Mapping the US Census Data Using the TIGER/Line Shapefiles¹

Young Gu Her and Ziwen Yu²

Introduction

Geospatial data are critical to understanding the spatial variations of a variable of interest. The US Census TIGER/ Line Shapefiles have been a useful and reliable source of demographic and geographic information, including administrative boundaries, population and housing unit counts, road lines, address information, and water features. Such information helps users understand and identify target stakeholders and areas. It is critical to develop Extension and research programs that can help users make informed decisions at the local, state, and national levels using the spatial information. This article introduces the TIGER/Line Shapefile datasets and demonstrates how we can extract and map spatial information from the US Census data using the shapefiles. This publication will help Extension agents and decision-makers to map and analyze the demographic and geographic data provided by the US Census survey data and the TIGER/Line Shapefiles using commonly available tools and software.

What is a shapefile?

A shapefile is a set of associated files that contain geospatial data and information (e.g., location, shape, and map projection) of spatial objects such as buildings (points or polygons), roads (lines or polygons), and areas (polygons) (Figure 1). Here, "shape" means the external boundary or outline of an object, and map projection is a way to represent the three-dimensional Earth surface on a two-dimensional plane or paper. The Environmental Systems Research Institute (ESRI) first created the shapefile format for use in its geographic information system (GIS) software, ArcGIS[®] (previously ArcInfo[®] and ArcView[®]), but the shapefiles work with other GIS software such as QGIS (Quantum GIS) (Flenniken et al. 2020) as well. In a shapefile, spatial objects are depicted as vectors, which can represent points (e.g., a point of interest such as a landmark and house), lines (e.g., roads), or polygons (e.g., boundaries of farms and counties) with vertices and paths (Figure 1). The vertices (e.g., points in Figure 1) and paths (e.g., lines in Figure 1) contain spatial information such as location (e.g., latitude and longitude). Nonspatial information associated with these vector objects, such as population size, density, and characteristics, are called attributes. Shapefiles are commonly used when representing spatial information of objects and storing their nonspatial attributes. A raster (or grid) is another common format of spatial data. In a grid, square cells are divided into rows and columns, and each cell has a value that represents the characteristics of the corresponding location, such as elevation and land use (Figure 2). Grid files are good at storing information that can be represented with regularly spaced data, such as an array of pixels of a photo and remotely sensed image (Figure 2). Grid formats are commonly used to represent continuous surface (i.e., elevations [topography], soil characteristics, land uses) and weather variables (e.g., air temperature and precipitation) across a region.

The Institute of Food and Agricultural Sciences (IFAS) is an Equal Opportunity Institution authorized to provide research, educational information and other services only to individuals and institutions that function with non-discrimination with respect to race, creed, color, religion, age, disability, sex, sexual orientation, marital status, national origin, political opinions or affiliations. For more information on obtaining other UF/IFAS Extension publications, contact your county's UF/IFAS Extension office. U.S. Department of Agriculture, UF/IFAS Extension Service, University of Florida, IFAS, Florida A & M University Cooperative Extension Program, and Boards of County Commissioners Cooperating. Nick T. Place, dean for UF/IFAS Extension.

^{1.} This document is AE557, one of a series of the Department of Agricultural and Biological Engineering, UF/IFAS Extension. Original publication date May 2021. Visit the EDIS website at https://edis.ifas.ufl.edu for the currently supported version of this publication.

^{2.} Young Gu Her, assistant professor, hydrology and agricultural engineering, Department of Agricultural and Biological Engineering, UF/IFAS Tropical Research and Education Center; and Ziwen Yu, assistant professor, big data analytics, Department of Agricultural and Biological Engineering; UF/IFAS Extension, Gainesville, FL 32611.



Figure 1. Types of spatial objects in a shapefile. The numbers in the parentheses represent the horizontal and vertical location of a vertex on a plane.

Credits: Young Gu Her and Ziwen Yu, UF/IFAS

(3	9,74)						
	2	1	3	4	6	2	9
	4	2	5	1	4	5	4
	7	7	1	9	4	6	1
	6	5	2	8	2	7	2
	1	3	6	7	5	8	7
	5	8	9	4	7	9	11
	8	12	10	5	6	10	12

Figure 2. A grid (or raster) data format. The numbers in the parentheses at the upper-left corner represent the reference location of this grid on a plane.

Credits: Young Gu Her and Ziwen Yu, UF/IFAS

What are TIGER/Line Shapefiles?

The US Census Bureau uses the TIGER/Line Shapefiles to store geographic and cartographic information from the US Census Bureau's Master Address File/Topologically Integrated Geographic Encoding and Referencing (MAF/ TIGER) database. "MAF/TIGER is the Census Bureau's geographic database. MAF is a complete inventory of housing units and business locations in the United States, and it was originally built from the US Postal Service's Delivery Sequence File of all residential addresses. MAF/ TIGER refers to the coupling of the MAF with the TIGER spatial database" (DiBiase 2014). The TIGER/Line Shapefiles do not include demographic data but geographic entity codes (GEOIDs), which can serve as geospatial identifiers of the Census Bureau's demographic data, linking the two databases (Figure 3). The TIGER/Line Shapefiles contain geospatial information for the 50 states, the District of Columbia, Puerto Rico, American Samoa, the Commonwealth of the Northern Mariana Islands, Guam, and the United States Virgin Islands. This information includes the

boundaries (areas; polygons) of states, counties, and census blocks, roads and hydrography (streamlines; lines), and landmarks (e.g., schools, airports, and parks; points) (Table 1). In addition to the TIGER/Line Shapefiles, "the Census Bureau creates additional shapefiles and geodatabases that include demographic data. These are as-is products and are created by Census Bureau staff as time permits. All shapefiles and geodatabases with demographic data are available at: https://www.census.gov/programs-surveys/geography. html." The details of the methods used to estimate populations for the US Census data can be found from the US Census (2020a).

Relationship between the TIGER/ Line Shapefiles and Census Statistical Data

The TIGER/Line Shapefiles contain a standard geographic identifier (GEOIDs) for each spatial object. The object links to GEOIDs of each demographic record from censuses and surveys, including the Decennial Census, Economic Census, American Community Survey, and the Population Estimates Program (Figure 3). The US Census data are not prepared in the shapefile format; therefore, it is necessary to link the census data to a geospatial layer including the TIGER/Line Shapefiles to map interesting demographic variables such as populations, ages, genders, and races. We can join data from many of the Census Bureau's surveys and censuses, which are available in American FactFinder (US Census 2020b), to spatial objects of the TIGER/Line Shapefiles using GIS software such as ArcGIS® and QGIS to see the spatial distributions of a variable of interest. For instance, we can map the roads and water bodies on the top of county boundaries, count the number of people in age groups in the counties of interest, and map population compositions at the county level. Such examples are demonstrated later in this article.

Attribute Table of a TIGER/Line Shapefile

STATEFP COUNTYFP

	1.00			1	
GEOID	NAME		STATE	COUNT	G
				- I	

			-> Coi	mmoi	1 Uniqu	e Identi	ifier
	L				1		
:	: 1	:	1 :	:		:	
12	095	12095	Orange			12	
12	086	12086	Miami- Dade			12	:
12	001	12001	Alachua			12	

J.S. Cens	us Demogra	phic Surve	y Data
-----------	------------	------------	--------

STATE	COUNT	GEOID	YEAR	AGEGRP	
12	1	12001	7	4	
12	86	12086	7	4	
12	95	12095	7	4	
÷	÷	:	÷	:	:
	L				

Figure 3. Joining two datasets using a common unique identifier (GEOID).

Credits: Young Gu Her and Ziwen Yu, UF/IFAS

Table 1. Layer types of the TIGER/Line Shapefiles.

Geographic Areas	American Indian Area Geography
	Blocks
	Block Groups
	Census Tracts
	Congressional Districts
	Consolidated Cities
	Core Based Statistical Areas
	Counties (and equivalent)
	County Subdivisions
	Estate
	Places
	Public Use Microdata Areas
	School Districts
	States (and equivalent)
	State Legislative Districts
	Subbarrio (SubMinor Civil Division)
	Urban Areas
	Zip Code Tabulation Areas
Features	All Lines
	Coastline
	Landmarks
	Roads
	Rails
	Military Installations
	Water
Feature Relationships	Relationship Files

Tools Available for Mapping the Data

The TIGER/Line Shapefiles data can be viewed using multiple tools with different functionalities. To map the vector features on a map and to view the labels, various districts, roads, and some specific areas, the online tool, TIGERweb (https://tigerweb.geo.census.gov/tigerwebmain/ TIGERweb_main.html), would be the most convenient interface. It is supported by the US Census Bureau. It also contains the types of features used in the US Census Bureau's surveys and stored in their digital mapping database. To further analyze the geospatial distribution of certain attributes found in the TIGER/Line Shapefiles data, offline tools are desired for their full functionalities. The offline or standalone GIS tools include, but are not limited to, Arc-GIS® (by ESRI), MapInfo® (by Pitney Bowes Software), and QGIS (Open Source GIS licensed under the GNU General Public Licenses). In this article, QGIS was selected as a GIS

tool to demonstrate the association between TIGER/Line Shapefiles vector features and US Census data, because QGIS is a free open source software that anyone can use and modify (Flenniken et al. 2020).

Examples

This article introduces three case studies to demonstrate how to use the TIGER/Line Shapefiles with the US Census data: mapping counties, roads, and water bodies; counting the number of people in an age group; and mapping population compositions by race and ethnicity.

To obtain the software and data required for these examples, follow the steps below.

1. Download and install QGIS software.

- a. Download the installation file of a QGIS version that is suitable for the operating system (e.g., Windows, iOS, and Linux) of your computer: https://qgis.org/en/site/.
- b. Install QGIS on your computer by running the downloaded installation file. QGIS 3.10.10 was used for the examples in this article.
- 2. Download the county boundary shapefile (polygons) from the TIGER/Line Shapefiles.
 - a. Go to https://www.census.gov/cgi-bin/geo/shapefiles/ index.php.
 - b. Select "2019" from the "Select year" dropdown menu and "Counties (and equivalent)" from the "Select a layer type" dropdown menu. Click the "Submit" button to download a ZIP file, "tl_2019_us_county.zip."
 - c. Unzip (or extract) the downloaded file.
- 3. Download the road shapefile (line) from the TIGER/Line Shapefiles.
 - a. Go to https://www.census.gov/cgi-bin/geo/shapefiles/ index.php.
 - b. Select "Roads" from the "Select a layer type" dropdown menu, then click the "Submit" button to move to the next webpage (https://www.census.gov/cgi-bin/geo/ shapefiles/index.php?year=2019&layergroup=Roads).
 - c. On the next webpage, select "Florida" from the "Select a State" dropdown menu under "Primary and Secondary

Roads" and click the "Submit" button to download a ZIP file, "tl_2019_12_prisecroads.zip."

d. Unzip the downloaded file.

- 4. Download the water (e.g., waterbody and water boundary lines) area shapefile (polygons and lines) from the TIGER/Line Shapefiles.
 - a. Go to https://www.census.gov/cgi-bin/geo/shapefiles/ index.php.
 - b. Select "Water" from the "Select a layer type" dropdown menu and then click the "Submit" button to move to the next webpage (https://www.census.gov/cgi-bin/geo/ shapefiles/index.php?year=2019&layergroup=Water).
 - c. On the next webpage, select "Florida" from the "Select a State" dropdown menu.
 - d. Select "Alachua County" from the "Select a County" dropdown menu and click the "Download" button to download a ZIP file, "tl_2019_12001_areawater.zip."
 - e. Unzip the downloaded file.
- 5. Access the population data with age attributes from the US Census for Florida.
 - a. Go to https://www.census.gov/data/tables/time-series/ demo/popest/2010s-counties-detail.html.
 - b. Select "Florida" under "Annual County and Resident Population Estimates by Selected Age Groups and Sex: April 1, 2010 to July 1, 2019 (CC-EST2019-AGESEX)" to download the resident population estimates by selected age groups, "cc-est2019-agesex-12.csv." Details of the dataset can be found at https://www2.census.gov/ programs-surveys/popest/technical-documentation/ file-layouts/2010-2019/cc-est2019-agesex.pdf.
 - c. Select "Florida" under "Annual County Resident Population Estimates by Age, Sex, Race, and Hispanic Origin: April 1, 2010 to July 1, 2019 (CC-EST2019-ALLDATA)" to download the resident population estimates by races, "cc-est2019-alldata-12.csv."

To load all the shapefiles into QGIS, you need to run QGIS and create a new project. Flenniken et al. (2020) provide a useful primer for those who are unfamiliar with QGIS. More detailed instructions on using QGIS can be found in a QGIS user guide and manual (https://docs.qgis.org/3.10/ en/docs/training_manual/index.html).

Example 1: Mapping Counties, Roads, and Waterbodies

The first example is intended to demonstrate how to compile different spatial objects in multiple layers (or TIGER/Line Shapefiles) in a QGIS project.

- 1. Open the downloaded shapefiles, including the county boundary shapefile, the road shapefile, and the water area shapefile, in QGIS.
- 2. Map all their features at the state level (primary and secondary roads; Figure 4), then to Gainesville, FL (waterbodies and linear water; Figure 5).



Figure 4. Primary and secondary roads of Florida and waterbodies of Alachua County.





Figure 5. Waterbody boundaries and roads of Alachua County. Credits: Young Gu Her and Ziwen Yu, UF/IFAS

Example 2: Counting the Number of People in an Age Group in a County

In this example, a set of US Census survey data will be linked to a TIGER/Line Shapefile to count the populations in the age group of 14 to 17 in Florida. The population census data are tabulated with the dimensions of age and sex attributes aggregated at the county level. The key to this example is to join the tabulated demographic data to the shapefile to map the population data at the county level across the state of Florida.

- To join the two different datasets, the US Census data and the TIGER/Line Shapefile, a common identifier (GEOID) will be used to match each record of the US Census data to objects in the TIGER/Line Shapefile.
- 2. Open up the attribute table of the shapefile.
- 3. To see the county-level population (in the age group of 14 to 17) in this example, select the previously downloaded county boundary layer ("tl_2019_us_county.shp" in "tl_2019_us_county.zip") of the TIGER/Line Shapefile with the identifier data field, "GEOID," in the fourth column from the left (Figure 6).
- 4. The GEOID values consist of two digits of "STATEFP" (state FIPS codes) and three digits of "COUNTYFP" (county FIPS codes). The analysis processes strictly follow the Federal Information Processing Series (FIPS) Codes of GEOIDs defined by the US Census Bureau. "FIPS codes for smaller geographic entities are usually unique within larger geographic entities. For example, FIPS state codes are unique within nation and FIPS county codes are unique within state. Since counties nest within states, a full county FIPS code identifies both the state and the nesting county" (US Census 2020c). The US Census data ("cc-est2019-agesex-12.csv" and "cc-est2019-alldata-12. csv") do not have the GEOID values; therefore, the state and county FIPS codes included in the census data need to be combined to create the GEOID values. This data manipulation can be done using common spreadsheet software such as Excel.

12 H C 19 H	HIS BIG S	4 Y X & D		FZ 9.									-
STATEFP	COUNTYFP	COUNTYNS	GEOID	NAME	NAMELSAD	LSAD	CLASSEP	MTFCC	CSAFP	CBSAFP	METDINFP	PUNCSTAT	
18	063	00450358	18063	Hendricks	Hendricks County	/ 05	H1	G4020	294	26900	NULL	A	
25	021	00606937	25021	Norfolk	Norfolk County	05	H1	G4020	148	14460	14454	A	
45	043	01248002	45043	Georgetown	Georgetown Co.	05	H1	G4020	396	23860	NULL	A	
17	077	00424240	17077	Jackson	Jackson County	06	H1	G4020	NULL	16060	NULL	A	
49	019	01448024	49019	Grand	Grand County	05	H1	G4020	NULL	NULL	NULL	A	
38	041	01034209	38041	Hettinger	Hettinger County	05	H1	G4020	NULL	NULL	NULL	A	
51	650	01498554	51650	Hampton	Hampton city	25	C7	64020	545	47260	NULL	F	
49	045	01448036	49045	Tooele	Tooele County	05	HI	G4020	482	41620	NULL	A	
51	069	01480124	51069	Frederick	Frederick County	05	H1	G4020	548	49020	NULL	A	
55	011	01581065	55011	Buffalo	Buffalo County	05	Н1	G4020	NULL	NULL	NULL	A	
27	119	00659505	27119	Polk	Polk County	05	H1	G4020	NULL	24220	NULL	A	
54	041	01550027	54041	Lewis	Lewis County	06	H1	G4020	NULL	NULL	NULL	A	
47	047	01639742	47047	Fayette	Fayette County	05	81	G4020	368	32820	NULL	A	
27	127	00659509	27127	Redwood	Redwood County	05	H1	G4020	NULL	NULL	NULL	A	
22	089	01629449	22009	St. Charles	St. Charles Parish	15	H1	G4020	406	35380	NULL	A	
60	040	01805244	60040	Swains Island	Seains Island	00	H4	G4020	NULL	NULL	NULL	N	
46	031	01265811	46031	Corson	Corson County	06	HI	G4020	NULL	NULL	NULL	A.	
47	151	01639788	47151	Scott	Scott County	05	H1	G4020	NULL	NULL	NULL	A	
37	181	01008591	37181	Vance	Vance County	05	H1	G4020	450	25780	NULL	A	
46	053	01265765	46053	Gregory	Gregory County	05	H1	G4020	NULL	NULL	NULL	A	
45	011	01247963	45011	Barrowell	Barnwell County	05	H1	G4020	NULL	NULL	NULL	A	
21	033	00516863	21033	Caldwell	Caldwell County	05	HI	G4020	NULL	NULL	NULL	A	
18	009	00450404	18009	Blackford	Blackford County	05	HI	G4020	NULL	NULL	NULL	A	
47	039	01639739	47039	Decatur	Decatur County	05	H1	G4020	NULL	NULL	NULL	A	
16	025	00399408	16025	Camas	Camas County	05	HI	G4020	NULL	25200	NULL	A	
01	055	00161553	01055	Etowah	Etowah County	05	H1	G4020	NULL	23460	NULL	A	

Figure 6. Attribute table of a TIGER/Line Shapefile ("tl_2019_us_ county.shp") and its GEOID field. Credits: Young Gu Her and Ziwen Yu, UF/IFAS 5. In the case of the age-sex dataset ("cc-est2019-agesex-12. csv"), for instance, a new field or column (e.g., the field "D") can be generated by giving the name of "GEOID" to the new field (e.g., in the cell of "D1") and filling the column with the following formula in Excel: "=TEXT(B2, "000") & TEXT(C2, "000")" (Figure 7). The U.S. Census data ("cc-est2019-agesex-12.csv") have the population data at twelve different time points or periods (from April 1, 2010 to July 1, 2019; https://www2.census.gov/ programs-surveys/popest/technical-documentation/ file-layouts/2010-2019/cc-est2019-agesex.pdf), which means that each county has twelve rows, but the TIGER/ Line Shapefile ("tl_2019_us_county.shp") has only one polygon per county. Thus, one polygon matches twelve rows, which will prevent them from being joined correctly in GIS software (e.g., QGIS and ArcGIS®).

	Contraction of the same		1 Q1	4 8		-				ES12013-1	aye	sex-12	
F	ile Horr	ie Ins	ert	Page	e L	ayout F	ormulas	Data	Re	view	٧	fiew	н
D1			×	~	ſx	STNAM	٩E						
1	А	В		с		D	E	F		G		н	1
1	SUMLEV	STATE		COUNTY		STNAME	CTYNAME	YEAR	F	OPESTIN	M.A	POPES	5T_1
2	50		12		1	Florida	Alachua Co		1	24733	36	11	978
3	50		12		1	Florida	Alachua Co		z	24733	37	11	978
4	50		12		1	Florida	Alachua Co		з	24761	14	11	995
5	50		12		1	Florida	Alachua Co		4	24983	34	12	091
6	50		12		1	Florida	Alachua Co		5	25152	20	12	165
7	50		12		1	Florida	Alachua Co		6	25247	75	12	206
8	50		12		1	Florida	Alachua Co		7	25545	56	12	359
9	50		12		1	Florida	Alachua Co		8	25905	52	12	538
0	50 AutoSave 💽	e e	12	୨୦୧୯	1	Florida	Alachua Co		9 cc-	26395 est2019-	i9 agi	12 esex-12	2 •
10 F	50 AutoSave 💽 Île Horr	re Ins	12 sert) (H Page	1 > L	Florida ayout F Alachu	Alachua Co Formulas Ia County	Data	9 cc- Re	26395 est2019-	59 agi	12 esex-12 /iew	2 •
F2	50 AutoSave (ile Horr	⊡ E ne Ins • E	12 sert	2 C Page	1 2 L <i>f</i> x	Florida	Alachua Co Formulas Ia County E	Data	9 CC- Re	26395 est2019- eview	39 agi	12 esex-12 /iew H	774 2 -
F2	50 AutoSave (ile Horr A SUMLEV	⊡ E ne Ins ▼ i E B STATE	12 sert	Page	1 2 L <i>f</i> x	Florida ayout F Alachu D GEOID	Alachua Co Formulas la County E STNAME	Data F	9 CC- Re	26395 est2019- eview G /EAR	39 agi	12 esex-12 /iew H POPES	774 2 • H
F2	AutoSave AutoSa	re Ins ■ In	12 sert ×	2 - C Page C C COUNTY	1 2 L <i>f</i> x	Florida ayout F Alachu D GEOID 12001	Formulas E County E STNAME Florida	Data F CTYNAM Alachua (9 Re E	26395 est2019- eview G /EAR	39 agr	12 esex-12 /iew H POPES 24	774 2 • H STIF
F2	AutoSave AutoSa	erri) (⊒ ne Ins ▼ i [B STATE	12 sert × 12	Page Page C C	1 e L fx	Florida ayout F Alachu D GEOID 12001 12001	Formulas Formulas E STNAME Florida	Data F CTYNAM Alachua (Alachua (9 Re E Co	26395 est2019 eview G YEAR	39 agr 1 2	12 esex-12 /iew H POPES 24 24 24	774 2 • H 5TH 733
F2	AutoSave AutoSa	e Ins e Ins B STATE	12 sert ×	Page Page C C	1 2 L <i>f</i> x 1 1 1	Florida ayout F Alachu D GEOID 12001 12001 12001	Alachua Co Formulas la County E STNAME Florida Florida	Data F CTYNAM Alachua (Alachua (Alachua (9 CC- Re E CO CO CO	26395 est2019 eview G /EAR	39 age 1 2 3	12 esex-12 /iew H POPES 24 24 24 24	774 2 • H STII 733 761
10 F F2 1 2 3 4 5	AutoSave AutoSa	e Ins • Ins	12 sert × 12 12 12	Page Page C C	1 P L fx 1 1 1 1 1	Florida ayout F Alachu D GEOID 12001 12001 12001	Alachua Co Formulas a County E STNAME Florida Florida Florida	Data F CTYNAM Alachua (Alachua (Alachua (Alachua (9 CC- Re E CO CO CO CO	26395 est2019 eview G YEAR	39 39 1 2 3 4	12 esex-12 /iew POPES 24 24 24 24 24	774 2 • 1 5TH 733 735 765
F2	50 AutoSave (ile Horr A SUMLEV 50 50 50 50 50 50 50 50 50	œn) (E ne Ins ▼ i [B STATE	12 sert 12 12 12 12	2 - C Page C C COUNTY	1 e L fx 1 1 1 1	Florida ayout F Alachu D GEOID 12001 12001 12001 12001 12001	Formulas Formulas a County E STNAME Florida Florida Florida Florida Florida	Data F CTYNAM Alachua (Alachua (Alachua (Alachua (9 Re E Co Co Co Co	26395 est2019 eview G YEAR	39 age 1 2 3 4 5	12 esex-12 /iew POPES 24 24 24 24 24 24 24 25	774 2 - 1 5 7 3 5 7 5 2 - 1 5 2 - 1 5 2 - 1 5 2 -
F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F	AutoSave AutoSave AutoSave AutoSave AutoSave AutoSave AutoSave AutoSave Source	œn) (E ne Ins ▼ i [B STATE	12 sert × 12 12 12 12 12	Page	1 P L fx 1 1 1 1 1 1 1	Florida ayout F Alachu D GEOID 12001 12001 12001 12001 12001 12001 12001	Alachua Co Formulas a County E STNAME Florida Florida Florida Florida Florida	Data F CTYNAM Alachua (Alachua (Alachua (Alachua (Alachua (Alachua (9 Re E Co Co Co Co Co	26395 est2019 eview G YEAR	1 2 3 4 5 6	12 esex-12 /iew H POPES 24 24 24 24 24 24 25 25	774 2 * 1 5TH 733 763 983 152 247
F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F	50 AutoSave (AutoSave (Horr SUMLEV 50 50 50 50 50 50 50 50 50	⊡ (= ne Ins ▼ : _ B STATE	12 sert 12 12 12 12 12 12 12	Page	1 P L fx 1 1 1 1 1 1 1 1 1	Florida ayout F Alachu D GEOID 12001 12001 12001 12001 12001 12001 12001 12001	Alachua Co Formulas la County E STNAME Florida Florida Florida Florida Florida Florida	Data F CTYNAM Alachua (Alachua (Alachua (Alachua (Alachua (Alachua (9 Re E Co Co Co Co Co Co	26395 est2019 eview G YEAR	1 2 3 4 5 6 7	12 essex-12 /iew POPES 24 24 24 24 24 25 25 25	774 2 • H 5TIN 733 733 733 733 733 733 733 733 733 73
F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F2 F	50 AutoStive ile Hom A SUMLEV 50 50 50 50 50 50 50 50 50 50 50 50	⊡ (= ne Ins ▼ : B STATE	12 sert 2 12 12 12 12 12 12 12 12	Page	1 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1	Florida ayout F Alachu D GEOID 12001 12001 12001 12001 12001 12001 12001 12001 12001 12001	Alachua Co Formulas a County E STNAME Florida Florida Florida Florida Florida Florida Florida	Data F CTYNAM Alachua (Alachua (Alachua (Alachua (Alachua (Alachua (Alachua (9 Re Co Co Co Co Co Co Co	26395 est2019 eview G YEAR	1 2 3 4 5 6 7 8	12 esex-12 fiew POPES 24 24 24 24 24 25 25 25 25 25	774 2 • H 571N 733 733 733 733 733 733 733 733 733 73

Figure 7. Creating the GEOID field and identifiers in the US Census data ("cc-est2019-agesex-12.csv"). Credits: Young Gu Her and Ziwen Yu, UF/IFAS

- 6. Therefore, a specific period (or "time point") of the population estimates (or data) needs to be selected to solve the one-to-many matching issue.
- 7. In this example, the YEAR key of 7 is chosen, which will lead to investigating the population (or the number of people in the age group of 14 to 17) of Florida's counties on July 1, 2014. It is worth noting that the "YEAR" column of the US Census data ("cc-est2019-agesex-12.csv") represents a specific time point for which the corresponding population estimates were made (rather than years or

months) (https://www2.census.gov/programs-surveys/ popest/technical-documentation/file-layouts/2010-2019/ cc-est2019-agesex.pdf).

- 8. Once the period (or "time point"; i.e., July 1, 2014; the YEAR key of 7) of interest is determined, the rows that correspond to the time point of interest will be selected and imported to QGIS for the joining process.
- 9. Use the "join" function in QGIS to join the two datasets that have the common data identifier (GEOID) (Figure 8). To map the population data (or show the spatial variation of the population over counties) using the TIGER/Line Shapefile ("tl_2019_us_county.shp"), the US Census data ("cc-est2019-agesex-12.csv") will be joined into the shapefile (rather than joining the attribute table of the shapefile into the US Census data).

Q1	Service and	11-1		×
9	Sating	Weins		
💭 e kene alame				
Source				
🐮 waladag				
🗢 La pela				
St. Sector				
🗢 2017 etc.				
ڬ -446.				
S arrbate Fo v				
-d can				
file. dies deute	10			
🛎 Mus				
📮 Séra w				
W Asserts Window				
S Malakia				
Corporation inst				
- agend				
Million Server	and the second second			
🖬 Jag Lang	÷ =	2).		
	Cole -		24. Cancel	Auch Heip

Figure 8. Joining the two datasets using GEOIDs in QGIS. Credits: Young Gu Her and Ziwen Yu, UF/IFAS

10. Once the joining process is complete, we can map the US Census population data on top of the TIGER/Line Shapefile data (Figure 9).



Figure 9. Spatial (county-level) variations of people in the age group 14 to 17 on July 1, 2014. Credits: Young Gu Her and Ziwen Yu, UF/IFAS

Example 3: Mapping Population Compositions by Race and Ethnicity

This example demonstrates how to determine the spatial distributions of the population compositions by race and ethnicity across Florida using the TIGER/Line Shapefile ("tl_2019_us_county.shp") and the US Census data ("cc-est2019-alldata-12.csv"; https://www2.census.gov/programs-surveys/popest/technical-documentation/file-layouts/2010-2019/cc-est2019-alldata.pdf).

- 1. The US Census data have population estimates (or data) by 18 different age groups. This example will focus on the age group of 15 to 19 (the AGEGRP key of 4) on a particular time point of July 1, 2014 (the YEAR key of 7).
- 2. The US Census data do not have a common identifier data field that matches the GEOID field of the TIGER/ Line Shapefile; therefore, an identifier field needs to be created by combining the two digits of the state FIPS and the three digits of the county FIPS code numbers in a spreadsheet (Figure 10).

	File	Home	Insert	Page Lay	out Formulas	Data Rea	(ex V	ev He	ip Acrol	at														d Share	Core	sevents
	02			~ fr	12000																					
	4	A 8		c	0 8	F	6	н	1		ĸ	L	M	N	0	Ρ	Q	R	s	T	U	v	w	x	¥.	2 =
1 1	1 5	UNLEY STATE	: 0	OUNTY 05	STNAME OC	CTYNAME YE	948. A	100304	101_10P	TOT_MALE T	TOT_PEMAN	NA_MALE V	VA_PEMAIS	A_MALE E	A_PEMALU	UMALE IN	CIEMALE A	A MALE A	PEMAL NO	MALE >	IA_PEMALT	OM_MALID	OW_REMAY	AC_MAUW	AC TEMPS	54C_M4
	2	50	12	1	12001 Florida	Alachua Co	7	- 4	20472	9725	10738	6604	7222	2214	2468	41	24	527	649	5	6	224	250	69:00	7552	24
	3	50	12	- 8	12003 Florida	Baker Court	7	4	2701	891	810	758	700	120	26	2	7	6	4	0	0	25	23	762	722	1
	4	50	12	5	12005 Florida	Bay County	7	- 4	5835	5207	4629	4070	3579	752	668	54	42	55	57	- 4	7	225	236	4281	3790	8
	5	50	12	7	12007 Florida	Bradford G	7		1227	708	619	558	492	122	202	2	2	4	2	0	1	21	17	\$74	509	- 1
	6	50	12	9	12009 Plorida	Breverd Co	7	4	51220	16436	14784	126-09	11447	2485	2121	67	72	413	367	21	50	803	747	15554	12128	25
	2	50	12	11	12011 Florida	Broward Cc	7	- 4	113360	50373	54987	33784	31058	20569	20178	270	276	1900	1613	40	-00	1681	1622	35347	32364	219
	8	50	12	13	12013 Florida	Caliboan Co	2	4	\$13	420	393	345	553	52	37	3	6	2	6	0	0	17	11	361	342	
	9	50	12	15	12005 Ploride	Charlotte C	7	4	6775	5620	3163	3000	2665	405	250	33	14	71	71	z	2	123	125	5315	2772	- 4
	10	50	12	17	12017 Florida	Otres Cour	7	- 4	6220	3260	2960	2850	2625	223	152	15	15	54	54	0	3	114	111	2957	2726	2
	11	50	12	19	12039 Florida	City County	7	4	34259	7346	6913	\$453	5332	1051	994	43	34	228	194	8	54	363	345	5982	5647	12
	12	50	12	21	12021 Florida	Collier Cou	7	- 4	17614	5215	8399	7787	6560	1063	3022	70	85	205	136	2	13	181	185	7544	7116	11
	13	50	12	22	12023 Florida	Columbia C	7		2222	2191	1902	1555	1242	557	251	12	22	7	20	1	3	45	62	1599	1400	
B B	14	50	12	27	12027 Plovida	DeSoto Cou	7	4	2307	1222	885	951	737	217	118	20	15	10	4	2	1	22	10	973	767	2
N O D <thd< th=""> <thd< th=""> <thd< th=""> <thd< th=""></thd<></thd<></thd<></thd<>	15	50	12	29	12025 Florida	Dixie Count	7	- 4	754	387	367	325	323	46	32	3	2	2	0	0	1	7	2	335	331	
No S	16	50	12	21	12031 Florida	Duval Court	2	6	\$3465	27124	26341	14512	12979	20241	10021	99	115	1141	1012	22	36	1163	11-12	15486	14999	209
10 10<	17	50	12	55	12055 Plorida	Escemble C	7	4	22905	12574	2222	8234	6303	2355	2800	118	85	427	403	41	34	386	525	8741	6566	32
10 10 <th10< th=""> 10 10 10<!--</td--><td>10</td><td>50</td><td>12</td><td>25</td><td>12035 Florida</td><td>Flagler Cou</td><td>7</td><td></td><td>5432</td><td>2859</td><td>2573</td><td>2183</td><td>1934</td><td>454</td><td>478</td><td>10</td><td>0</td><td>65</td><td>49</td><td>G</td><td>0</td><td>133</td><td>204</td><td>2302</td><td>2026</td><td>2</td></th10<>	10	50	12	25	12035 Florida	Flagler Cou	7		5432	2859	2573	2183	1934	454	478	10	0	65	49	G	0	133	204	2302	2026	2
B B	19	50	12	37	12037 Florida	Fraeklin Co	7	4	483	267	216	225	183	22	26	10	1	1	0	0	0	9	6	233	189	
20 0 10 </td <td>20</td> <td>50</td> <td>12</td> <td>52</td> <td>12035 Florida</td> <td>Gadaden Cr</td> <td>7</td> <td>4</td> <td>2545</td> <td>1272</td> <td>1275</td> <td>425</td> <td>420</td> <td>808</td> <td>823</td> <td>11</td> <td>3</td> <td>8</td> <td>7</td> <td>1</td> <td>2</td> <td>12</td> <td>15</td> <td>442</td> <td>435</td> <td></td>	20	50	12	52	12035 Florida	Gadaden Cr	7	4	2545	1272	1275	425	420	808	823	11	3	8	7	1	2	12	15	442	435	
	21	50	12	41	12011 Florida	Gildwist Cc	7	4	1291	902	699	611	451	176	25	2	2	0	0	2	0	9	10	623	661	1
20 30<	22	50	12	43	12043 Florida	Glades Cou	7	4	623	345	278	238	206	54	21	48	41	1	0	0	0	4	10	242	216	
20 10 10 100	23	50	12	45	12045 Florida	Gulf Countr	7	4	681	352	322	220	265	54	43	2	1	3	1	0	0	10	12	200	276	
3 3 10 <td>24</td> <td>50</td> <td>12</td> <td>47</td> <td>12017 Florida</td> <td>Hamilton C</td> <td>2</td> <td>4</td> <td>222</td> <td>478</td> <td>221</td> <td>252</td> <td>190</td> <td>198</td> <td>112</td> <td>10</td> <td>6</td> <td>3</td> <td>2</td> <td>0</td> <td>0</td> <td>15</td> <td>10</td> <td>265</td> <td>200</td> <td>2</td>	24	50	12	47	12017 Florida	Hamilton C	2	4	222	478	221	252	190	198	112	10	6	3	2	0	0	15	10	265	200	2
B D <thd< th=""> <thd< th=""> <thd< th=""> <thd< th=""></thd<></thd<></thd<></thd<>	25	50	12	42	12045 Florida	Harden Cru	7		2005	1117	891	120	795	85	55	18	8	15	20	1	1	10	15	999	807	
20 0 10 </td <td>26</td> <td>50</td> <td>12</td> <td>51</td> <td>12051 Elocida</td> <td>Handry Cru</td> <td>7</td> <td></td> <td>2685</td> <td>1440</td> <td>1246</td> <td>1161</td> <td>1014</td> <td>204</td> <td>121</td> <td>45</td> <td>25</td> <td>4</td> <td></td> <td>- 1</td> <td>1</td> <td>10</td> <td>20</td> <td>1177</td> <td>1031</td> <td></td>	26	50	12	51	12051 Elocida	Handry Cru	7		2685	1440	1246	1161	1014	204	121	45	25	4		- 1	1	10	20	1177	1031	
3 3 10 100	27	50	12	53	12053 Florida	Herrando (2	4	9256	5079	6577	4330	4060	425	252	25	25	88	67	6	2	205	165	4529	4211	
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	28	50	12	55	12055 Florida	Hablands (7		44.70	7444	2226	1881	1687	410	583	18	24	47	51		2	64	81	1955	1759	
B B	20	50	12	57	12057 Elocida	Mildoreau	2		86431	44222	42154	31493	20714	9327	6935	150	305	1367	1421	30	50	1006	1210	22128	21264	104
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	20	50	12	50	13068 Elucida	Molones Cox			1110	618	500	5.03	155	41	75	4			5	1		10	11	569	145	
20 10 10 100	51	50	12	61	12061 Florida	Indian Ske	7	4	7744	4740	1504	1142	2611	216	500	15	25	55	57		1	107	104	1218	2904	
	32	50	12	62	12062 Glorida	Indexes Cor	2		3600	1204	1225	002	633	420	220	24	16	12	12	- 6	4	10	21	033	057	- 2
Dist Dist <thdis< th=""> <thdist< th=""> Dist Di</thdist<></thdis<>	88	50	12	65	12065 Florida	Jefferson C	7		587	807	280	152	181	139	136		1	0	2	0		10	10	162	13.0	-1.
B 1 3	14	50	12	67	12067 Elorida	Lafavarra C	7		524	304	220	238	193	40	21	e e	1	2		2	1		2	245	195	
B 1 1 10 10 10 10 10 100 <	15	50	12	60	12068 Elyste	Lake Court	2		16872	9716	9157	6769	6222	1255	1234	101	22	319	222	10	22	274	344	2011	65/16	- 12
		10	11	11	11073 Blootda	Los Causin		- 3	11111	17074	12410	148.11	11000	1417	1400	110	107	111	100	10	12	141	101	18047	14114	- 11
B G D <thd< th=""> <thd< th=""> <thd< th=""> <thd< th=""></thd<></thd<></thd<></thd<>	37	50	12	73	12073 Elorida	Lens Court	2		35231	11675	13556	2000	7036	2014	4173	26	25	125	112			141	201	7335	0266	- 22
B G D1 D2 D2 <thd2< th=""> D2 D2 D2<td>20</td><td>50</td><td>12</td><td>25</td><td>13075 Elucida</td><td>Level Count</td><td>2</td><td></td><td>3124</td><td>1143</td><td>001</td><td>0.23</td><td>974</td><td>110</td><td>122</td><td>6</td><td>1</td><td>11</td><td>5 6</td><td>- 2</td><td></td><td>17</td><td>32</td><td>004</td><td>0.46</td><td></td></thd2<>	20	50	12	25	13075 Elucida	Level Count	2		3124	1143	001	0.23	974	110	122	6	1	11	5 6	- 2		17	32	004	0.46	
		10	11	78	11077 Blootda	Librate Car			22.54	100	100	374	187	47	155				- 2					110	141	- 1
	40	50	12	29	12070 Elocida	Madana Cr	2		1010	500	432	221	222	201	100		2	2	1	0	1		12	222	210	-
20 50 100 1000 Monto 2 4000 1000 1000 100 </td <td>41</td> <td>50</td> <td>112</td> <td></td> <td>11081 Shudda</td> <td>Magazine C</td> <td></td> <td></td> <td>18524</td> <td>66.72</td> <td>2055</td> <td>7491</td> <td>7155</td> <td>1200</td> <td>1124</td> <td>16</td> <td></td> <td>144</td> <td>174</td> <td>16</td> <td></td> <td>101</td> <td>210</td> <td>7861</td> <td>2461</td> <td>- 3</td>	41	50	112		11081 Shudda	Magazine C			18524	66.72	2055	7491	7155	1200	1124	16		144	174	16		101	210	7861	2461	- 3
B D B Differed Marcol 7 4 Differed Marcol 7 A Differed Marcol	41	10	15		11063 Florida	Marian Car			17343	0007	4336	6833	6383	1474	12.99	40	65	249	101	10		192	319	7111	401	- 3
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	12	10	- 15	0.5	Allows Plonds	Margin Coll			1/352	3037	1713	2022	2262	-010	43/3	10	53	243	153	2		324	253	2111	3347	
eme 59 17 00 11.000 FUNDO MURETANO 7 4 12015 000000 00000 12012 2000 10000 10000 10000 10000 10000 10000 10000 10000 10000 10000 10000 10000 1000 10000 1000 1000 1000 10000 10000 10				24	Adams Horida	manufi Lou			7814	2005	A724	4977	4,75%	439	781		20				14	106	119	and a	Ailb	
Mail Display Display <thdisplay< th=""> <thdisplay< th=""> <thdisp< td=""><td></td><td>50</td><td>- 11</td><td>00</td><td>12066 Pionda</td><td>Manual Ca</td><td></td><td></td><td>156715</td><td>1000</td><td>1436</td><td>39322</td><td>1300</td><td>17044</td><td>17444</td><td>159</td><td>250</td><td>1203</td><td>1114</td><td>-</td><td>34</td><td>1150</td><td>1.094</td><td>1407</td><td>57630</td><td>- 100</td></thdisp<></thdisplay<></thdisplay<>		50	- 11	00	12066 Pionda	Manual Ca			156715	1000	1436	39322	1300	17044	17444	159	250	1203	1114	-	34	1150	1.094	1407	57630	- 100
an nr 12 an that the second se	10	10	- 15	87	A MARY PROPIDE	mare de Co			3075	1587	2438	11/2	1004	123	158	10		41	71		- 1	39		2407	1043	- 1
en 50 1/ 21 1/07/170708 UNROBEL / + 121/2 2242 5067 4527 2590 725 554 55 55 154 134 22 15 414 540 4058 4276 5	-	**	- 11	203	Aramy Phirida	manuali COL			4457	7433	21.68	2064	1304	177	284	*		14	14			5.K	52	2117	1043	
10 TA 13 A3 1340 Table Company 3 A 3700 1475 1040 1440 013 377 41 14 17 3 7 () A 16 10 147 000 1	40	50	- 12	91	12091 Pionda	Charachasha			11022	1460	5087	43.00	3960	195	524	39	30	154	134		15	-10	349	4035	4//0	- 14
	-	10 million	10.00	4414-12-140	Addres Phonda	CH44C5058			7524	1499	1040	1243	914	10	81	18	17					18	19	119.9	300	

Figure 10. Creating the GEOID field and common unique identifiers in the US Census dataset ("cc-est2019-alldata.csv"). Credits: Young Gu Her and Ziwen Yu, UF/IFAS

- 3. Then, the processed population dataset needs to be imported into QGIS and joined to the county shapefile using GEOID.
- 4. There are many race, ethnicity, and sex classes. For demonstration, the "Black or African American along female population," "American Indian and Alaska Native along female population," and "Two or More Races male population" are selected and mapped in Figures 11 to 13.



Figure 11. Spatial (county-level) variations of the "Black or African American along female population." Credits: Young Gu Her and Ziwen Yu, UF/IFAS



Figure 12. Spatial (county-level) variations of the "American Indian and Alaska Native along female population." Credits: Young Gu Her and Ziwen Yu, UF/IFAS



Figure 13. Spatial (county-level) variations of the "Two or More Races male population."

Credits: Young Gu Her and Ziwen Yu, UF/IFAS

The TIGER/Line Shapefiles are useful geographic datasets that can help map the spatial variations of variable and attribute data collected for different interests, such as the US Census data. The unique GEOIDs are the key information enabling the integration of the shapefiles and census data at various geographic levels. Users need to pay particular attention to identifying the proper (unique) identifier shared by both shapefiles and survey datasets. The join function of GIS software may only accept one join key, which could be the combination of multiple fields in one of the joining tables.

Summary

The US Census data provide primary information about the American people and the economy on which policy and decision-making rely. The TIGER/Line Shapefiles enable the spatial visualization of the US Census data and help users better understand the demographic features of the areas of interest. This article demonstrates how to map shapefiles, integrate the two datasets, and extract secondary information useful to Extension programs and stakeholders' decision-making processes. Although the examples provided in this article focus on the county-level analysis of certain demographic features, the methodology can be applied to other combinations of the TIGER/Line Shapefile types (e.g., block and ZIP code area shapefiles and coastal lines; Table 1) and the US Census population datasets. The 2020 Census results, such as the new population counts, were planned to be released in May 2021 (https://www. census.gov/programs-surveys/popest/about/schedule.html). The analysis method presented in this article is expected to help EDIS readers to quickly understand how demographic and economic changes in the United States have occurred over the past decade.

References

DiBiase, D. 2014. *TIGER*, *Topology and Geocoding*. *Nature of Geographic Information: An Open Geospatial Textbook*.

Flenniken, J. M., S. Stuglik, and B. V. Iannone. 2020. "Quantum GIS (QGIS): An Introduction to a Free Alternative to More Costly GIS Platforms." *EDIS 2020* (2). https:// doi.org/10.32473/edis-fr428-2020

US Census. 2020a. "Methodology for the United States Population Estimates: Vintage 2019." Accessed on October 6, 2020. https://www2.census.gov/programs-surveys/ popest/technical-documentation/methodology/2010-2019/ natstcopr-methv2.pdf

US Census. 2020b. "TIGER/Line Shapefiles." Accessed on October 6, 2020. https://www.census.gov/geographies/ mapping-files/time-series/geo/tiger-line-file.html

US Census. 2020c. "Understanding Geographic Identifiers (GEOIDs)." Accessed on October 6, 2020. https://www.census.gov/programs-surveys/geography/guidance/geo-identifiers.html