewalks, on-street parking, etc. to give more space and comfort for non-car transportation (FDOT 2017).

EXPECTATIONS

Walkability is considered the extent that an environment supports a human's ability and desire to engage in walking. The reasons to walk are identified as leisure, exercise, or recreation; to access services; or to travel to work. People who move to new locations have been shown to change their habits if offered a more pedestrian environment. Distances under one mile are need if walking is to be competitive with other methods (Leslie et al 2007).

There is ample evidence of positive health outcomes correlating with environmental characteristics considered to be associated with high walkability. Studies show:

- A decrease in Body Mass Index (BMI) is associated with an increase in housing density
- Reductions in obesity in the highest and lowest population densities
- Positive associations between gross population density and walking
- Housing density is a strong predictor of walking for transport
- High land use mix is associated more with walking for transport than with walking for errands
- Positive associations between intersection density and walking in general
- A one-unit increase in intersection density results in a 20% increase in walking for transport and an 11% increase in walking for errands
- Positive correlations between composite walkability measures and the number of minutes walked weekly
- Residents in highly walkable areas walk 210% more than residents of low walkable areas (Grasser et al 2013).

There are a limited number of popular measures of walkability. Walkscore™ is widely known as a measure of walkability. The website's original formula calculates proximity to destinations using distance-decay methodology, where the score drops with increased distance to destinations. Recent versions consider population density and road intersection density. Walkscore™ has been shown to be a reliable measure of walkability (Carr et al 2010, Nykiforuk et al 2016). Frank (2010) developed a formula that is widely accepted to quantify walkability using GIS data of population density, transportation density, land use mix, and retail area. Several articles use a customized version of Frank's formula to fit their data needs (Adams et al 2015, Todd et al 2016).

LIMITATIONS

A limitation of walkability studies in general is that they focus on a single motivation for walking: transportation or recreation. Thus, a state park could be considered unwalkable when analyzed by transportation measures, and similarly a walkable but unpleasant street could receive a low walking score when analyzed by recreation criteria. A second limitation of general walkability formulae is that the final assigned score is often a single metric that does not lend information as to how the score was calculated, thus not easily explaining the reason(s) for the score assignment and not offering assistance to local planners interested in increasing walkability.

Walkability formulae can be developed for specific purposes. It is possible for walkability formulae to contain biases due to lack of inclusion of other densities and walking purposes. Two potential limitations of current formulae are:

- Transportation and Recreation: People walk for transportation or recreation. Some walkability studies can serve as a measurement of one or the other, but not both.

- Urban and Rural: High population areas typically have high densities of other amenities where activities and functions take place, and typically have a high walkability metric. However, there are many small towns with low populations that are highly walkable. Neighborhood walkability in rural areas should acknowledge that walking may be for leisure and some traditional walkability domains may not apply (Kegler et al 2015). Destination-based walkability measures may be appropriate for older large population centers, however, challenges exist for medium and small populated areas (Nykiforuk et al 2016).

Field verifications of walking scores are important as the validation of these metrics is often unknown (Hajna et al 2013). There are documented examples of highly walkable areas receiving low walking scores due to formulae that value characteristics not found in the neighborhood. One neighborhood receiving a low score had a transportation system based on curvilinear shape with many cul-de-sacs and low land use mix. To overcome the street design, residents had developed their own footpaths to connect housing, schools, and shopping. Consequently, the neighborhood was highly walkable via the footpaths, yet the walkability formula valued road intersection density and high land use mix. A second example is a highly walkable older neighborhood with a gridded street pattern, wide tree-lined streets, and good access to shopping and recreational activities. The low score was attributed to low dwelling density and low land use mix (Leslie et al 2007).

Scale

Geographic scale is an important concept that should receive more attention and care in map-making. "Scale" can be synonymous with "scope" or "extent." Data on a map can appear different when mapped at different scales as the data distribution changes. Larger regions can mask data patterns and clusters. "Optical illusions" are possible as the human eye is drawn to large and colorful areas before smaller neutral tones even if the smaller area has a higher concentration of data. Three possible data scales—area, point, and grid—are discussed below with advantages, disadvantages, and examples.

- Area (City, Neighborhood, Census Unit, Zip Code)

Walkability studies typically report findings for areas, possibly a city, neighborhood, census unit (tract, block group, or block), or zip code. Areas can be named and have an advantage of being a familiar, recognizable geographic region. It is easy to compare walkability results between cities and conclude in general terms that City A is more walkable than City B. Maps showing results by census unit or zip code are common and easy for the map reader to understand. A disadvantage of this approach is the impression is that all areas within the geographic boundary are homogenous with equal walkability potential, when it is more likely that the geographic area contains private property, lakes, or other features that would not be considered walkable. Krambeck (2006) notes that the average walkability score for Alexandria, Virginia is a blend of the very walkable historic district and other parts of the city are that are less walkable, thus confusing the issue of how to interpret a walk score at a city level. It is important for map readers to understand that the walkability results using areal boundaries are generalized and the score would not apply equally to all areas within the region. Larger areas will likely contain more variability than smaller areas.

- Point (Street Address)

WalkScore™ uses points instead of geographic areas and provides a walking score for each address. Results are not aggregated into geographic regions. An advantage of using a point address approach is the fine-grain results where addresses relatively close together can have different results based upon their proximity to potential destinations. Point data does not falsely convey homogeneity. A disadvantage is that the results are difficult to visualize as point data can quickly become cluttered on a map. To combat this visualization challenge, the WalkScore™ website's online map includes a heatmap to visually convey the walkability results. Another disadvantage is that point data is problematic for statistics and analysis, making it difficult to archive results for future detections of changes in walkability metrics.

- Grid (Cell)

An alternative scale is a grid system using uniform geometry of a small size. Uniform grid cells retain the density of information being analyzed, making it is easy to compare and contrast regions. Grid cell boundaries are not arbitrary as other geographic regions such as zip codes and census units. The fine-grained nature of a grid cell makes it possible to focus on specific regions and to distinguish changes in walkability over a landscape. A disadvantage to a grid system is that familiar nomenclature—such as referring to an area such as a city or zip code by name—is not possible with a grid system.

This research uses the United States National Grid (USNG) at a 1-kilometer scale. The USNG—a modernized version of the Military Grid Reference System (MGRS) from the 1940s—is a consistent *language of location* capable of locating any point on earth at multiple scales. The USNG is a national standard, recognized by the Federal Geographic Data Committee (FGDC), all branches of the U.S. military, the U.S. Park Service, the U.S. Geological Survey (USGS), the Federal Emergency Management Agency (FEMA), the Florida Division of Emergency Management (FDEM), the Florida Fire Chief's Association (FFCA), and many local emergency responders, including search-and-rescue personnel. Each cell of the USNG has a unique identifier that conveys spatial location and size and is understandable by anyone familiar with this system (USNG Center 2018, USNG Florida 2014). The 1-kilometer grid size is sufficiently fine-grained to distinguish changes in walkability within an area.

Method

Gathering Formulae and Potential Data Inputs

The Community Preventive Services Task Force (2016) reviewed 90 studies through June 2014 that explored the relationships between pedestrian and bicycle transportation systems with environmental design and land use with focus on the effectiveness of increased physical activity. This report is the most rigorous evaluation of the current state of scientific knowledge on the environmental correlates of physical activity behavior. The report's findings identified specific pedestrian transportation characteristics and specific recommendations for land use and environmental design that could be effective in increasing physical activity. The specific pedestrian transportation system characteristics include: street pattern design and connectivity, pedestrian infrastructure (sidewalks, lighting, landscaping, etc.), and public transit infrastructure and access. Land use and environmental design characteristics include: mixed land use, increased residential density, proximity to destinations (stores, banks, etc.), and access to parks and recreational facilities.

To supplement the Task Force's research, we performed our own literature review. Searches for literature items were made at Google Scholar and the Florida State University libraries (www.lib.fsu.edu). The first search term was "walkability measure", followed by "walkability metrics," "walkability metrics GIS," "walkability formula," and "walkability formula GIS." We were searching for a collection of various walkability formulae for comparison. Each search term produced thousands of results, with many of the returned articles having little or nothing to do with the topic at hand but rather articles that happened to contain two of the search terms in unrelated context. (For example, a returned article might be flagged because it contains the words "walkability" and "GIS" but the article focus was on a different topic such as interpretation of socioeconomic data.) We were specifically looking for a collection of walkability formulae. However, while there are thousands of articles on walkability, few focus on the development of a formula. Many articles focused on use and validation of walkability formulae, such as studies comparing the results from WalkScore™ to perceptions of walkability by local residents, studies assessing walkability and socioeconomic characteristics, walkability's relation to physical exercise and health outcomes, motivation to walk, and other related topics.

To narrow the focus of our literature review, we returned to the original term of "walkability measure" and eliminated non-pertinent and redundant articles within the first few pages of results. Repeating this process for the remaining terms seemed to produce some of the same core overlapping articles, while eliminating those with coincidental terms. Further, we recognized some of this subset of articles as being widely cited (e.g. Frank, Leslie). While, there are few articles focusing on development of a formula, we expanded our search to include several articles that assess formulae for use in a specific context so that we could observe how the various formulae were being used. The final selection of 25 articles appeared in these searches as described within the first few pages of results.

REFINING POTENTIAL DATA INPUTS

The definitions of walkability are diverse. Similarly, the methods used to quantify walkability vary widely. Table 1 shows a list of the currently available walkability measures in the literature. Each method has its own purpose and uses different sets of data inputs.

Walkability Measure	Author(s)	Purpose	Data Inputs
Walkability Index	Frank et al	Operationalize and simplify development of walkability measures using property parcel data.	Residential density, Land use diversity, Intersection density, Destinations.
Walk Score™	Walk Score™	Market apartments for rent through promotion of neighborhood walkability.	Intersection density, Intersection types, Destinations.
Walk Opportunity Index	Kuzmyak et al	Collect the number, character, and desirability of key activities within walking distance of a household.	Intersection types, Destinations.
Pedshed	Porta and Renne	Focus on walkable urban design and sustainable placemaking.	Network directness.
Extended Walkability Index and Moveability Index	Buck et al	Extend concept of walkability to include urban opportunities for physical activity in children.	Residential density, Land use diversity, Intersection density, Green space, Transit access.
Neighborhood Destination Accessibility Index	Witten et al	Measure pedestrian access to neighborhood destinations.	Destinations, Green space, Transit Access.
Pedestrian Index of the Environment	Singleton et al	Estimate the probability of a pedestrian trip through area-based empirical relationships between individuals and the built environment.	Population density, Intersection density, Infrastructure comfort, Destinations, Transit Access.
Global Walkability Index	Krambeck	Rank cities across the world on safety, security, and convenience of their pedestrian environments.	Safety, security, infrastructure comfort, public policy.

Table 1. Overview of currently recognized walkability measures.

To develop a finite list of data inputs, we examined each paper and noted the data inputs used for the study. The full list is summarized in Table 2. The data input *slope* was mentioned several times but this was not included because Florida is typically of flat terrain and this factor did not seem to be relevant for walking but would be for cycling. Table 2 provides an alternative perspective by tabulating all characteristics mentioned in the walkability articles. Table 3 summarizes the total counts by categories.

Paper	HUMAN DENSITY			LAND USE	COMMERCIAL DESTINATIONS		ROAD DENSITY		PUBLIC TRANSIT	RECREATION		PEDESTRIAN INFRASTRUCTURE					AESTHETICS														OTHER		
	Population density	Housing density	Employent density	Land Use Mix: Entropy or HHI	Destinations	Retail Floor Area Ratio	Road Intersection Density	Street Block Length	Public Transit Access	Public Park Access	Private Recreation Access	Percieved or Actual Crime	Traffic Accidents w Pedestrians	Vehicle Speed	Crossings	Buffering/Separation from Vehicles	Accessible for Different Abilities	Sidewalks / Pedestrian Routes / Footpaths	Pavement Width	Lighting	Traffic Volume	Cleanliness	Amenities (e.g. toilets, benches, water fountains)	Perceived walkability	Complexity / Visual Interest	Uniqueness / Imageability	Vegetation & Shade Trees	Human Scale	Transparency (vision not blocked)	Absence of noise or presence of Pleasant Sounds	Motivation	Weather	Policy Support
Naderi & Raman 2005													x	x		x		x							x		x			x	x	x	
Krambeck 2006												x		x	x	x	x	x					x										x
Leslie et al 2007		x		x		x	x																										
Lo 2009									x			x			x	x	x	x		x					x	x	x		x				x
Frank et al 2010	x			x		x	x																										
Carr et al 2010	x						x	x	x			x												x									
Kelly et al 2011												x		x	x				x	x	x	x											
Manaugh & El-Geneidy 2011	x			x	x		x																										
Hajna et al 2013		x		x			x																										
Grasser et al 2013	x	x	x	x		x	x	x																									
Glazier et al 2014	x	x			x		x																										
Ameli et al 2015	x			x	x	x	x		x										x						x	x		x	x				
Li et al 2015					x		x	x	x			x	x	x				x															
Carlson et al 2015	x			x	x	x																											
Adams et al 2015		x		x		x	x		x	x	x																						
Soria-Lara 2015					x				x			x		x	x	x		x	x	x		x	x		x	x	x	x	x	x		x	
Todd et al 2016	x			x		x	x		x	x	x																						
Rundle et al 2016	x			x		x	x		x																								
Nykiforuk et al 2016					x		x	x		x																							
Zuniga-Teran et al 2016	x			x				x	x	x				x	x	x		x							x		x				x		
Tsiompras & Photis 2017				x	x		x																										
Cruise et al 2017	x			x		x	x											x															
Lefebvre-Ropars et al 2017	x		x	x	x		x		x									x					x										
Su et al 2017					x		x	x				x			x		x															x	
Fan et al 2018		x		x			x		x																								x
TOTALS	12	6	2	15	10	9	18	6	11	4	2	7	2	6	6	5	3	8	3	3	1	2	3	1	5	3	4	2	3	2	2	3	3

Table 2. Details of data inputs in the literature review.

Category	Count
Road Intersection Density	18
Land Use Mix	15
Population (Human) Density	12
Public Transit Access	11
Destinations	10
Retail Floor Ratio	9
Sidewalks / Pedestrian Routes / Footpaths	8
Perceived or Actual Crime	7
Housing Density	6
Vehicle Speed	6
Street Block Length	6
Crossings	6
Complexity / Visual Interest	5
Buffering / Separation from Vehicles	5
Public Park Access	4
Vegetation / Shade Trees	4
Pavement Width	3
Lighting	3
Transparency (vision not blocked)	3
Accessibility for Different Abilities	3
Amenities (e.g. toilets, benches, water fountains)	3
Uniqueness / Imageability	3
Weather	3
Policy Support	3
Private Recreation Facilities	2
Traffic Accidents with Pedestrians	2
Cleanliness	2
Employment Density	2
Human Scale	2
Absence of Noise or Pleasant Sounds	2
Motivation	2
Traffic Volume	1
Perceived Walkability	1

Table 3. Summary of data inputs from literature review.

NARROWING DATA SELECTION

Further inspection revealed that several categories in Table 3 have multiple ways to quantify the concept:

- Human Density - Population, housing, and employment densities are measurements for human activity in an area.
- Commercial Destinations – A count of destinations and a ratio of retail floor space related to land size are both intended to quantify proximity of potentially walkable destinations.

- Road Compactness - Intersection density (intersections are defined as having at least 3 branches) and a linear measure of street block length.

Access to private recreation facilities was removed because this research is not a study of physical activity but rather a measure of environment walkability, thus private recreation facilities is treated as a potential *destination* and is already included in the destination database.

Determining Statewide Data Availability

Table 4 shows whether the data is available at a state level and the data provider. Much of the data is not available at the state level and would need to be obtained from local cities or counties. Some concepts have multiple measurements. To avoid redundancy, we have selected only one measurement for each concept.

Walkability Characteristic	Available Statewide in GIS Format	Comments	To Be Tested in the Formula	Data Source
Road Intersection Density	YES	Measure of Road Compactness	YES	2018 NAVTEQ
Land Use Mix	YES	Measure of Land Use Mix	YES	2014 Department of Revenue Property Appraiser
Population Density	YES	Measure of Human Density	YES	2010 Florida Resources and Environmental Analysis Center, Florida State University
Public Transit Access	no		no	
Destinations	YES		YES	2018 NAVTEQ
Retail Floor Ratio	YES	Alternative Measure of Commercial Destinations	no	
Sidewalks / Pedestrian Routes / Footpaths	no		no	
Perceived or Actual Crime	no	Crime is available statewide at the county level -- scale is inappropriate	no	
Housing Density	YES	Alternative Measure of Human Density	no	
Vehicle Speed	YES	Alternative Measure of Road Compactness	no	
Street Block Length	YES	Alternative Measure of Road Compactness	no	
Crossings	no		no	
Complexity / Visual Interest	no		no	

Buffering / Separation from Vehicles	no		no	
Public Park Access	YES	Measure of Park Access (includes Trails)	YES	2011, 2015 GeoPlan Center, University of Florida.
Vegetation / Shade Trees	no		no	
Pavement Width	no		no	
Lighting	no		no	
Transparency (vision not blocked)	no		no	
Accessibility for Different Abilities	no		no	
Amenities (e.g. toilets, benches, water fountains)	no		no	
Uniqueness / Imageability	no		no	
Weather	no		no	
Policy Support	no		no	
Private Recreation Facilities	YES	Duplicated as this is included as a Destination	no	
Traffic Accidents with Pedestrians	no		no	
Cleanliness	no		no	
Employment Density	no		no	
Human Scale	no		no	
Absence of Noise and/or Presence of Pleasant Sounds	no		no	
Motivation to Walk	no		no	
Traffic Volume	no		no	
Perceived Walkability	no		no	

Table 4. Summary of data used in walkability reports and assessment of statewide availability and practicality.

Data Preparation

Road Intersection Density

The road data from NAVTEQ were converted into points representing intersections with three or more pathways. Intersections representing interchanges, complex intersections, and those within

100 feet of a major highway were removed. Density was calculated for each grid cell by counting the number of intersections present within each cell. A z-score was calculated for normalization purposes.

Land Use Mix

For each grid cell, total land area was calculated for each land use type from the 2014 Florida Department of Revenue property appraiser data using the land use code. The Herfindal-Hirschman Index (HHI) was used to determine the degree of land use mix within the grid cell. The HHI ranges from 0 to 1, where 1 is a monopoly with only one land use, and numbers closer to zero indicate more types of land use. To maintain consistency with other data inputs, the HHI score was inverted, or subtracted from 1 (e.g. 1-HHI), to reverse the range so that higher scores reflected greater land use mix. A z-score was calculated for normalization purposes.

Population Density

Census block 2010 data was disaggregated into individual property parcel using property appraiser and census group quarter data (Strode et al 2018). This type of population estimate is considered more precise than aerial interpolation measures. Population estimates were then aggregated to the 1-km grid cells. A z-score was calculated for normalization purposes.

Destinations

NAVTEQ data includes data on potential destinations. We did not include any data involving automobile services as this included weigh stations and car dealerships which were not considered potential walking destinations. From the community service dataset, we removed police and sheriff departments and foreign consulates. We included all categories of financial institutions, entertainment, education, shopping, and restaurants. Destination counts were added to grid cells. A z-score was calculated for normalization purposes.

Exploratory measures showed that a large national chain store chosen at random contained five destinations: an ATM, bank, grocery store, clothing store, and a pharmacy. We concluded it best to leave this unedited (leave the destination count for that store as five) as these are potential walking destinations.

Parks and Trails

Data was obtained from the GeoPlan Center, Department of Urban & Regional Planning, of the University of Florida. Park data was minimally verified to ensure that parks were actually walkable and one deemed unwalkable was removed—a marsh in Palm Beach County was removed as it did not appear walkable according to satellite imagery. Myakka State Park was not included originally and was added. Trails not categorized as “hiking” or “multi-use” were removed, consequently removing paddling trails, all-terrain vehicle (ATV) paths, etc. Trails data was given a 2-meter buffer and merged with park data and subsequently dissolved so as not to double-count trails contained within parks. Percentage of land area with parks/trails was calculated and added to the grid cells. A z-score was calculated for normalization purposes.

Final Walkability Index

Cells with zero data values for all four data types were deleted from the overall grid so as not to introduce bias caused by large areas of land with no walkability features. The z-scores of the four data types were summed to create the final index. A 5-class Jenks Natural Breaks classification method divided the data into 5 categories.

DATA AND VISUALIZATIONS

Figures 1, 2, and 3 show maps with raw data for each of the four data inputs listed in Table 4. The maps show Pensacola, Florida. Visualizing the data points is a preliminary view of the data quality and can reveal data patterns.

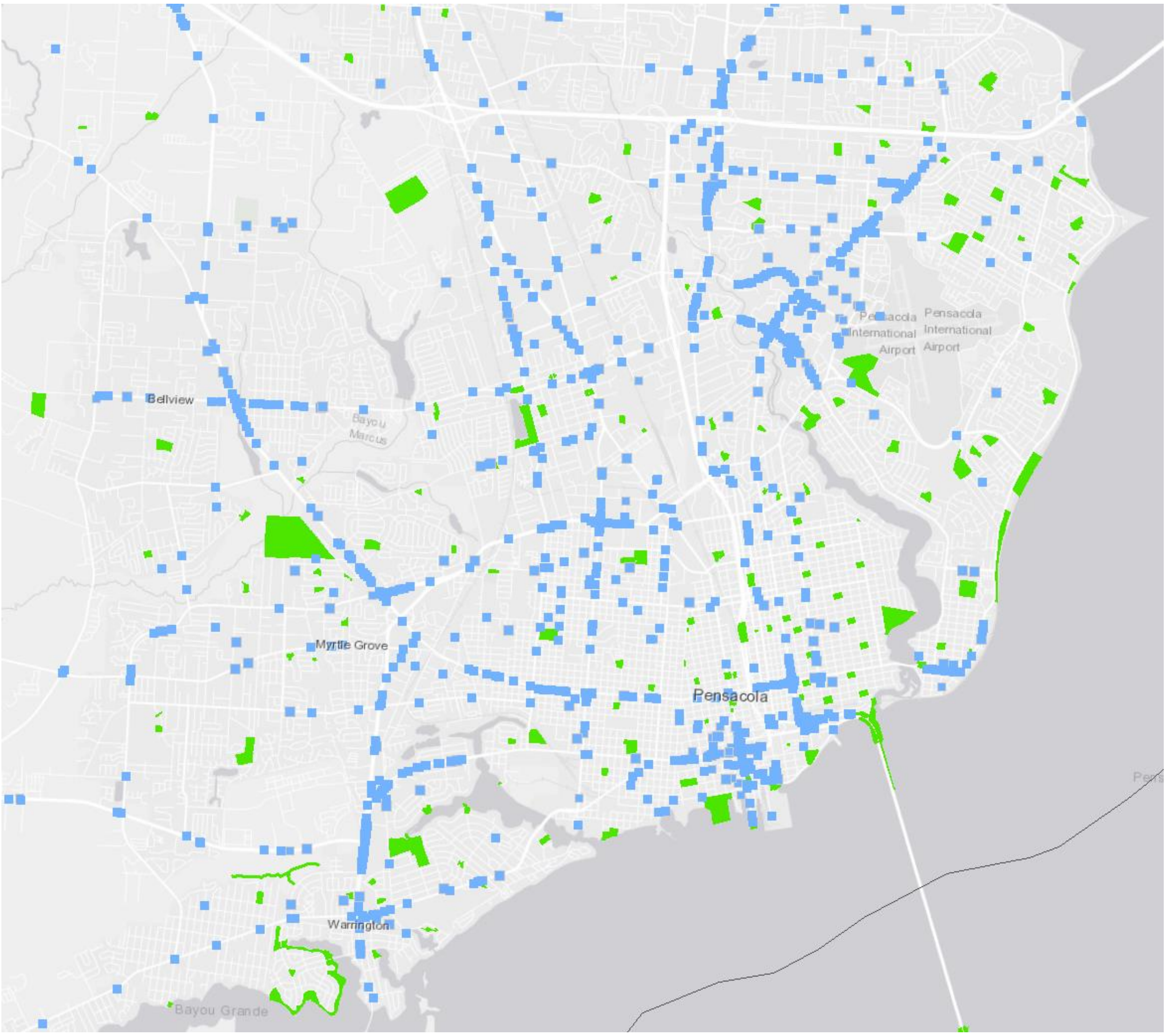

Figure 1. Parks and Trails (green) and Destinations (blue) in Pensacola.

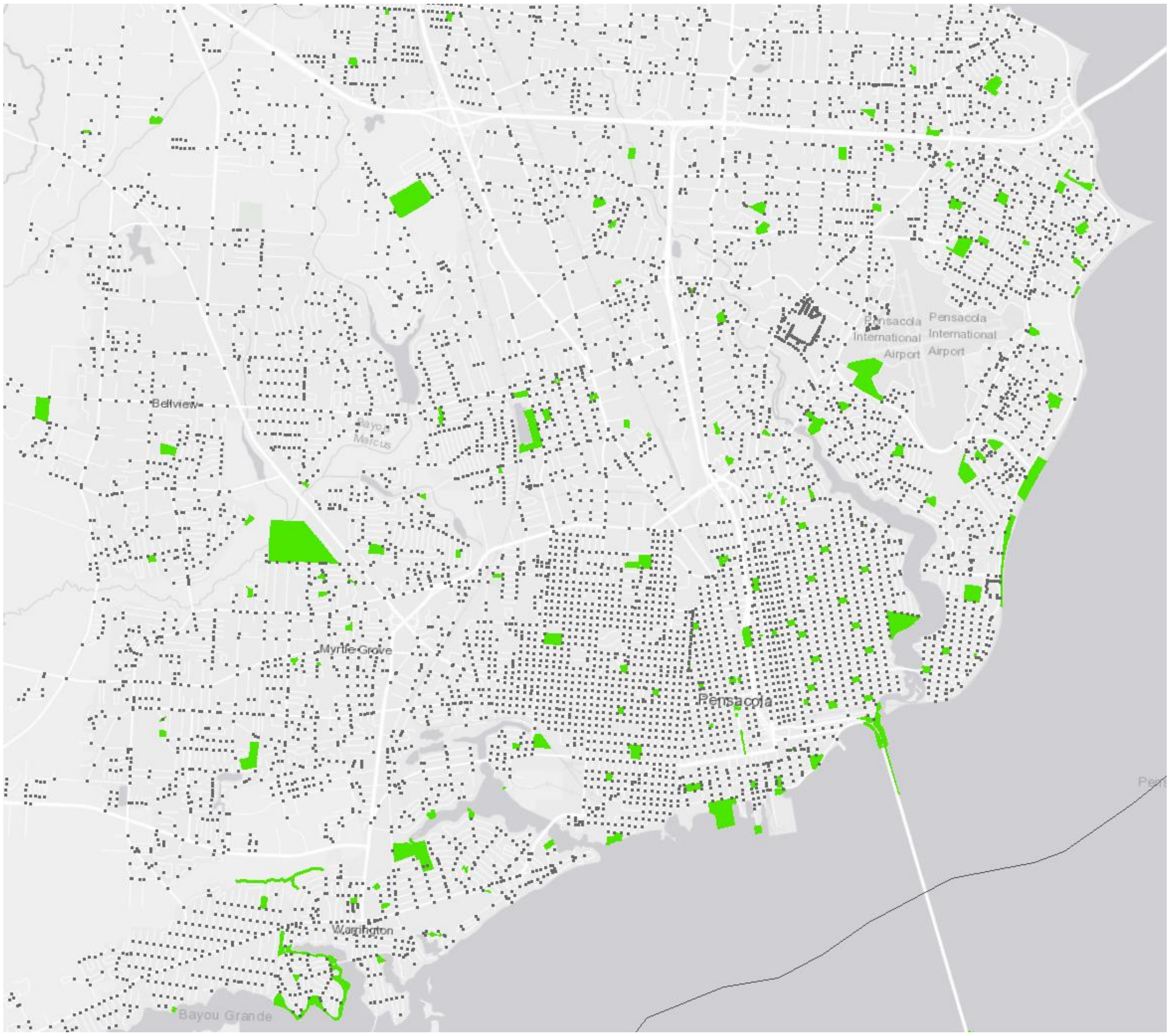

Figure 2. Parks and Trails (green) and Road Intersections (gray) in Pensacola.

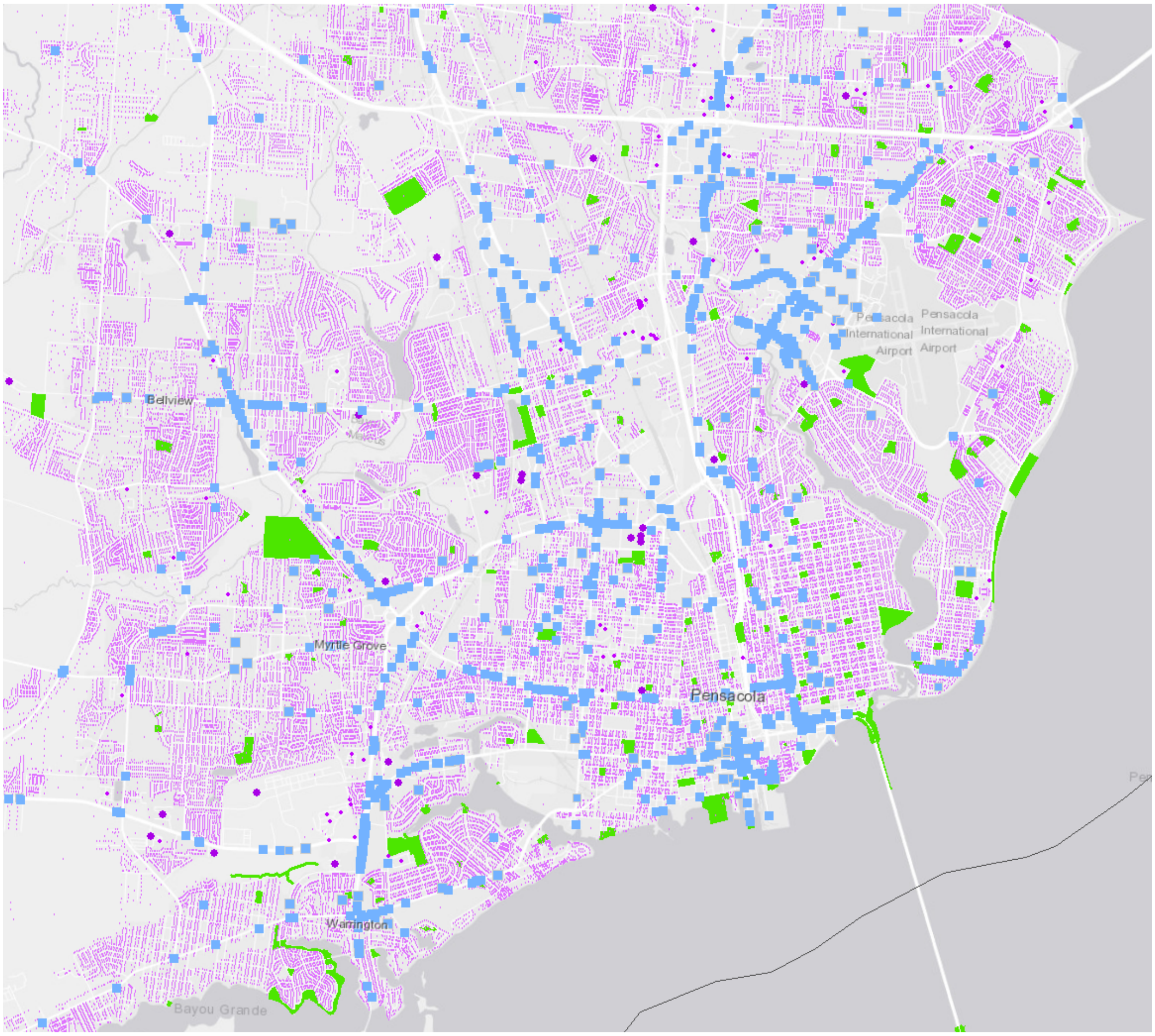

Figure 3. Population per land parcel (purple gradients), Destinations (blue), and Parks and Trails (green) in Pensacola.

The data are gridded to the USNG 1-km grid cells. Figure 4 shows maps with the z-scores for data selected in Table 4. Full-page maps of the grids are available in Appendix A.

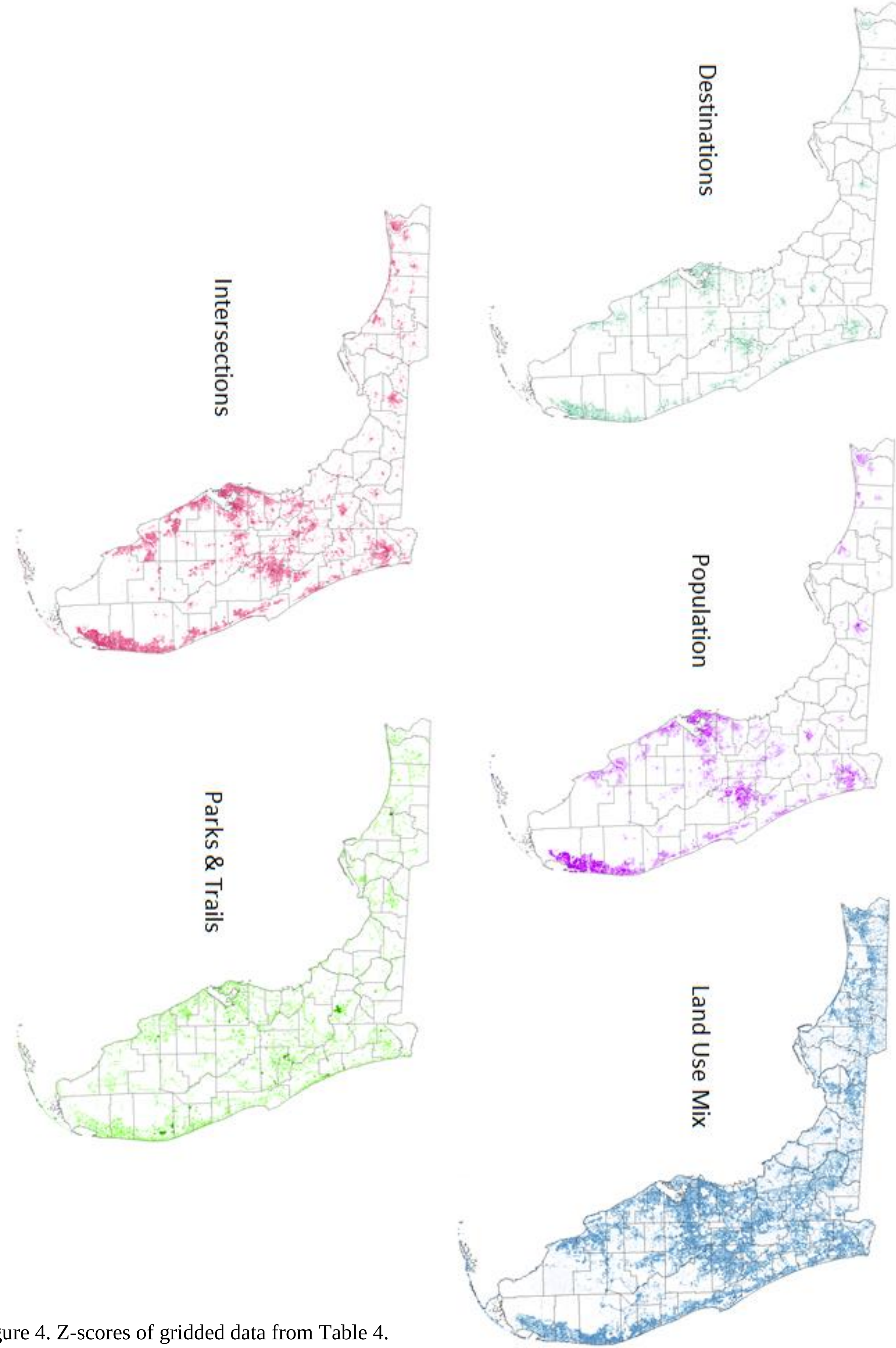

Figure 4. Z-scores of gridded data from Table 4.

Developing the Formula

Given the available five statewide datasets, we began by reproducing several of the current formulae in Florida at the 1-km scale using Leon and Gadsden counties as the initial testing areas. We considered weighting data inputs so that heavily weighted data will have more influence over the other data inputs. The 13 resulting maps are in Appendix B.

The first formula was a version of Frank (2010) that included intersection density weighted by 2, land use mix, population density, destination density. The resulting map is shown in Figure 5. We included park/trail density to include walking for the purpose of recreation or medical outcome. Figure 6 shows the results of this formula. The inclusion of the park/trail density revealed several popular parks.

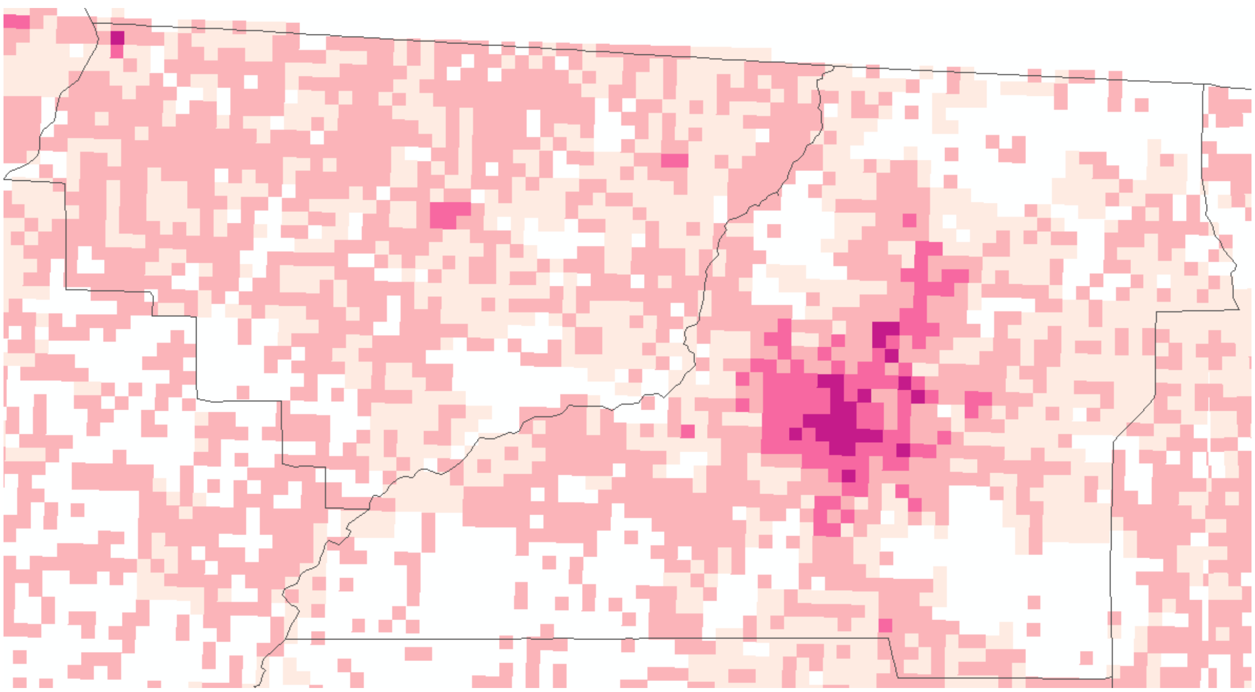

Figure 5. Inputs: Intersection density *2, Population density, Land use mix, Destination density.

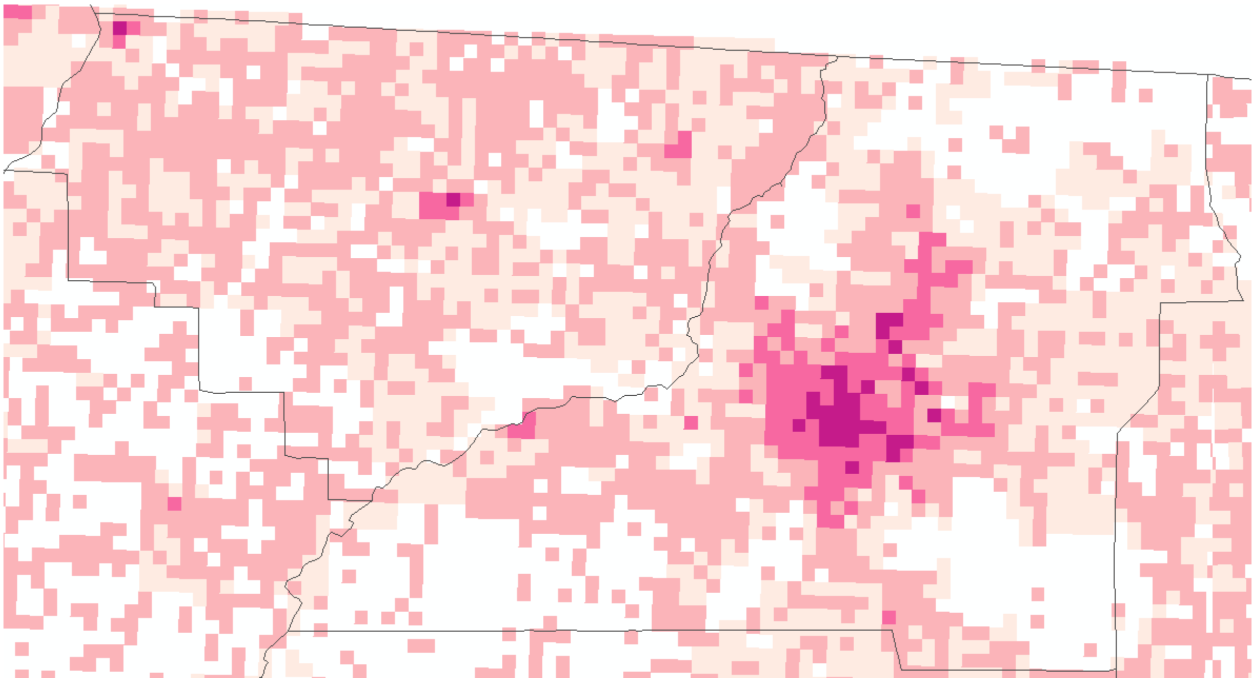

Figure 6. Inputs: Intersection density * 2, Population density, Land Use mix, Destination density, Park/Trail density.

We made several more tests and concluded that the land use mix was causing excessive "noise" in the map. This could be caused by the 1-km grid cell scale which could be amplifying the results. In rural areas, it could be possible to have agriculture and residential in the same location, and this could be considered high land use mix even though it would not be ideal for walking. Further research and thought into the purpose of including land use mix is that areas with high mix often have many people and many destinations present. We concluded that, while we recognize the value of a good mix, that there could be land use types that are more favorable to walking (e.g. residential, commercial) and other land uses that could be less favorable (e.g. agriculture, industrial). We concluded that land use mix could be a redundant input if the formula already includes population and destination densities.

The final formula for this research is:

$$\textit{Walkability Index} = z\text{-}IntersectionDensity + z\text{-}PopulationDensity + z\text{-}DestinationDensity + z\text{-}ParksAndTrailDensity$$

Results

Figure 7 shows a final statewide map and Appendix C contains maps of regional areas. The formula captures four important features that represent road transportation, residential areas, commercial areas, and nature. We hope that this formula reflects the environmental features related to both transportation and recreation.

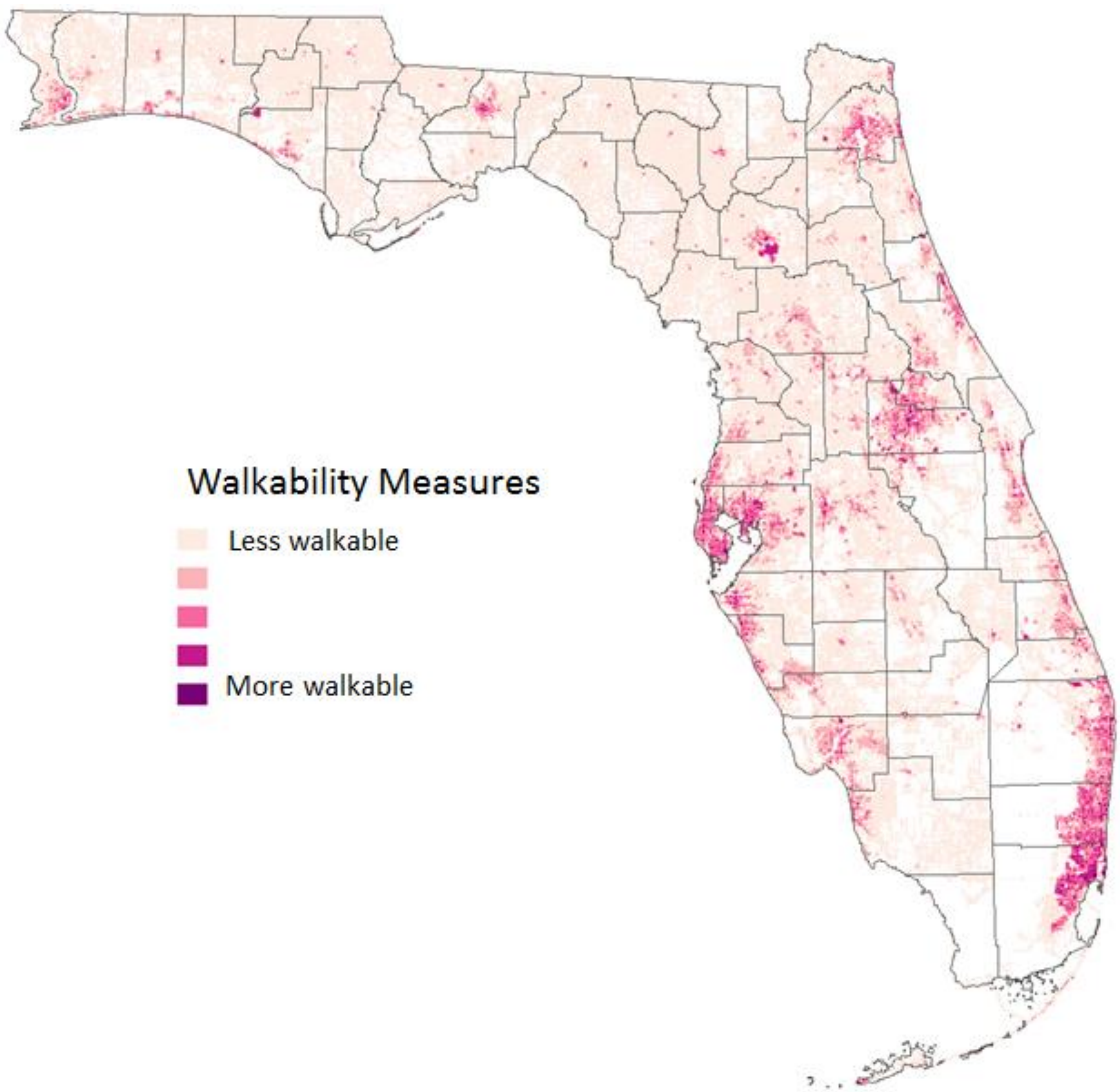

Figure 7. Statewide results reflecting quantities of features associated with walkability.

Case Study: Sidewalk Data for Leon County, Florida

Sidewalks and crime rates were originally considered as inputs to the formula even though not available at the state level, but could be available at localized scales such as city or county. Because these data are still considered important, this case study compares sidewalk data for Leon County to explore the value of sidewalk data.

Sidewalks are consistently cited as an important factor in walkability (Lo 2009, Krambeck 2006, Carr et al 2010). A pedestrian Level of Service (LOS) study by the Florida Department of Transportation concluded that if a sidewalk is present, the service score has a base minimum of a D (on a scale of A to F with A being the best score), and conversely areas without sidewalks can achieve no higher than a D (Petritsch & Scorsone 2014). However, a major component in walkability measures is road compactness and interconnected environments. Compact environments are more likely to have sidewalks, and through systematic co-variance, the presence of sidewalk may to some extent be captured by proxy (Leslie et al 2007).

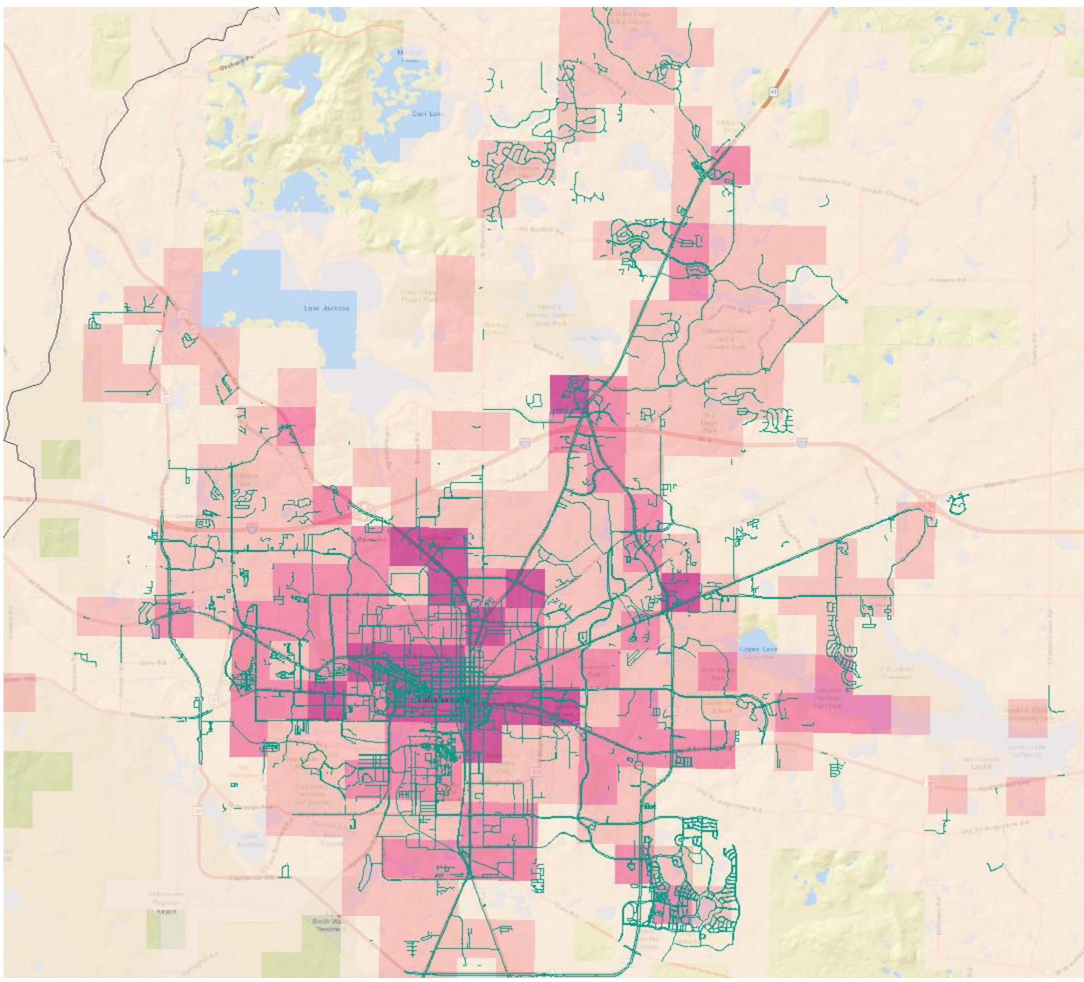

Figure 8. Sidewalk data (shown in green) over walkability results.

Figure 8 shows the sidewalk data for Leon County and the walkability results. Empirical observation shows that in many cases sidewalks could be considered redundant, as areas with many sidewalks also have high walkability. However, there are areas with sidewalks that are not scored as highly walkable. More research is needed on the importance of sidewalk data and its role in the pedestrian experience.

CONCLUSION

Walkable cities in the United States are difficult to achieve as more than half the typical metropolises have been built according to standards suitable for the automobile. It is difficult to retrofit built-up areas as patterns and habits are already established. However, with imagination and persistence, it is possible to modify networks to suit pedestrians and to insert mixed uses into low density areas. The modification process includes: assessing current walkability conditions; revising standards and regulations to support walking and mixed use zones; conducting research on walking behavior among a variety of social groups; learning from the experiences of European cities that have increased walkability over centuries; organizing educational activities (e.g. experimental city walks, pedestrian safety advertising campaigns); and focusing on the premise that pedestrian access is a necessary and integral part of the transportation process (Southworth 2005).

The findings of this research address the first step in the aforementioned modification process—assessing current walkability conditions of the built environment. The final map accurately identifies geographic areas with sufficiently high measures of quantifiable data inputs commonly used for walkability studies. These metrics serve as a statewide baseline of quantifiable GIS data that are commonly used across walkability studies that hopefully addresses the needs of pedestrians walking for transport as well as recreation. The metrics calculated in this project can be explained to the user through multiple visualizations so that the reasoning behind the final metric can be easily determined. It is hoped that the results of study can serve as a starting point for local planners to incorporate environmental interventions to improve walkability.

FUTURE WORK

This study assesses features associated with high walkability as a first step toward understanding a modification plan aimed at improving pedestrian transportation. This project measured quantifiable GIS data available at the state level. There is opportunity for further assessment in the following areas:

- Include local GIS data – GIS data available at city or county scales could be valuable in assessing the pedestrian experience. Local GIS data can be added to the statewide map (as its own separate layer) to provide a more detailed and perhaps user-friendly perspective of the environment as shown in the case study involving sidewalk data.
- Compare with other methods -- The results of this study have not been compared to other formulae to assess differences and their explanations.
- Include opinions from locals -- These results have not been field tested by pedestrians. Walkability assessments by local walkers should be incorporated into research where possible. Questionnaire results can be converted to a GIS format and included in the statewide map as its own GIS layer.
- Experiment with data weighting -- This formula gives all data inputs equal weighting. There is research supporting the idea of weighting these inputs according to the specific research needs. For example, if there is a focus on walking as exercise in a particular area, a researcher might choose to weight the park/trails input layer more heavily if there is knowledge that parks are influential in the decision of people to walk for exercise.
- Aggregate metrics to different scale – If it is necessary to have a walkability measure for a larger area such as zip code or census tract, grid cell values can be averaged over the geographic area to provide a unified metric for a larger named area. Users of this aggregated data should be aware that variations within the area will have been masked. This step would only be recommended for comparison between consistent geographic areas.
- Refine the parks and trails data – These datasets contain features defined as parks and trails and do not necessarily differentiate whether the areas are walkable. Visual inspection using aerial photography could be useful to winnow out features that could be considered less walkable.
- Experiment with bivariate/multivariate mapping – Bivariate maps show two phenomena simultaneously and multivariate maps can show two or more. While multivariate mapping can be complex, gridded maps are well-suited for this type of visualization due to the uniform size and shape of cells. A variety of symbologies can convey multiple data values effectively.

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APPENDIX A – VISUALIZATIONS OF STATEWIDE DATA INPUTS

The following full-page maps show the five inputs used in exploration for this project. Each dataset uses a 1-km grid cell and has a Z-score applied so that the disparate datasets can be comparably compared.

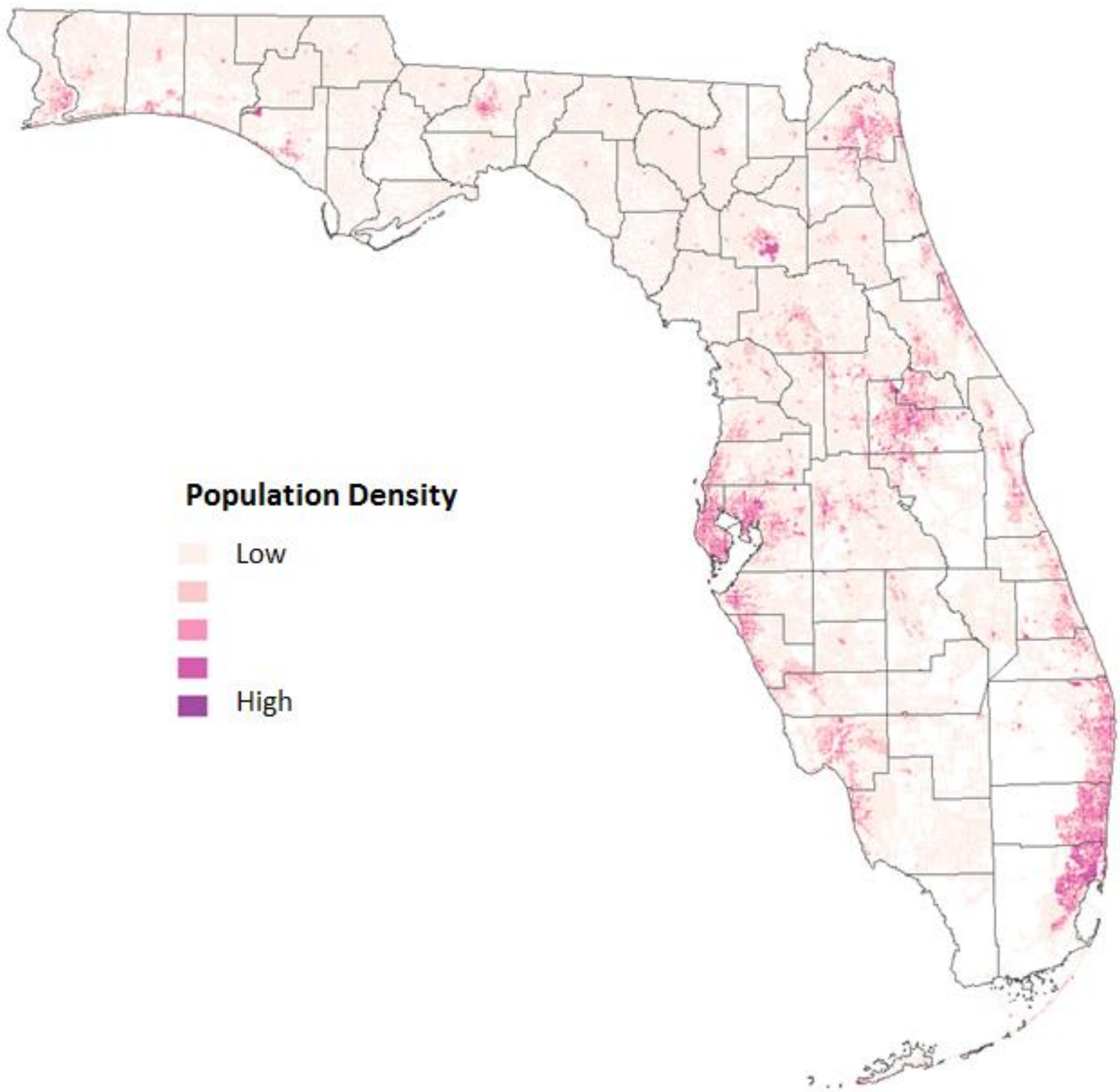

Figure A-1. Z-score of population density.

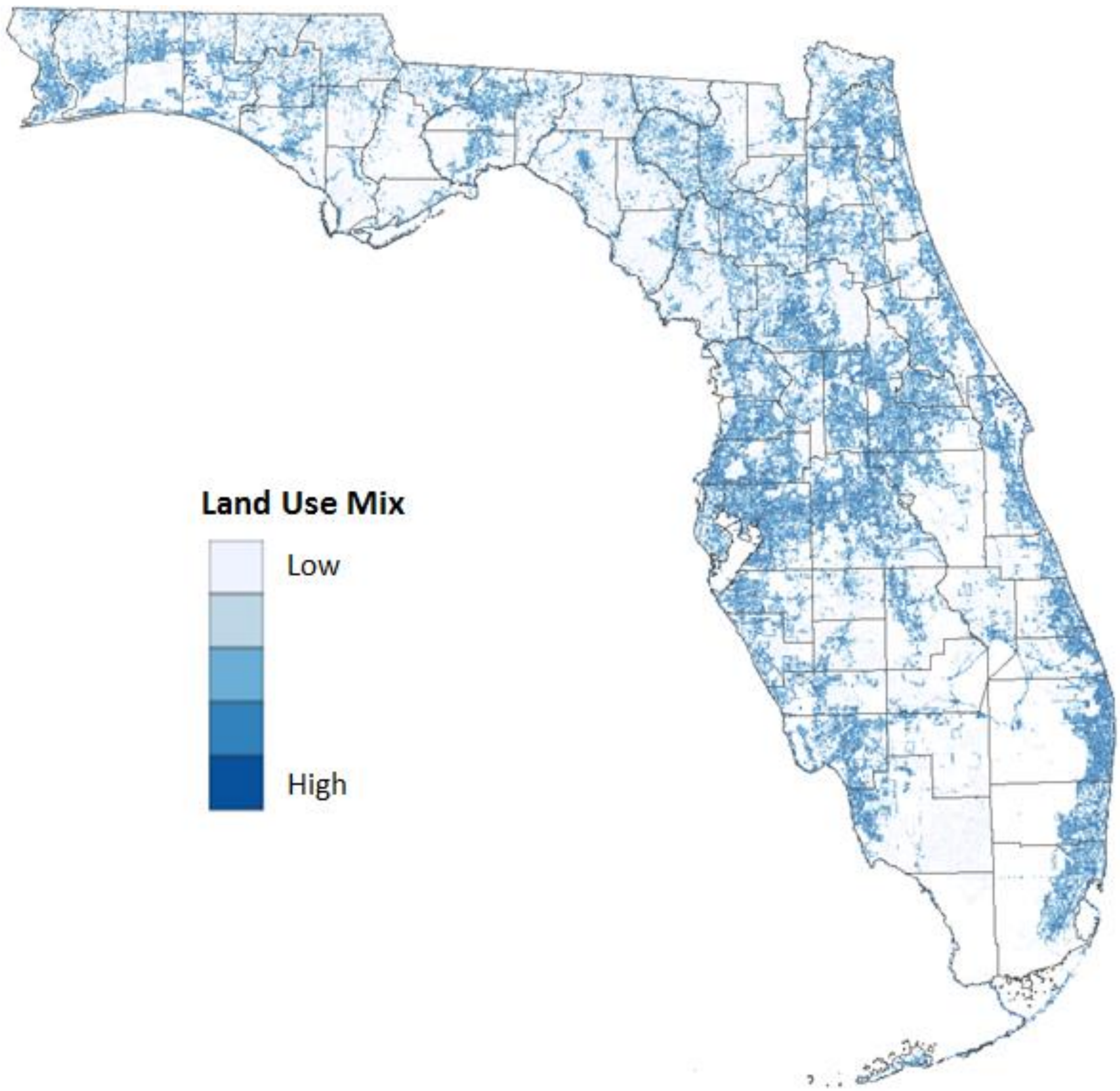

Figure A-2. Z-score of land use mix.

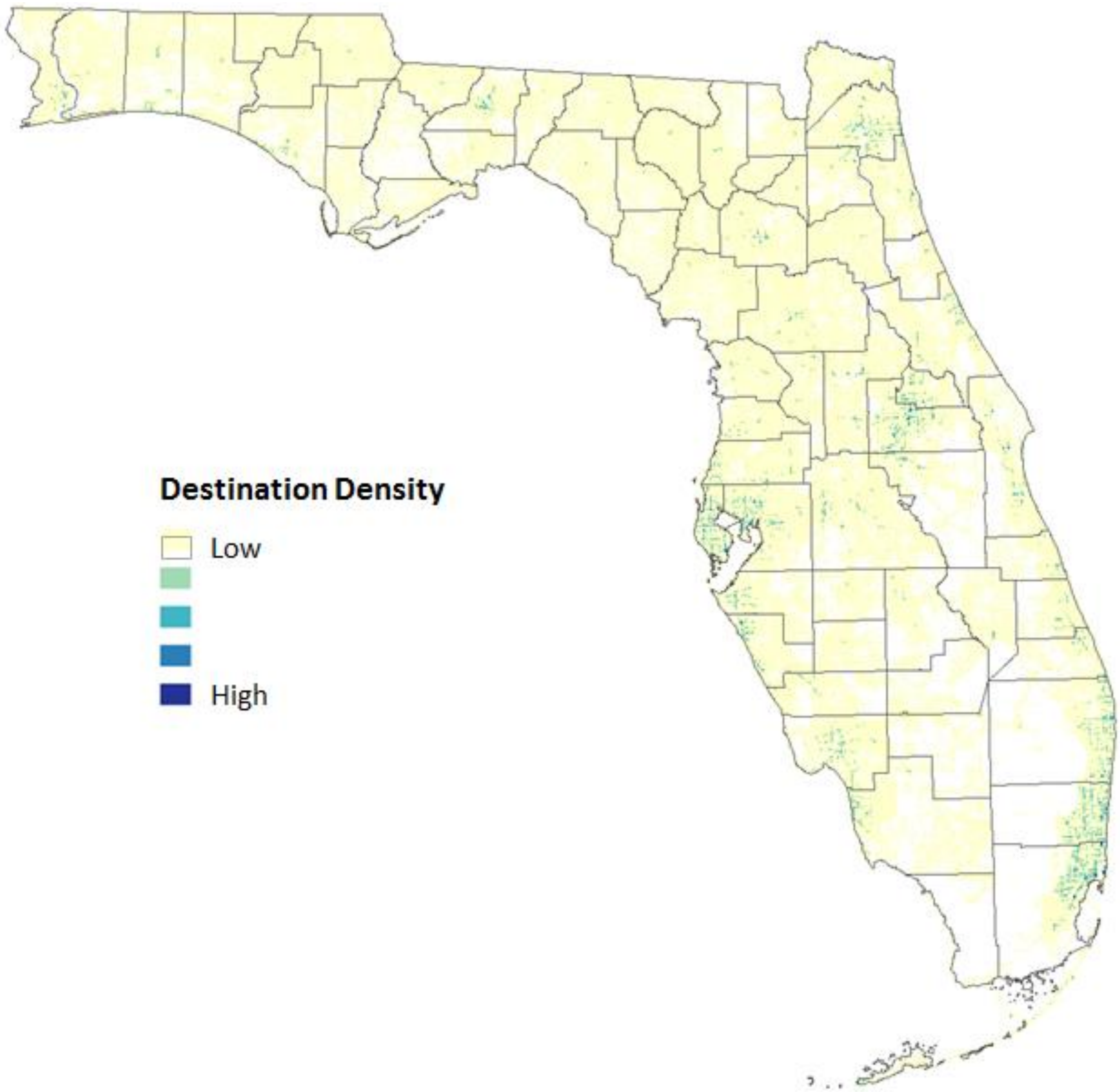

Figure A-3. Z-score of density of destinations.

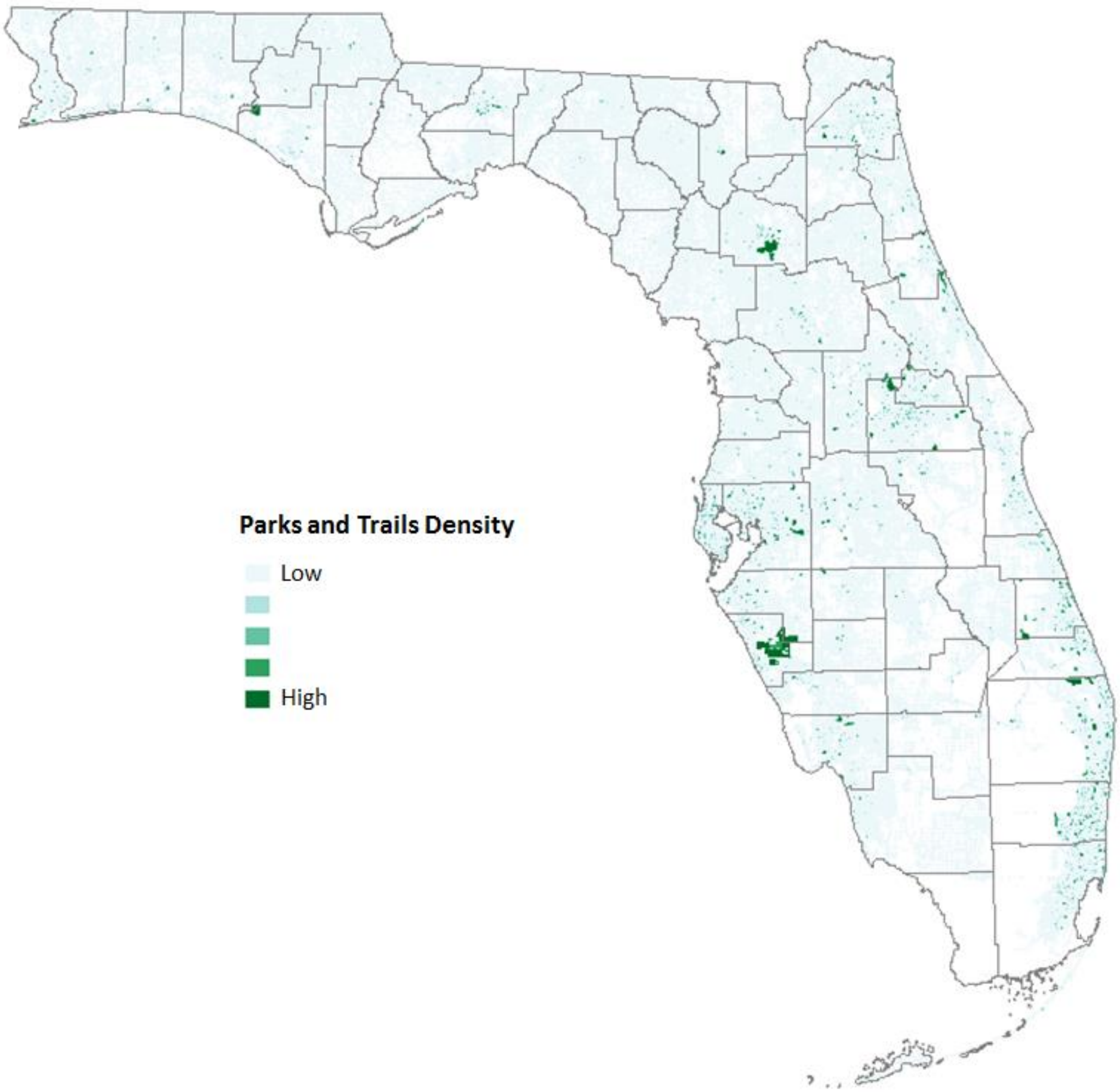

Figure A-4. Z-score of the percentage of land area containing parks or trails.

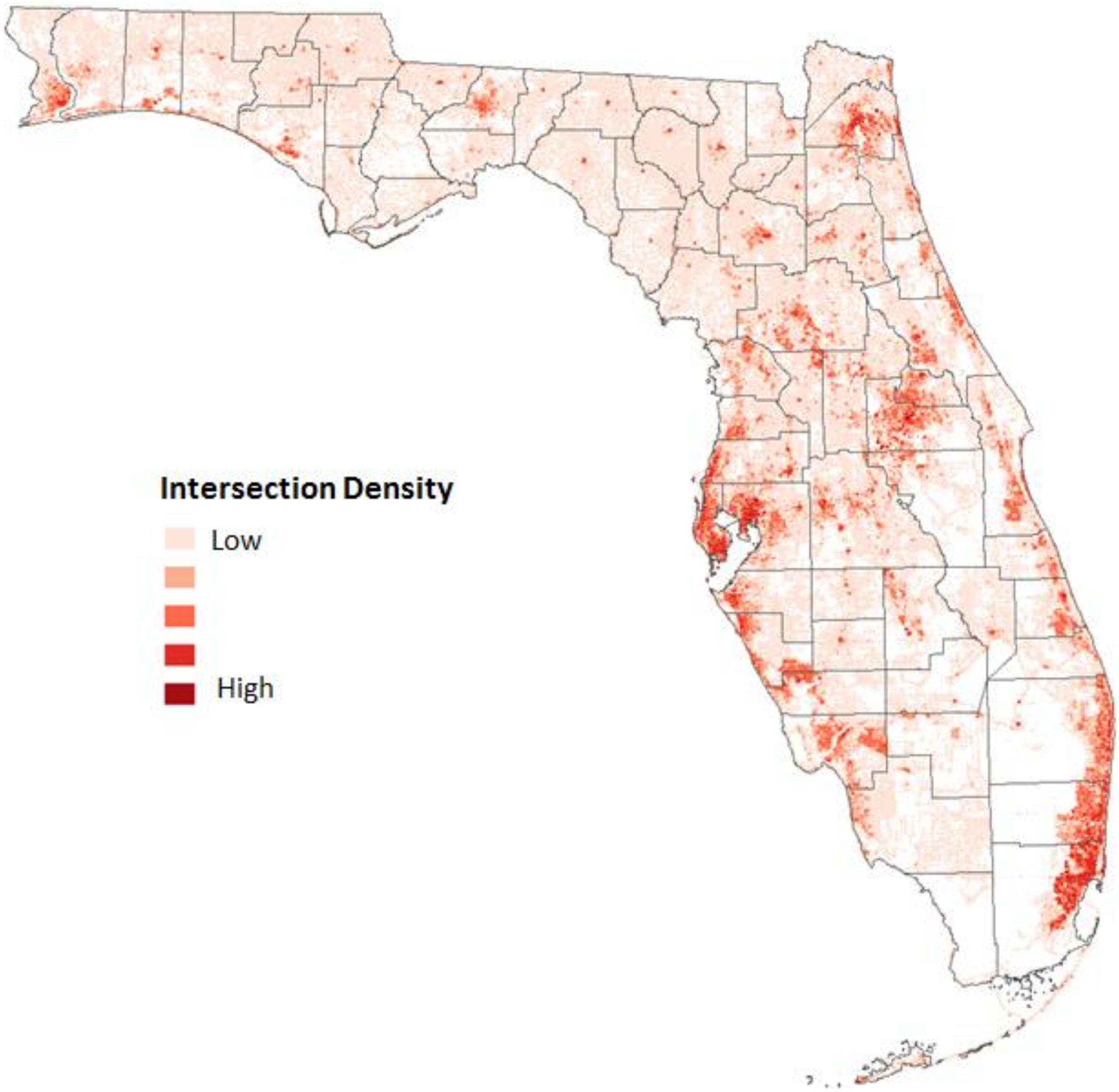

Figure A-5. Z-score of road intersection density.

APPENDIX B – EXPLORATION OF LEON AND GADSDEN COUNTIES WITH VARIOUS FORMULAE

The following 12 maps show exploration with various inputs and weighting techniques. Each formula and weighting combination focuses on different criteria and produces different outcomes. Each map uses a 5-class Jenks Natural Breaks classification method and the 5-class RdPu (red-to-purple) color scheme from ColorBrewer.org.

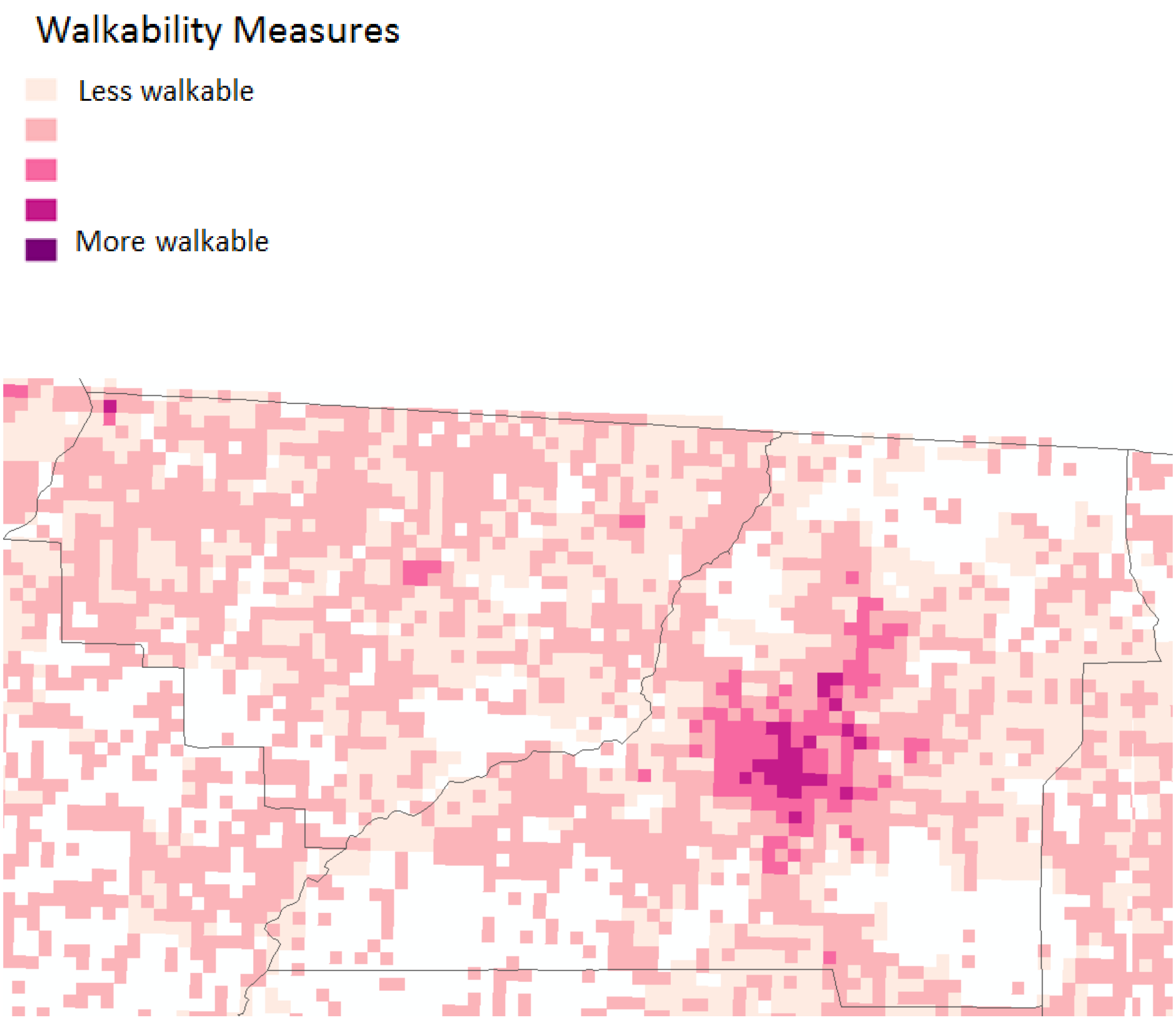

Figure B-1. Inputs: Intersection density * 2, Population density, Land Use mix, Destination density.

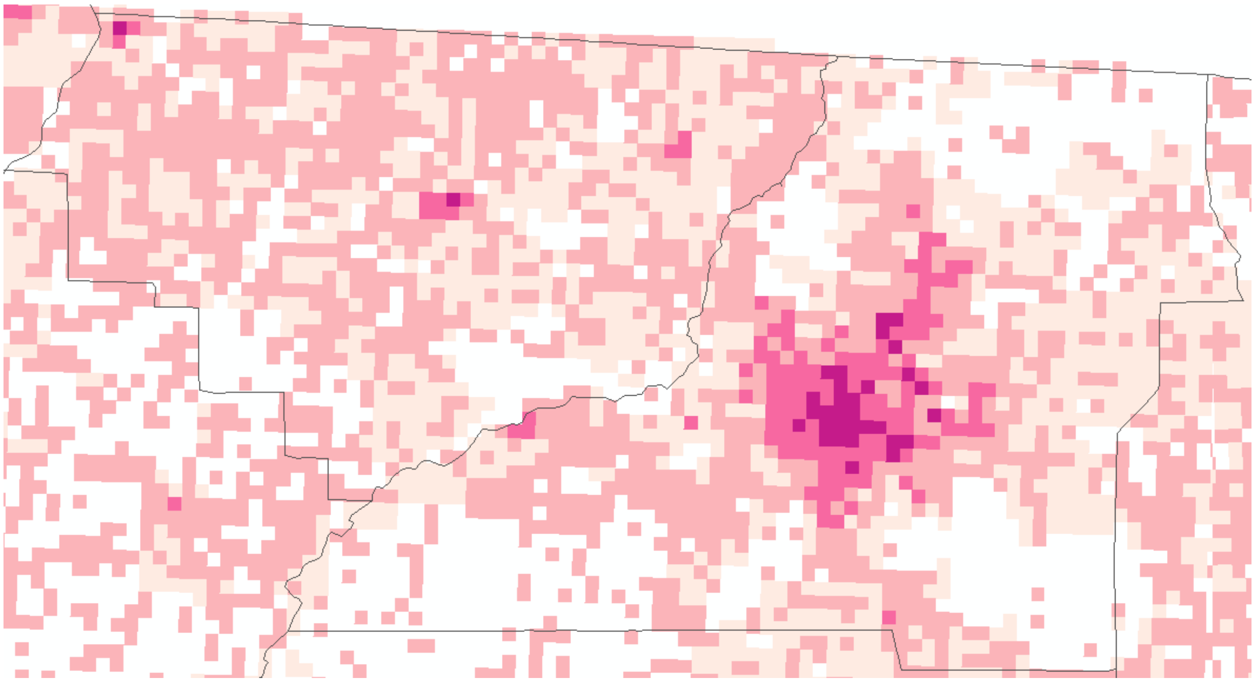

Figure B-2. Inputs: Intersection density * 2, Population density, Land Use mix, Destination density, Park/Trail density.

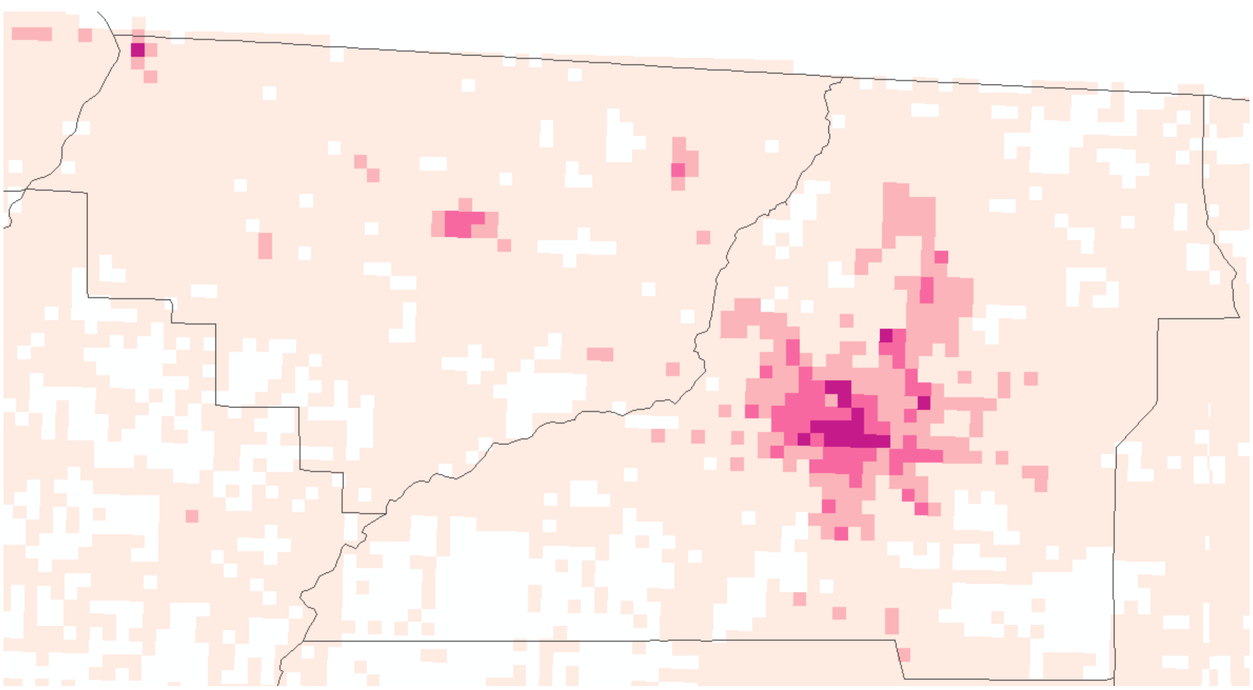

Figure B-3. Inputs: Intersection density * 2, Population density, Destination density.

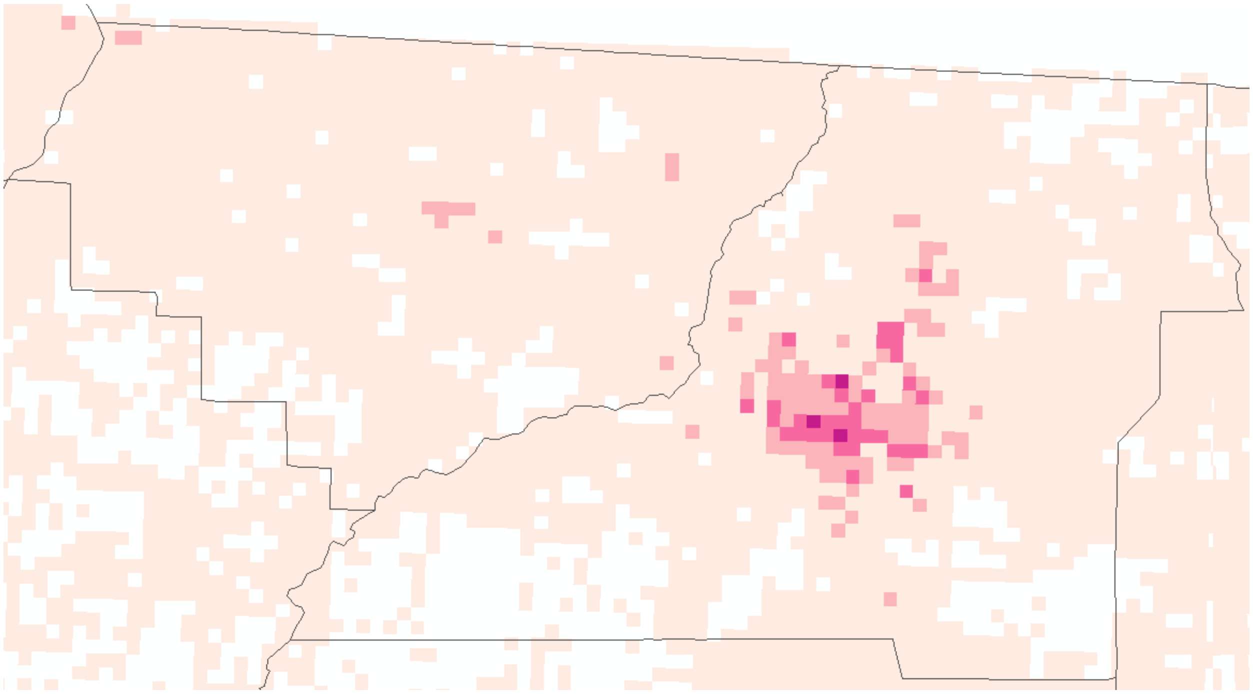

Figure B-4. Inputs: Population density, Destination density.

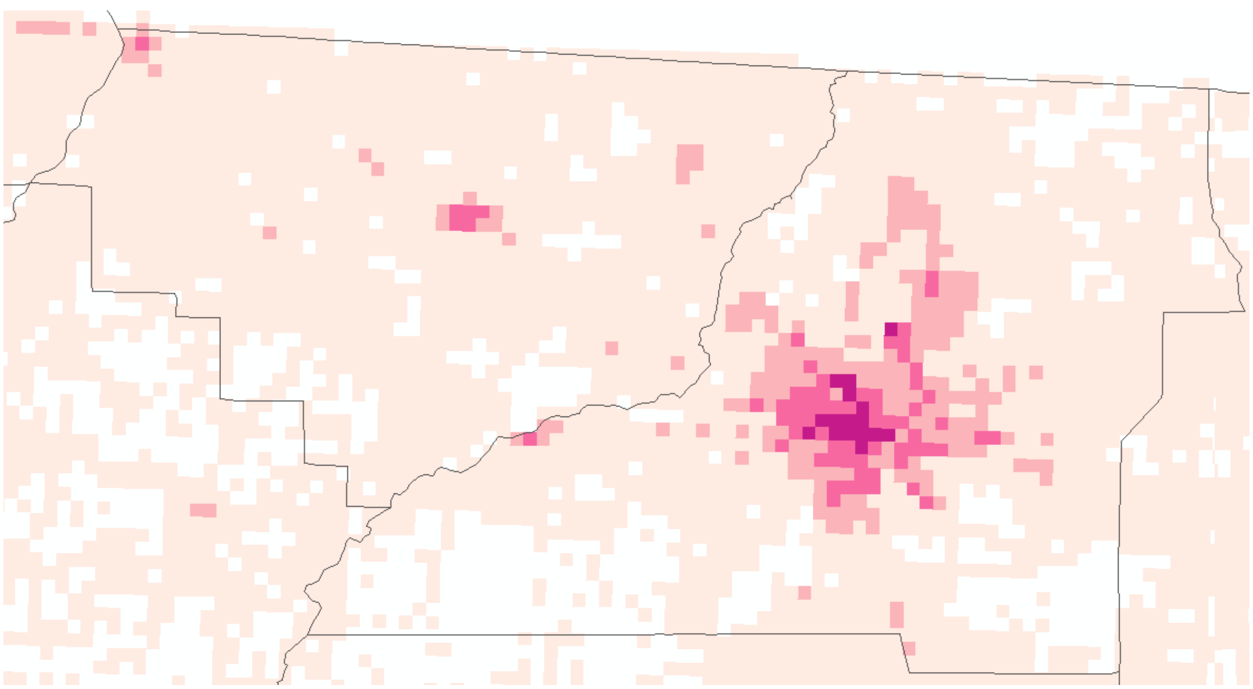

Figure B-5. Inputs: Intersection density * 2, Population density, Destination density, Park/Trail density.

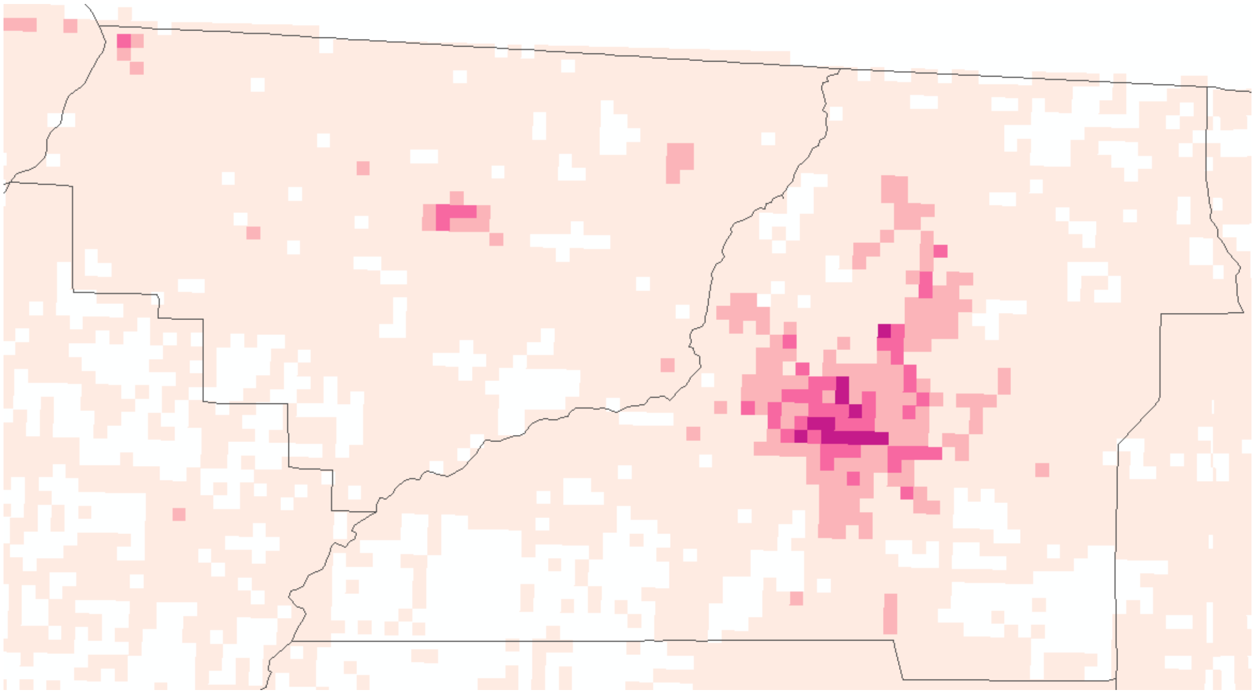

Figure B-6. Inputs: Intersection density, Population density, Destination density.

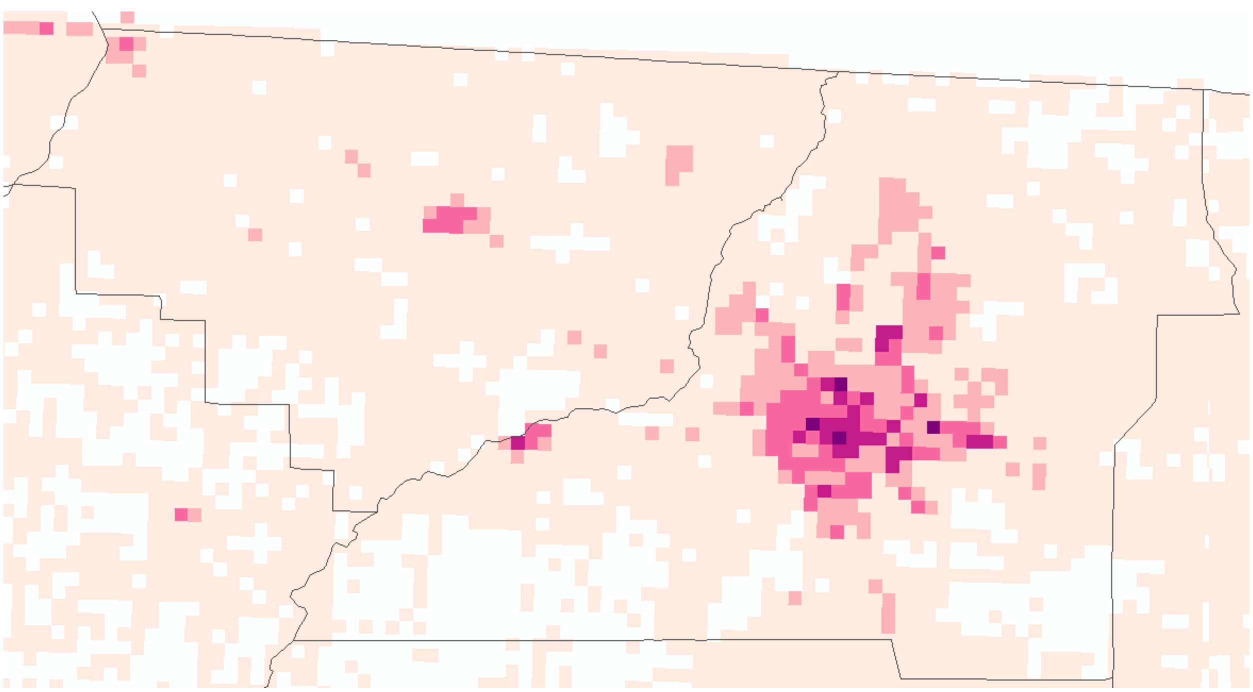

Figure B-7. Inputs: Intersection density, Population density, Destination density, Parks/Trails density * 2.

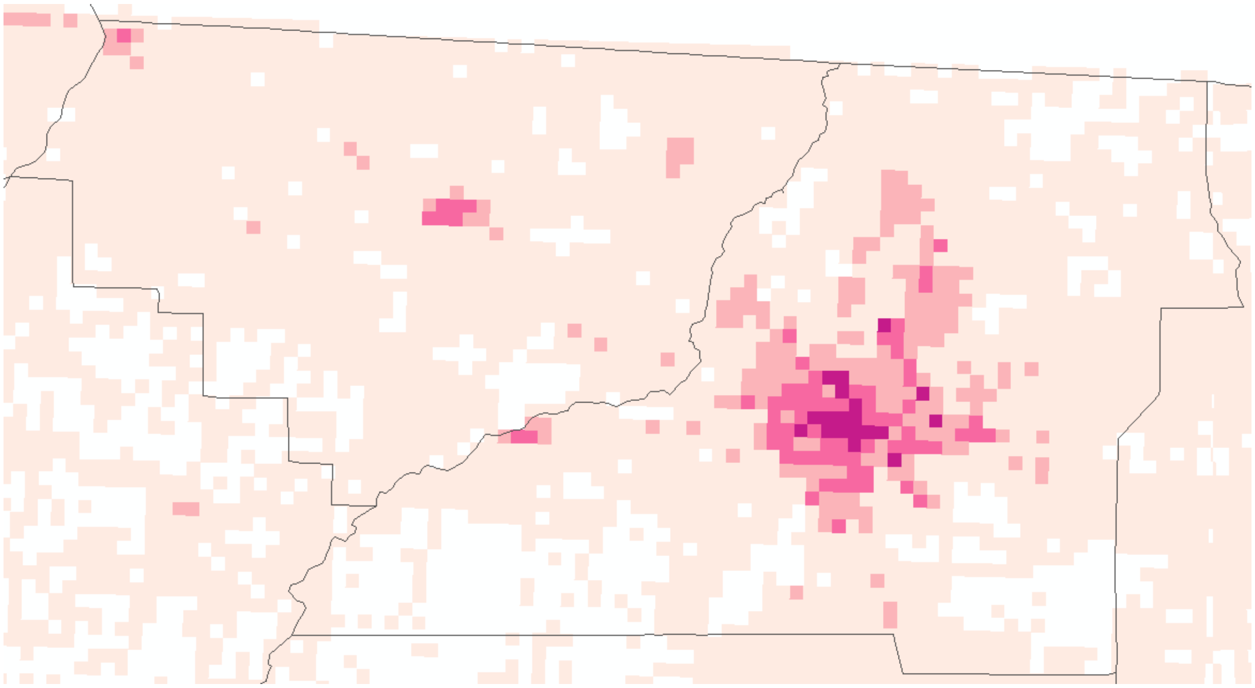

Figure B-8. Inputs: Intersection density * 1.5, Population density, Destination density, Parks/Trails density * 1.5.

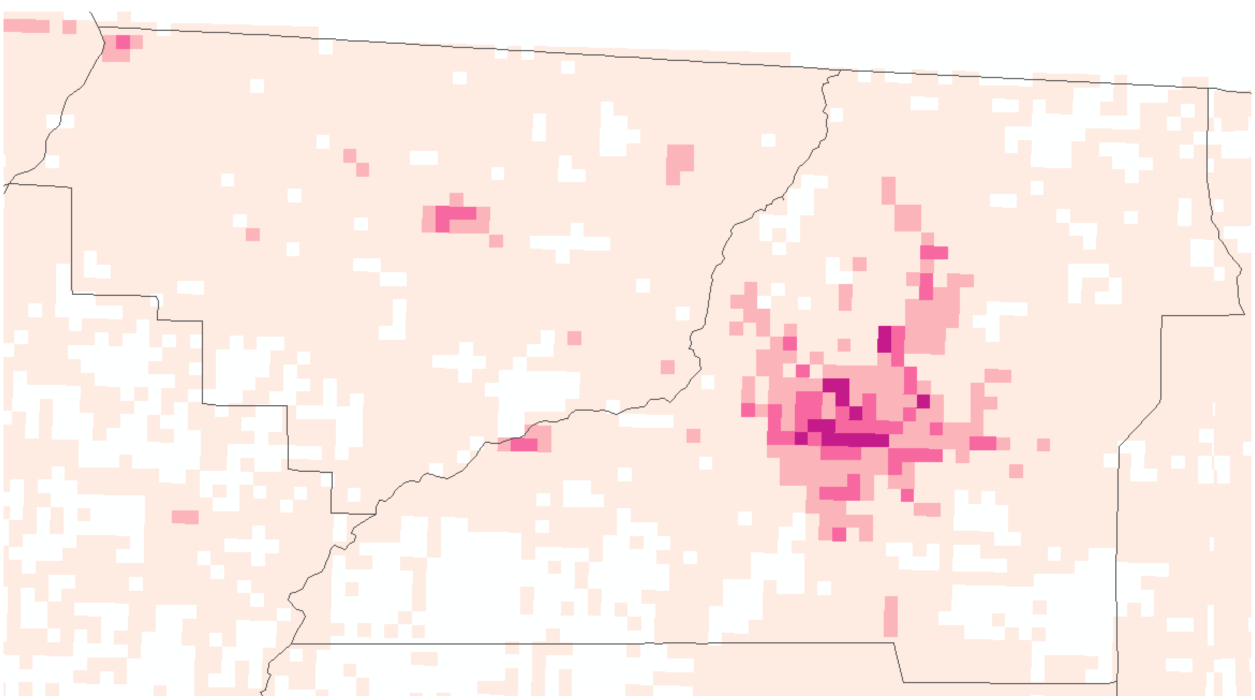

Figure B-9. Inputs: Intersection density, Population density, Destination density * 1.5, Parks/Trails density * 1.5.

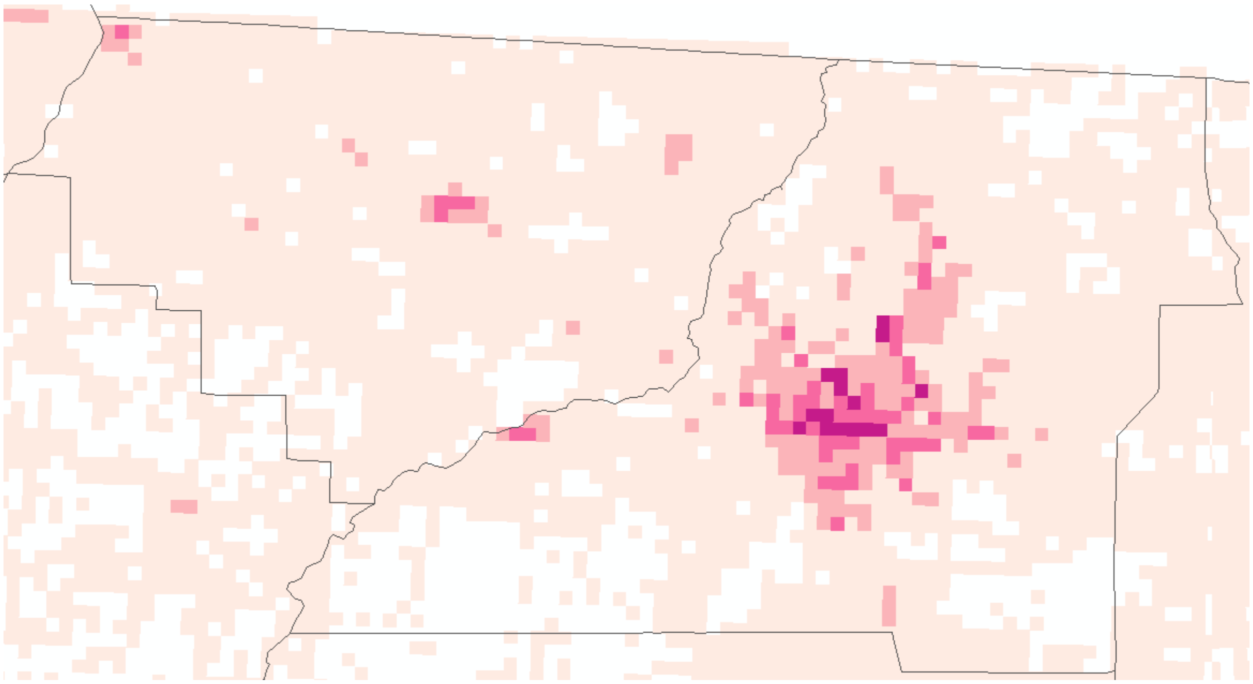

Figure B-10. Inputs: Intersection density, Population density * 0.5, Destination density, Parks/Trails density.

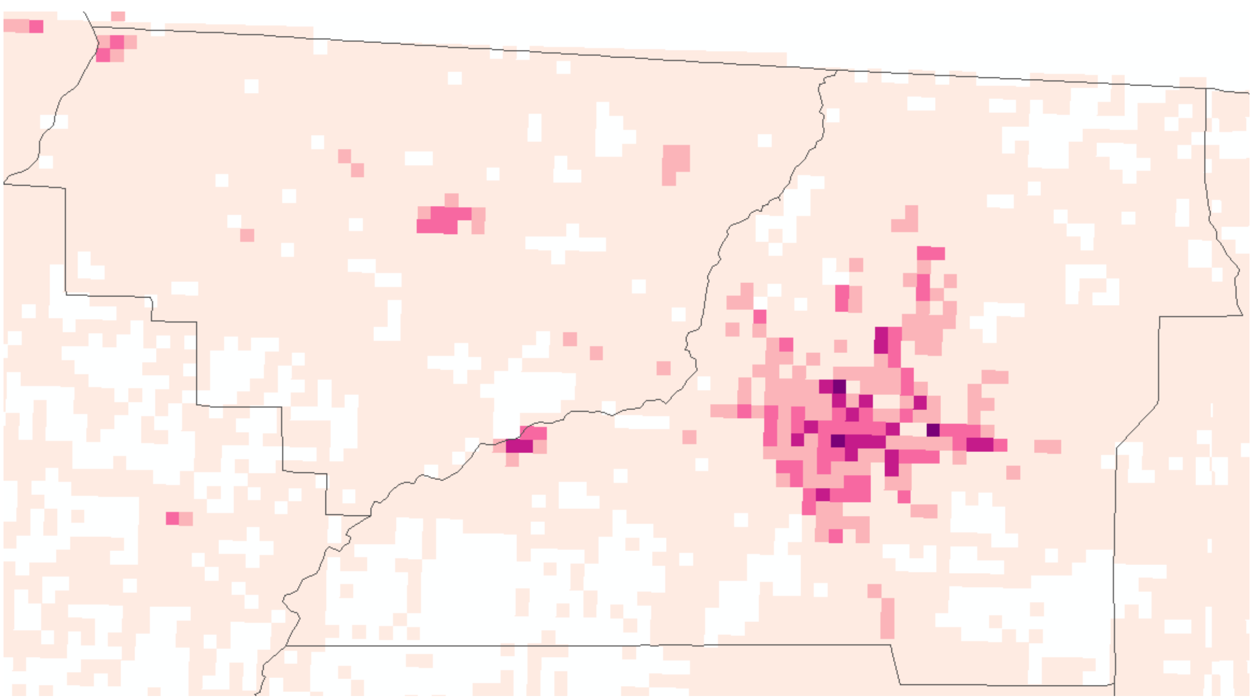

Figure B-11. Inputs: Intersection density, Destination density, Parks/Trails * 2.

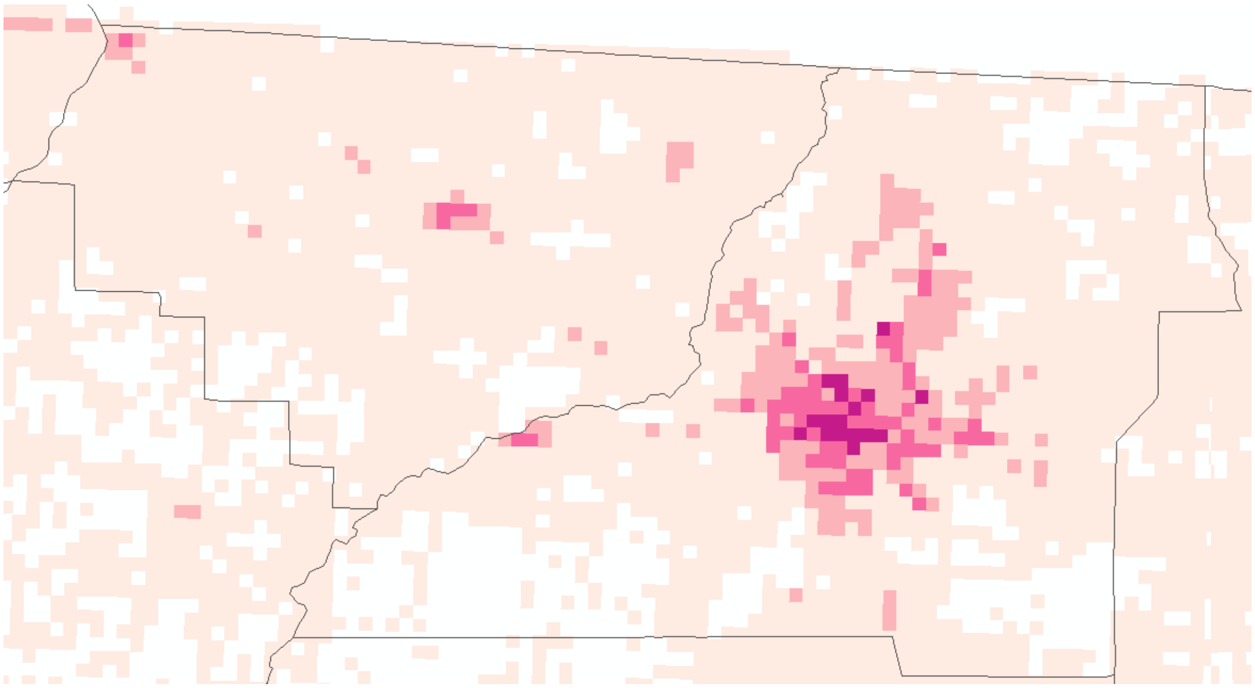

Figure B-12. Inputs: Intersection density, Population density, Destination density, Parks/Trails density.

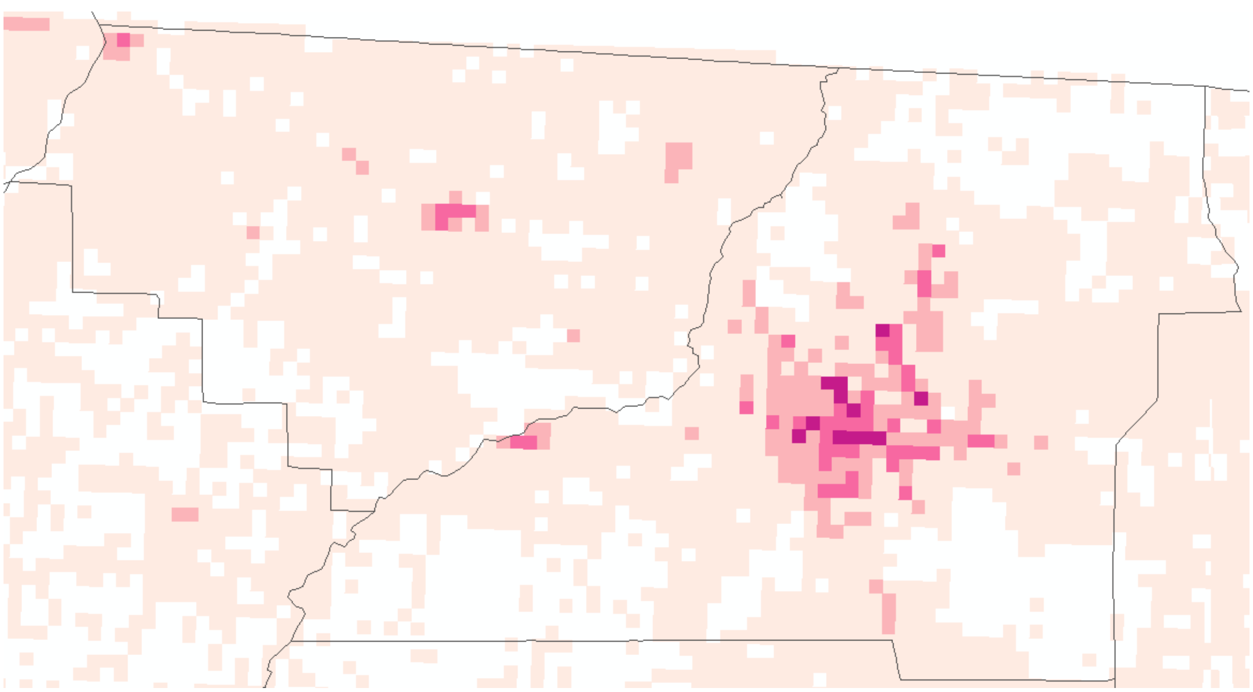

Figure B-13. Inputs: Intersection density, Destination density, Parks/Trails density.

APPENDIX C – FINAL RESULTS OF VARIOUS GEOGRAPHIC AREAS

The maps below are shown with 30% transparency to allow visibility of the underlying basemap. Each map uses a 5-class Jenks Natural Breaks classification method and the 5-class RdPu (red-to-purple) color scheme from ColorBrewer.org.

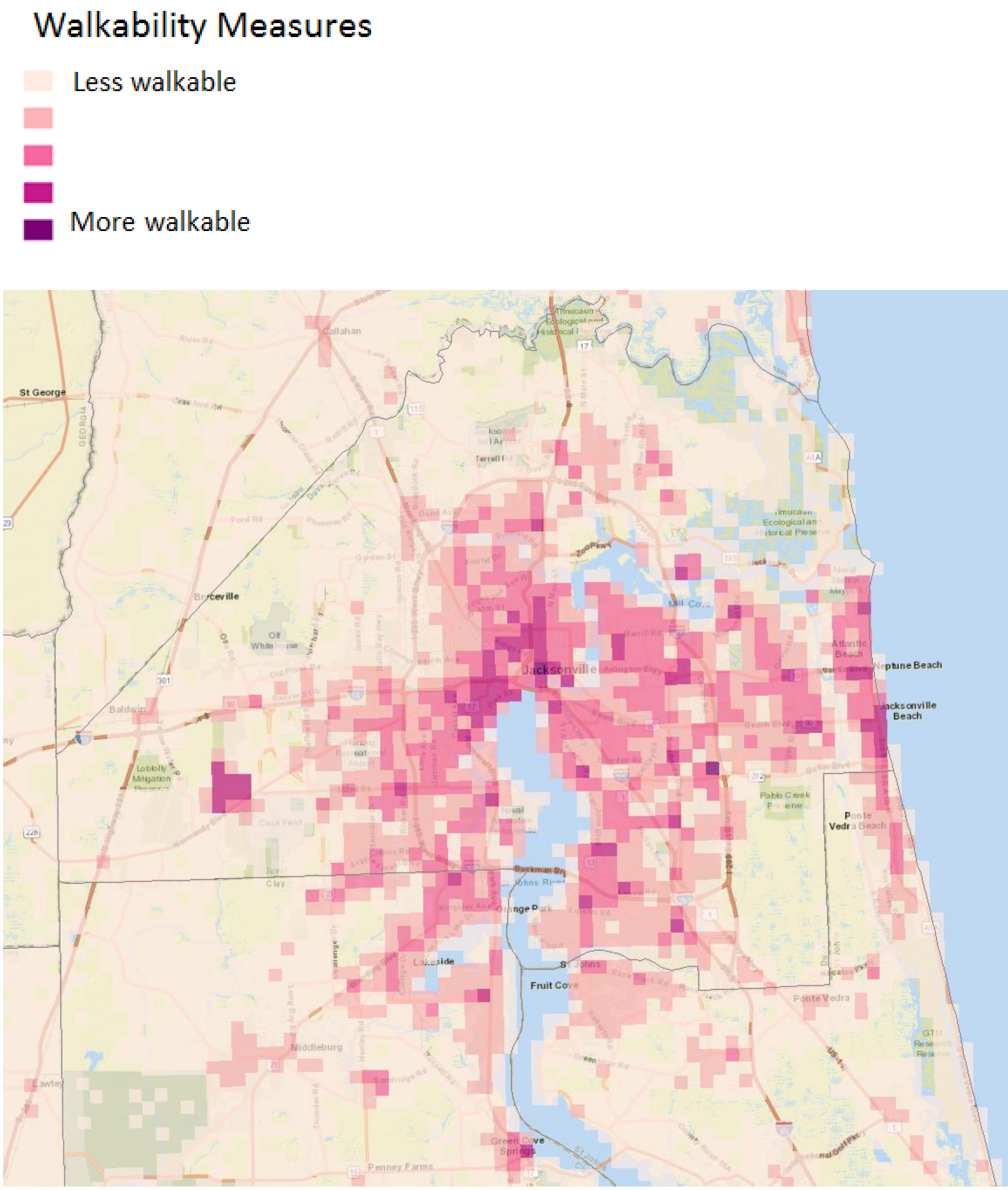

Figure C-1. Duval County.

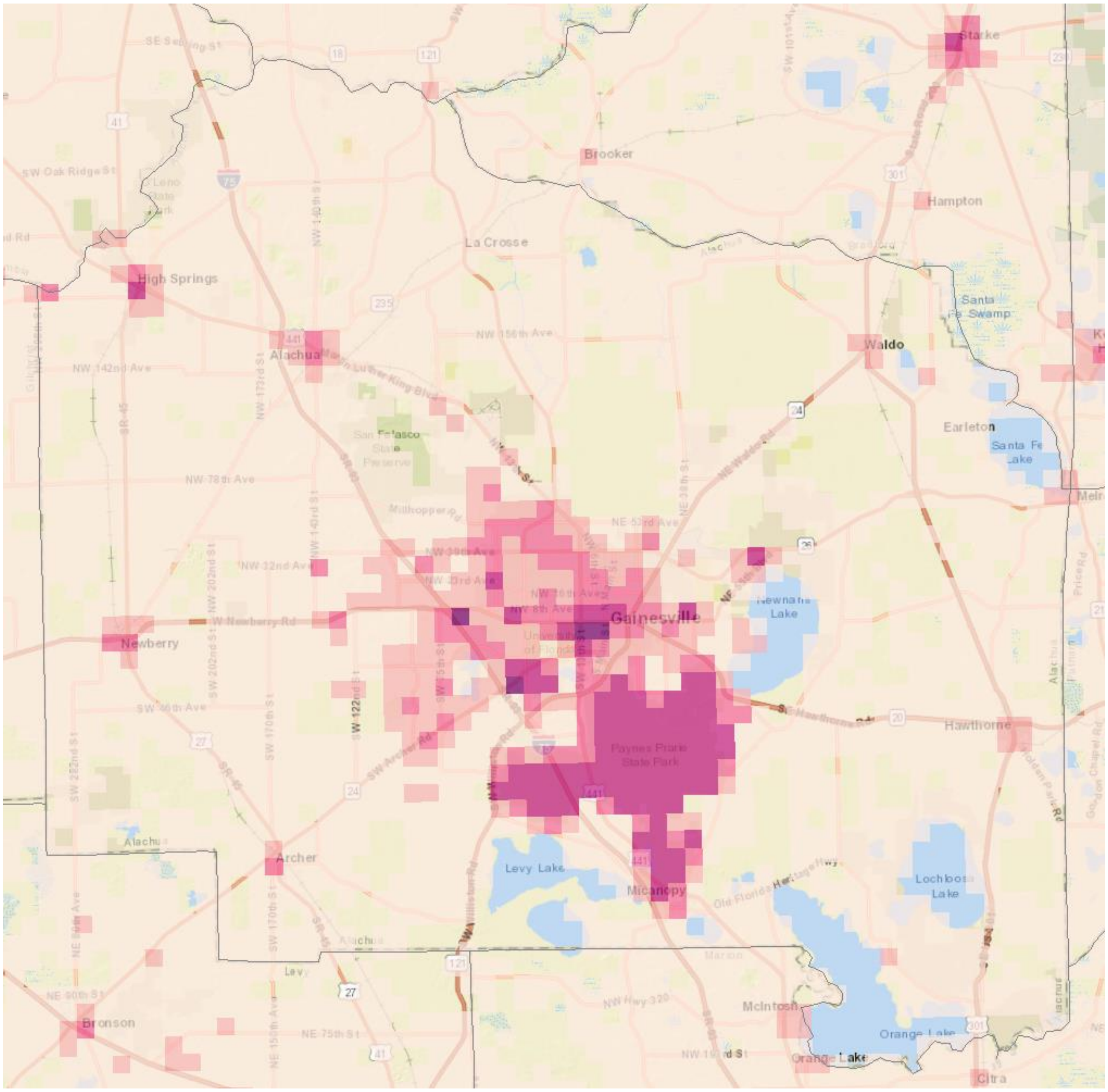

Figure C-2. Alachua County. The large walkable area is Payne's Prarie – the state's first preserve and now a National Natural Landmark with eight trails for hiking, horseback riding, and bicycling.

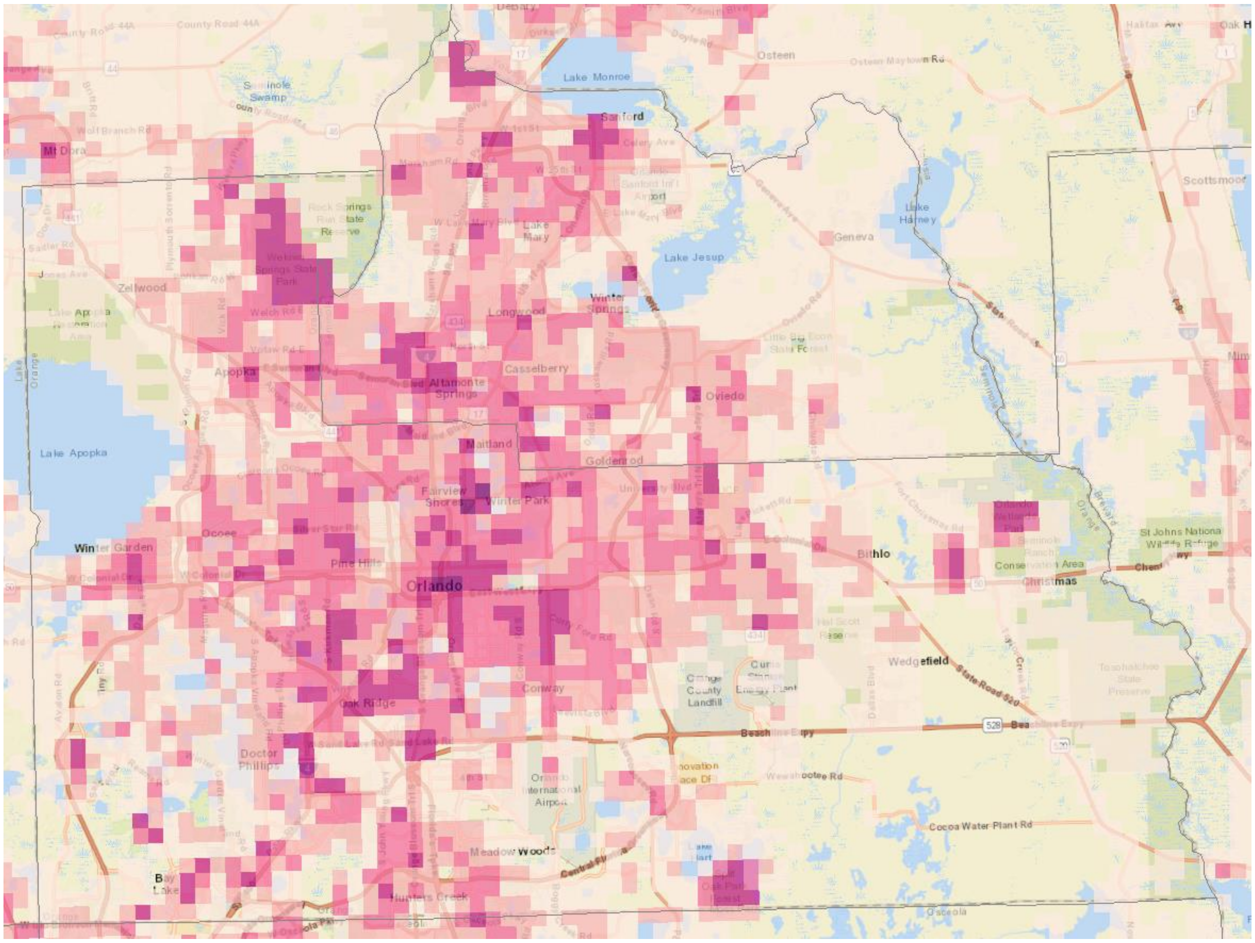

Figure C-3. Orange and Seminole Counties.

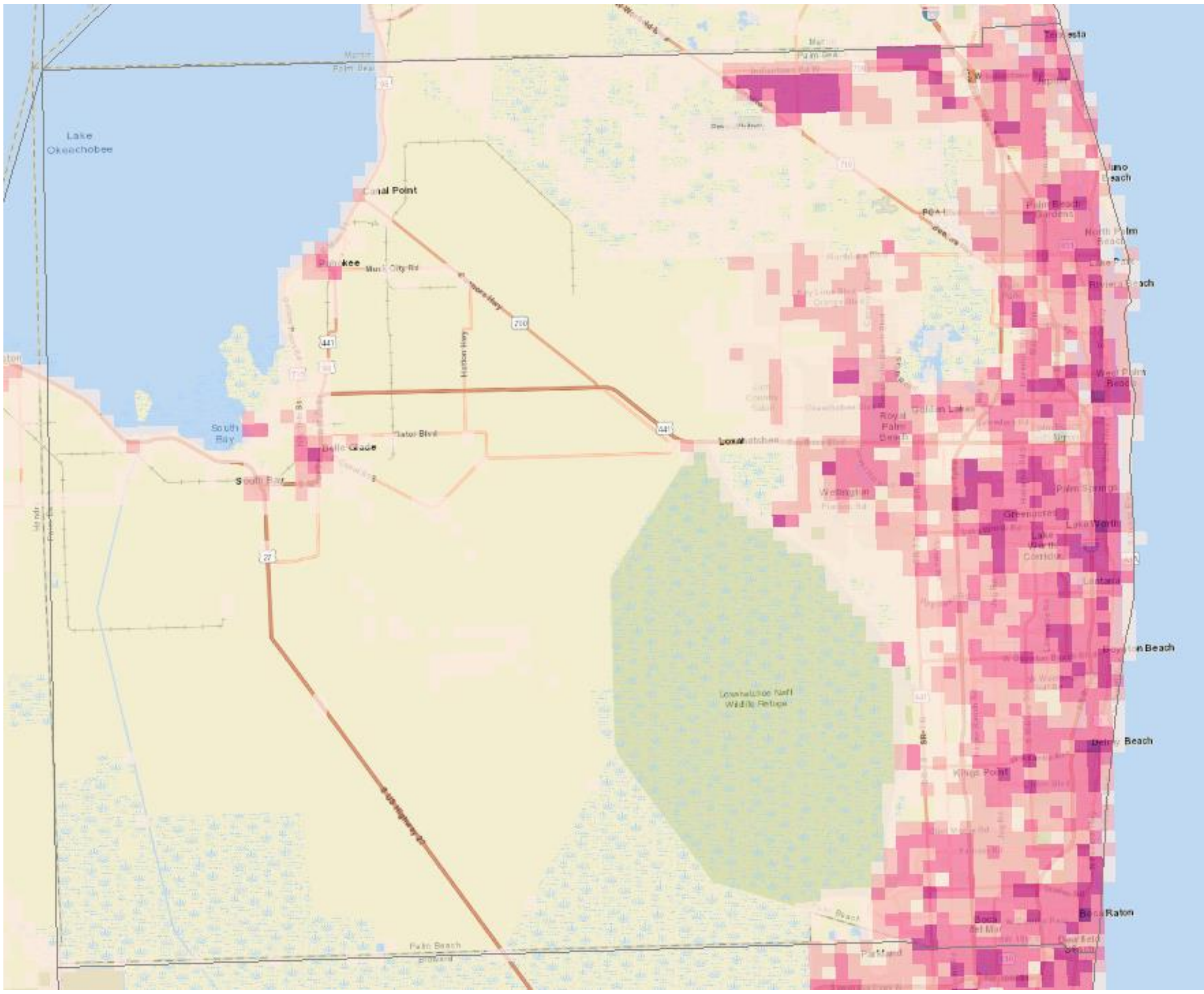

Figure C-4. Palm Beach County.

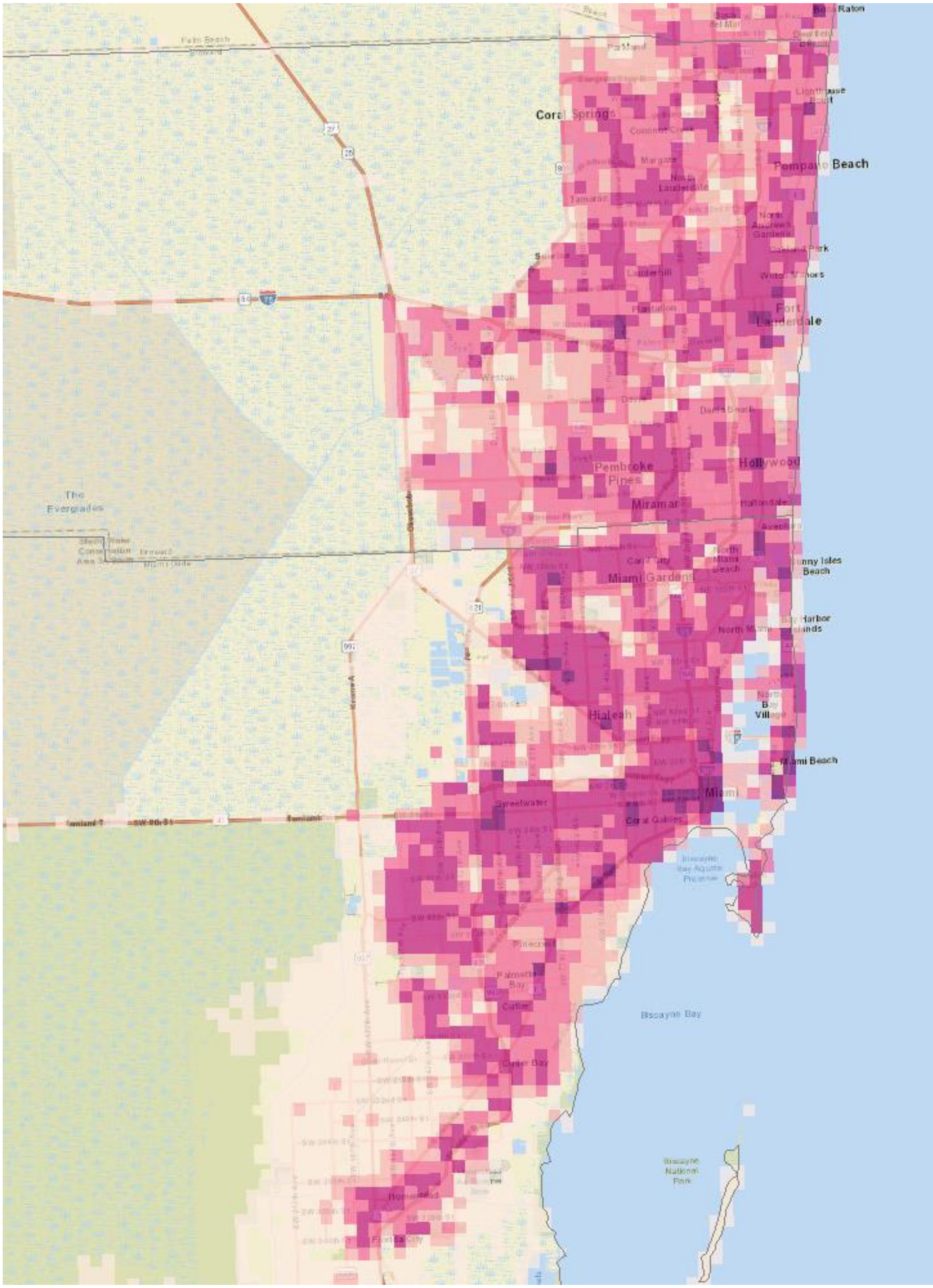

Figure C-5. Greater Miami Area.

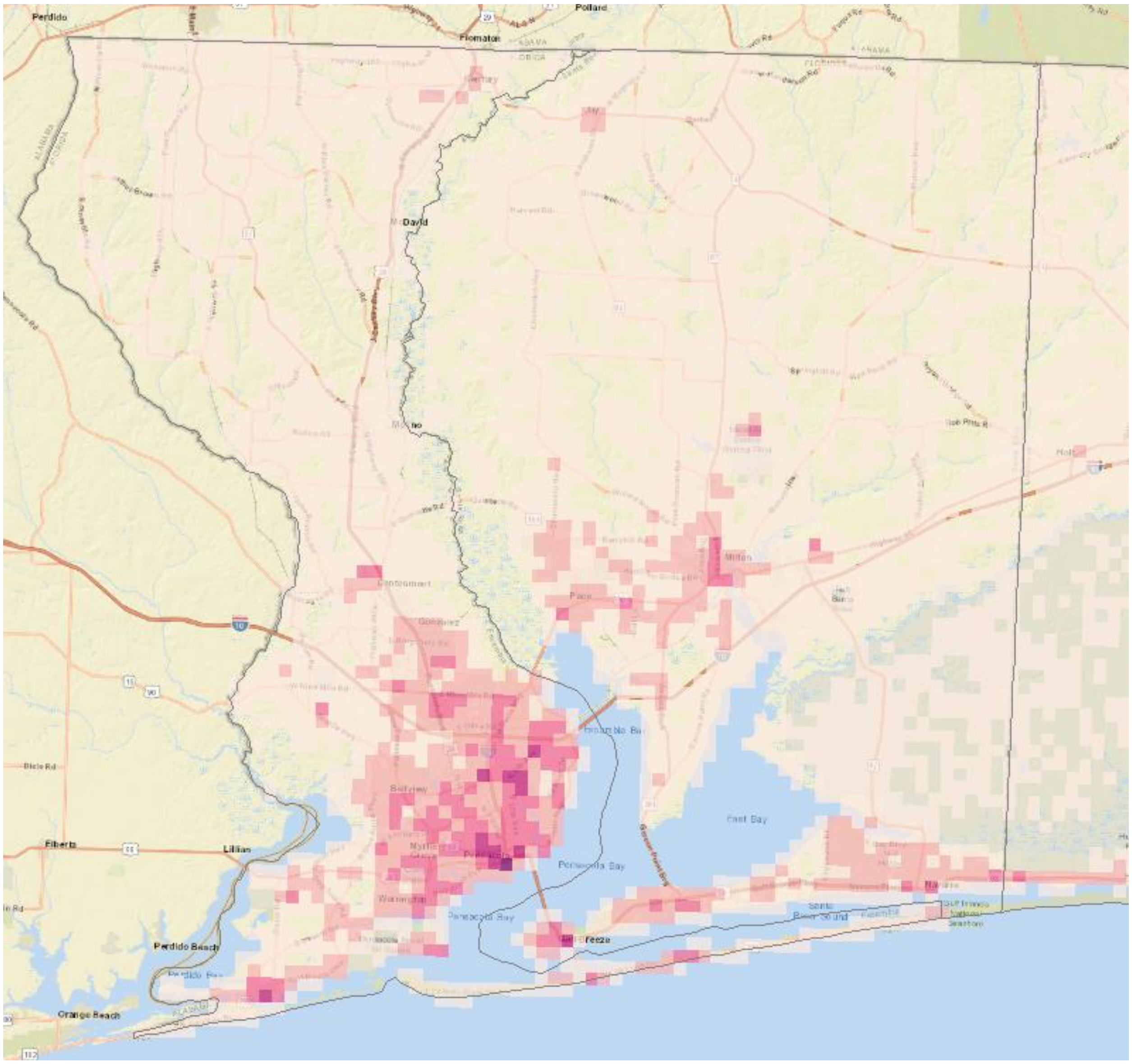

Figure C-6. Escambia and Santa Rosa Counties.

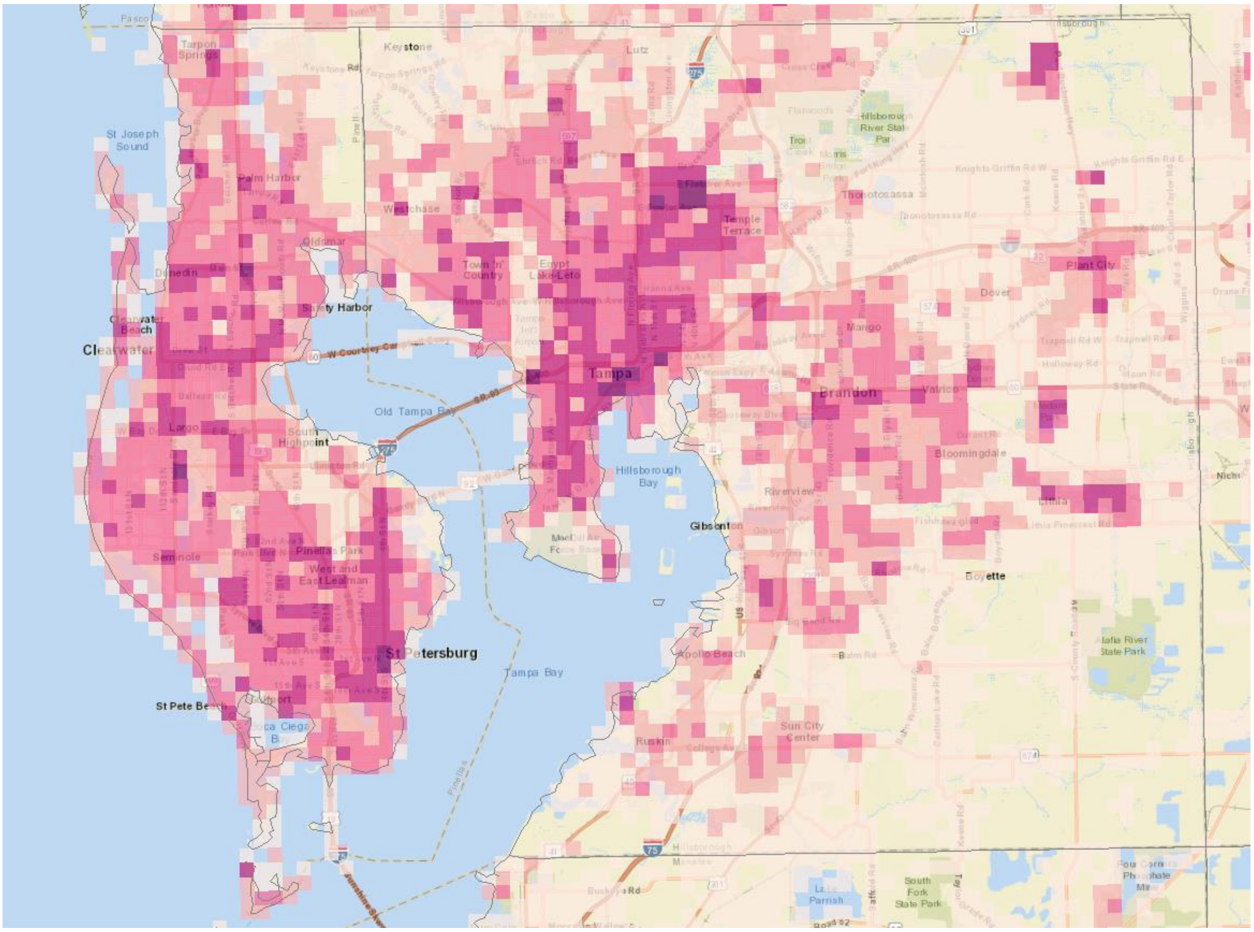

Figure C-7. Pinellas and Hillsborough Counties.