# Mapping racial diversity using grid-based racial dot maps and racial diversity maps

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## 1. Introduction

Residential segregation and racial diversity have been of great interest to researchers and policymakers for the decades. This topic has been traditionally studied using single number indices (Farrell, 2008; Frey and Farley, 1996; Frey and Myers, 2005; Iceland *et al.*, 2002; Iceland, 2004; Johnston *et al.*, 2007; Logan *et al.*, 2004; Massey and Denton, 1987) or classification schemes (Bader and Warkentien, 2016; Clark *et al.*, 2015; Farrell and Lee, 2011; Fasenfest *et al.*, 2004; Holloway *et al.*, 2012; Wright *et al.*, 2014). In the United States, the data for analyzing racial segregation/diversity comes from the U.S. Census Bureau in the form of aggregates over areal units of different sizes. Most studies utilize the census tract as a unit. The results of residential segregation/racial diversity studies are reported in the tabular form and usually summarized for the metropolitan areas (MSA). However, in the last decade, the focus has shifted into a spatial analysis of race distribution (Bader and Warkentien, 2016; Clark *et al.*, 2015; Dmowska and Stepinski, 2017b; Holloway *et al.*, 2012; Wong, 2015).

Logan (2016) points out that the most powerful tool for spatial analysis of racial segregation/diversity is a map that show spatial pattern of different race/ethnicity groups. Recently, mapping races became more popular in demographic studies, although they are still not widely used. Due to reliance on data at the resolution of census units the majority of maps used to depict racial composition are so-called choreploth maps. In a choreploth map a color corresponding to the value of a variable mapped (for example, to a percentage of blacks in a census unit) is assigned to the entire unit, even in the case when most of the unit is uninhabited. A variable mapped is usually a percentage of a given race or a racial diversity category. More recently, racial dot maps have also been used to visualize racial segregation and diversity. A dot map is also based on census units but it is not a choreploth map.

A percentage map shows a spatial distribution of a percentage of people of a given race. Such map can illustrate a distribution of a single race/ethnicity group at a time; to show the racial composition of a study area the set of percentage maps is required. A more lucid visualization of racial geography is provided by mapping diversity/dominant race categories (Bader and Warkentien, 2016; Fasenfest *et al.*, 2004; Holloway *et al.*, 2012). Each category is the combination of the level of racial diversity and a dominant race. A diversity map shows spatial changes of racial character

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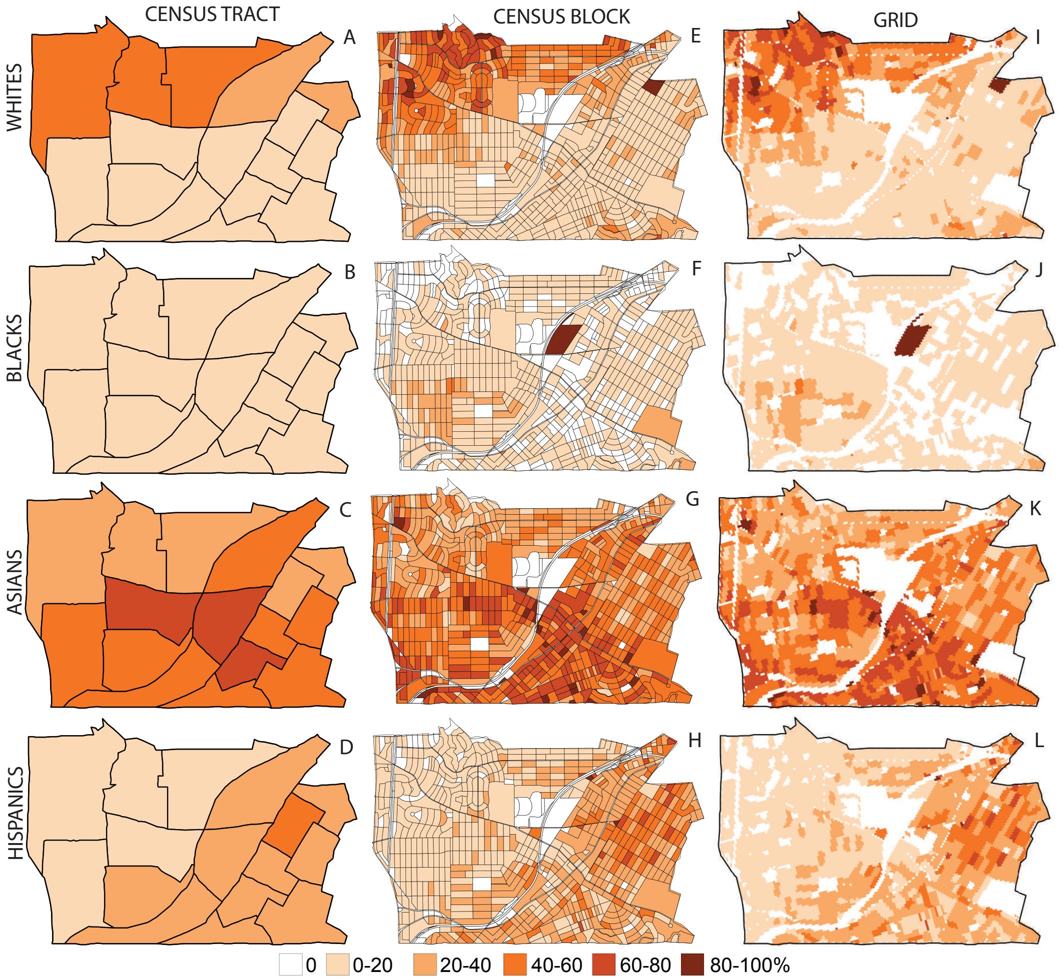


**Figure 1.** Maps showing spatial distributions of selected race/ethnicity group in the Balboa Park site in San Francisco using a percentage of the population. Maps on the left are based on census tracts data, maps in the middle are based on census blocks and maps on the right are based on gridded data. The top row shows maps depicting the percentage of the white population, the second row shows map depicting the percentage of blacks, the third row shows map depicting the percentage of Asians, the fourth row shows map depicting the percentage of Hispanic.

of neighborhoods in a single, easy-to-understand map. However, it does not show a specific mix of races in a given neighborhood. To show a specific mix of races a racial dot map is used. Racial dot map is a type of dot density map (or dot distribution map) - a map that uses a dot symbol to show the presence of a feature and a color to indicate feature's type. In a racial dot map, features are people and colors correspond to their race. A number of dots corresponding to the population count of a census unit and colored according to this unit race shares are placed in random locations within a unit, thus low diversity units appear as collections of single-colored dots, whereas higher diversity units appear as blends of colors corresponding to an actual racial mix.

Regardless of whether the map is a percentage map, diversity category map, or racial dot map, the fact that it is based on census areas introduces inaccuracies and mapping artifacts. The main limitation is the poor map resolution which restricts the usefulness of maps only to larger spatial scales (for example, to the entire metropolitan area or a county). Racial mapping of smaller areas, like for example a census tract or a number of census tracts may result in erroneous conclusions. The larger the census units used the more generalized and inaccurate are the resultant maps.

Given that the Census is not likely to release unaggregated demographic data, the only practical means of improving the resolution of racial maps is through the construction of high resolution gridded demographic datasets. A grid can have a sub-block resolution if it is constructed via a dasymetric model (Mennis, 2003; Petrov, 2012). A dasymetric model sharpens the spatial resolution of population distribution using an ancillary variable available at high resolution. Categories of land cover/land use (LCLU) are most often used as such ancillary variable. In the United States, LCLU data is available at 30m resolution. It has been demonstrated (Dmowska and Stepinski, 2017a) that different LCLU categories correlate with different population densities. A dasymetric model uses this correlation to disaggregate population in a census block and redistribute it away from inhabited areas and terrain know to be associated with low population density.

Since 2013 we worked on the project aiming at producing high resolution, U.S. wide grids of the total population, separate race/ethnicity groups and racial diversity/dominant race categories (Dmowska and Stepinski, 2017a,b, 2014; Dmowska *et al.*, 2015). These grids are available for 1990, 2000 and 2010 and can be downloaded either county-by-county or for the metropolitan areas from http://sil.uc.edu. They also can be viewed online using the SocScape web application (http://sil.uc.edu/webapps/socscape_usa/). Grid-based percentage-of-race maps and diversity maps have better spatial resolution than analogous maps based on census blocks and much better spatial resolution than analogous maps based on census tracts. High-resolution race/ethnicity grids can be also used to produce a more detailed racial dots map.

Fig.1 shows examples of percentage maps for (non-Hispanics) white, black, Asians, and Hispanic for the area centered around the Balboa Park in the city of San Francisco and covered by 19 census tracts (Census tract 255, 260-263, 309-314). Fig.1 is divided into 12 panels. Each column corresponds to different data model - census tract, census block, and high-resolution grid, respectively. Each row shows the map for one of the race/ethnicity groups: white, black, Asians and Hispanic. To show racial composition of this area at least these four maps are needed.

Using track-based maps (left column) we can draw following conclusions. The northern parts of the area are dominated by whites (from 60-80% in the north-west to 40-60% in the north-east). The southern parts of the area are dominated by Asians. Black population doesn't exceed 20% anywhere. Hispanics are concentrated in the south-east part of the area where they constitute of 20-60% of the population. Using block-based maps (central column), which have a better spatial resolution, lead to a revision of some conclusions reached by looking at the tract-based maps. It also reveals the existence of multiple uninhabited areas. Using grid-based maps (right column) further increases the spatial details of racial distribution. More uninhabited areas are uncovered and small areas of very high concentration of whites and Asians are now visible. Fig.1 demonstrates inconveniences of using percentage maps, at least four maps are needed to visualize racial geography in this area and the visualization is far from perfect as a user has to constantly compare four maps. When using a percentage map is called upon, block-based maps, or even better grid-based maps, should be used.

Fig. 2 shows racial diversity maps and racial dot maps for the same area as covered in maps in Fig. 1. These maps, which do not concentrate on a separate race/ethnicity group, but takes into consideration all races, provide more lucid visualization of racial geography.

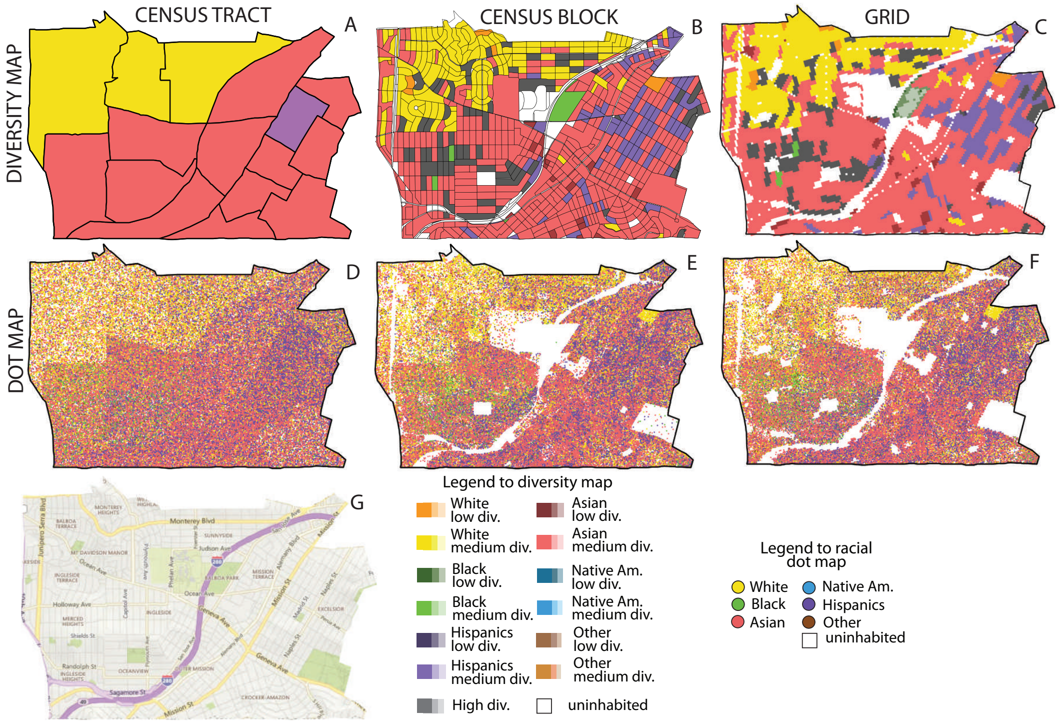


**Figure 2.** Comparison of different maps visualizing racial segregation/diversity in the Balboa Park site in San Francisco. Maps on the left are based on census tracts data, maps in the middle are based on census blocks and maps on the right are based on gridded data. The top row shows maps depicting diversity/top race classification, and the second row shows racial dot maps. Panel G is the Google street map of the site shown for a reference. Color shades in the legend for diversity classification maps reflect overall population density.

Maps in the top row in Fig. 2 (from left to right) were constructed using tracts, blocks, and a grid, respectively. Each of this maps can be considered as a compilation of information from the four corresponding maps in Fig. 1. Thus, for example, Fig. 2A, is a compilation of information depicted in Fig. 1 panels A,B, C, and D. Instead of four maps, a single map provides the same overall information about the racial geography of the study area. Fig. 2B is a block-based variant of diversity map. This map is significantly more accurate than the tract-based map. This is because in this study area the tracts are not homogeneous - they are not a good approximation for communities. At the block-level of details, it is impossible to deduce the racial geography of the study area (as accurately depicted by Fig. 2B) from the four percentages maps (Figs. 1 E, F, G, and H). Fig. 2C is a grid-based variant of a diversity map. In this area, its advantage over the block-based map is limited to having a precisely delineated uninhabited area, which is more extensive than it appears in Fig. 2B.

Maps in the bottom row in Fig. 2 (from left to right) are racial dot maps constructed using tracts, blocks, and a grid, respectively. Arguably, dot maps provide even better visualization of the racial geography than diversity maps because they explicitly account for a race of every person in the study area. However, they require a close-up view to be effective (a reader should zoom in on dot map panels in Fig. 2). Note that dot map does not show dots in locations corresponding to actual addresses of residents, but its construction creates an impression that it does. Again, note advantages of construction dot maps from blocks or from a grid; a dot map based on tracts does not correspond to reality.

The goal of this paper is to increase an awareness in the community for the usefulness of using block-based and grid-based diversity and dot maps for visualization of racial segregation and/or racial diversity. After a short description of gridded data and methods of constructing diversity maps and dot maps from a grid, the rest of the paper consists of specific examples of using these techniques to accurately depict racial geography on the small spatial scale.

## 2. Gridded data and mapping a geography of race from a grid

The construction of population gridded data for the United States is described in details in Dmowska and Stepinski (2017a) and the benefits of using gridded population data over census aggregates are discussed in Dmowska and Stepinski (2017b). Here we present a short summary of the grid construction procedure.

High-resolution grids are the results of dasymetric modeling. Dasymetric modeling (for a review see (Petrov, 2012)) refers to the process of disaggregating population data from Census units to a finer grid using ancillary data that correlates with population density but which has a higher resolution (Mennis, 2003). The source of demographic data for the high-resolution grids are the 1990, 2000, 2010 U.S. Decennial Censuses data aggregated to the blocks. The source of ancillary data is 30 m land cover data provided by the National Land Cover Datasets or NLCD. NLCD is a 30 m resolution maps with each 30x30m cells having one of the land cover classes (i.e residential area, forest, etc.).

Our dasymetric model of U.S. population is based on a statistical relation (Dmowska and Stepinski, 2017a) between population density and categories of land cover. This allows to redistribute people within a single census block and to obtain a sub-block resolution of population density. We also calculate grids corresponding to seven race/ethnicity sub-populations, (non-Hispanic white, non-Hispanic black, non-Hispanic Asian, non-Hispanic American Indian, non-Hispanic Native Hawaiian and Other Pacific Islander, non-Hispanic other race and Hispanic). Each sub-population is redistributed in the same as the total population due to lack of specific information (in the land cover data) about individual races. Thus an advantage of grid over the block data is to eliminate population from uninhabited areas and to increase spatial accuracy of population density while the ratio of different races remains the same over the entire block.

Diversity map is a result of classification of blocks or grid cells into several classes on the basis of diversity and dominant race. For detail of the classification see Dmowska and Stepinski (2017b). Diversity maps in this paper have 40 categories (39 diversity–race–density and uninhabited class). The classification is similar to the one used earlier by Holloway *et al.* (2012) but includes also population density. Racial diversity/dominant race maps provide good visualization of racial geography and they also could be used as an input data to spatial analysis.

Racial dot maps were popularized by web applications from the University of Virginia (https://demographics.virginia.edu/DotMap/), which is one-person-per-dot map based on census block data, and from the New York Times (https://www.nytimes.com/interactive/2015/07/08/us/census-race-map.html), which is a 40-people-per-dot map based on census tracts data. Racial dot maps have been shown to be a preferred tool in teaching about residential segregation (Seguin *et al.*, 2017). Constructing dot maps from a grid requires a method to find a proper number of dot to be put within a grid cell. Because grid cell carries a population density (a

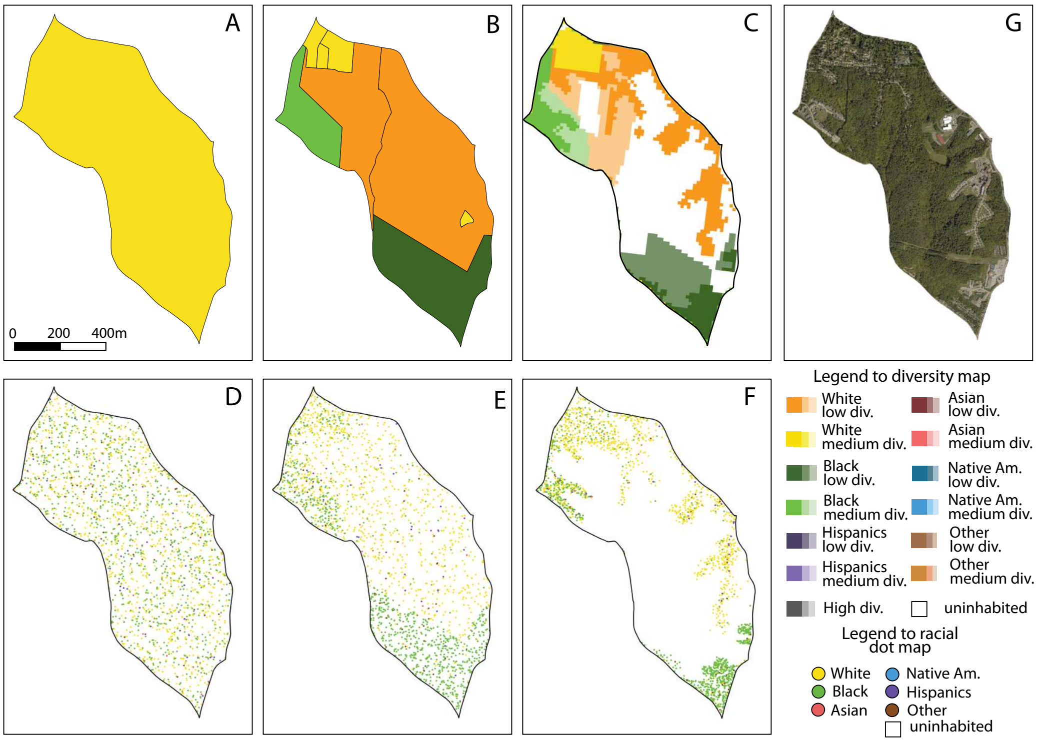


**Figure 3.** Comparison of racial diversity and dot maps of census tract number 008400 in Cincinnati, Hamilton County, OH using different areal units. (A) Racial diversity map based on census tract. (B) Racial diversity map based on census blocks. (C) Racial diversity map based on grid cells. (D) Dot map based on the census tract. (E) Dot map based on census blocks. (F) Dot maps based on grid cells. (G) An aerial image of the tract shows a distribution of inhabited and uninhabited areas.

fractional number) random numbers need to be drawn to decide whether the fractional part of density will correspond to a dot or not.

## 3. Examples of using diversity and dot maps to uncover sub-tract racial distribution

In this section we show four examples of mapping racial distribution within a census tract using either block-level data or a grid data. For each tract and for each data model we show the diversity/dominant race map and the racial dot map.

The first example is the tract 008400 in Cincinnati, Hamilton County, OH. This tract is located in the urban environment but is adjacent to a park as is revealed by its aerial image (Fig. 3G), so only portions of the tract are inhabited. Racial diversity census tract-based map has assigned one color indicating that the whole area is medium diverse, dominated by whites (Fig.3A). Dividing this tract into blocks reveals that the racial diversity of this area is more complicated (Fig. 3B). The south part of this tract is classified as low diverse, dominated by blacks, the center part is low diverse dominated by whites and the northern part is medium diverse, partially dominated by whites and partially by blacks. Grid-based map (Fig. 3C) reveals finer details by outlining precisely uninhabited areas. Block boundaries do not completely separate uninhabited park from inhabited areas, people are still shown to live in what is, in reality, a park. The grid-based map (Fig. 3C) separates uninhabited and inhabited

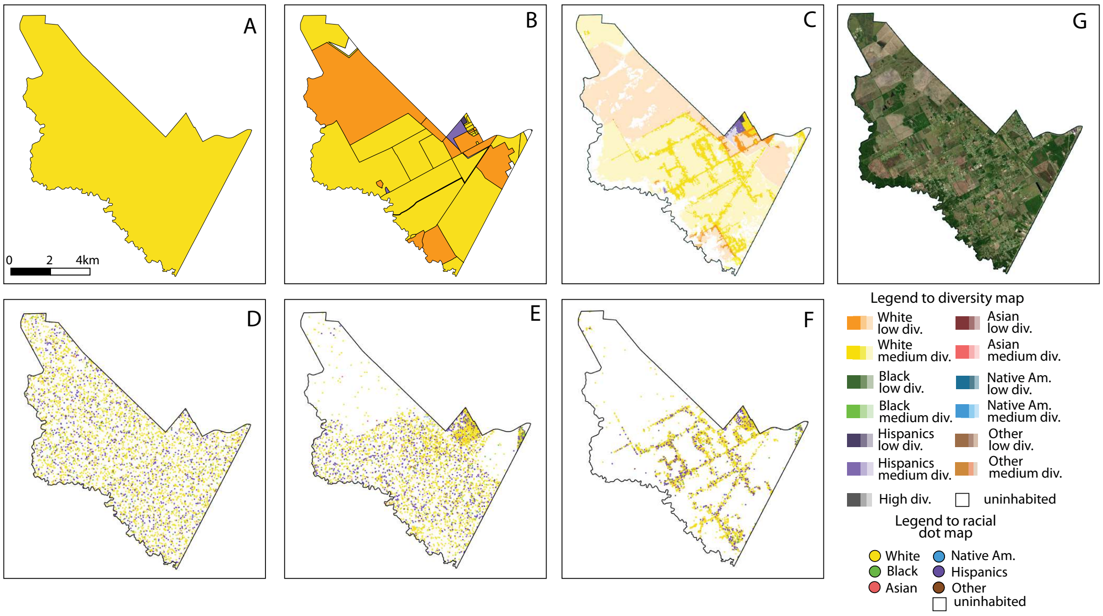


**Figure 4.** Comparison of racial diversity and dot maps of census tract number 6615.02 in the Brazoria County, TX using different areal units. (A) Racial diversity map based on census tract. (B) Racial diversity map based on census blocks. (C) Racial diversity map based on grid cells. (D) Dot map based on the census tract. (E) Dot map based on census blocks. (F) Dot maps based on grid cells. (G) An aerial image of the tract shows a distribution of inhabited and uninhabited areas.

areas in agreement with the aerial map (Fig. 3G). Clearly, this is a tract where a sub-tract racial structure is important and relying on tract-based assessment is insufficient.

The tract-based racial dot map of this tract (Fig. 3D) shows evenly distributed population of whites and blacks with a few Hispanic and Asians. This is an incorrect depiction of the actual situation in this tract. Block-based dot map (Fig. 3E) reveals that this tract is racially segregated with the majority of black population living in the southern part of the tract while of white population living in the eastern part of the tract. Only a northern part of the tract has mixed population. The grid-based dot map provides even more accurate depiction of racial spatial structure in this tract. It correctly shows an inhabited park and places people where they really live (compare Fig. 3F and Fig. 3G).

The second example is the tract 6615.02 located in the Brazoria County, TX. This tract covers a rural environment. Its aerial image (Fig. 4G) reveals the presence of croplands, with urban structures located only along few roads (see an aerial image). None of these facts are reflected in tract-based maps (Figs. 4A and D). Dividing this tract into constituent blocks isolates some of the agricultural and uninhabited areas but not all (Fig. 4B and E). Grid-based map (Fig. 4C and F) show the correct distribution of population along several roads present in this tract. The between roads areas in blocks with nonzero population are uninhabited agricultural lands. Due to the fact that populated locations constitute a small portion of the tract's area, the mapping benefits strongly from being based on block-level data or, even better, on the grid-based data.

The third example is the tract 6727.01 located in Sugar Land in the Fort Bend County,TX. This tract cover urban environment, but an aerial image of this tract (Fig. 5G) indicates the presence of significant sub-block uninhabited areas. This tract

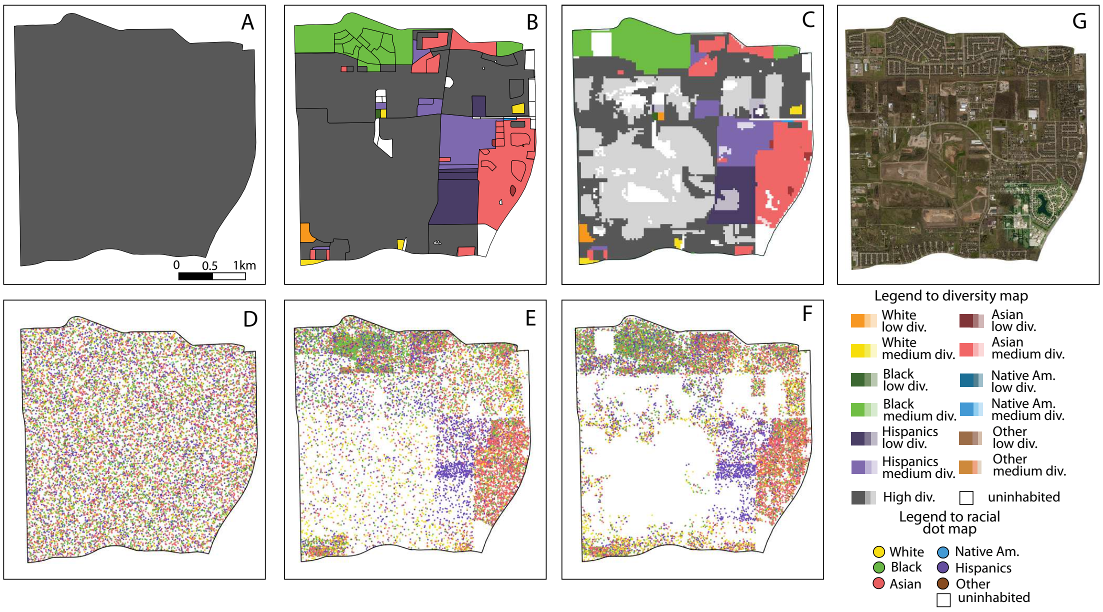


**Figure 5.** Comparison of racial diversity and dot maps of census tract 6727.01 in Sugar Land in Fort Bend County,TX using different areal units. (A) Racial diversity map based on census tract. (B) Racial diversity map based on census blocks. (C) Racial diversity map based on grid cells. (D) Dot map based on the census tract. (E) Dot map based on census blocks. (F) Dot maps based on grid cells. (G) An aerial image of the tract shows a distribution of inhabited and uninhabited areas.

is classified as having a highly diverse population (Fig. 5A and D). This conclusion is invalidated by mapping the tract at the block level (Fig. 5B and E). These two panels of Fig. 5 indicate that the middle of the tract is indeed inhabited by a highly diverse population but there are also parts of the tract, in the north and the east, inhabited by low diversity population. Using grid-based data we can further revise our conclusions about the racial configuration in this tract. Significant parts of the tract, those shown as diverse on block-based figures are indeed mostly uninhabited leaving most (but not all) parts of the tract best characterized as a low diversity (high segregation) areas. This is in a striking disagreement with a conclusion drawn on the basis of highly aggregated data (a tract level).

The fourth example is a tract 6607.01 in the Brazoria County, TX. This is another example of the situation where assessing racial diversity from tract-level data leads to wrong conclusions. Tract-based maps (Fig. 6A and D) indicate a highly diverse population. However, block-based diversity maps (Fig. 6B and E) and dot maps (Fig. 6C and F)reveal that this is true only for parts of the tract, with the remaining parts characterized by either medium diversity or low diversity. Unlike in the tract shown in Fig. 5, this tract does not have extensive uninhabited areas so the diversity maps and dot maps show similar, but not identical distributions; there are still some uninhabited areas correctly reflected on the grid-based maps and not reflected on the block-based maps.

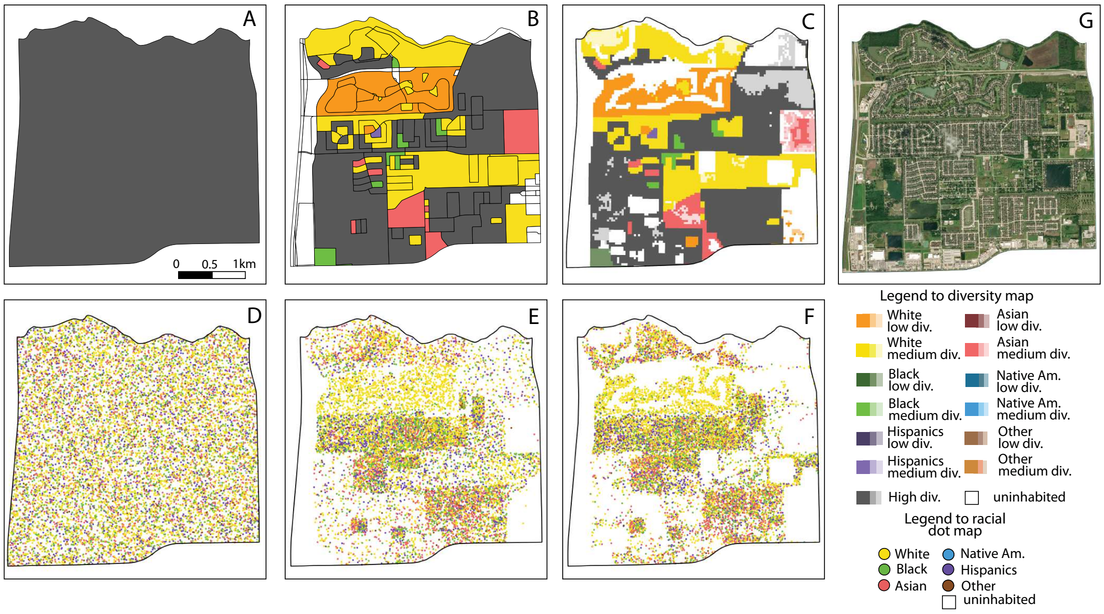


**Figure 6.** Comparison of racial diversity and dot maps of census tract 6607.01 in Brazoria County,TX using different areal units. (A) Racial diversity map based on census tract. (B) Racial diversity map based on census blocks. (C) Racial diversity map based on grid cells. (D) Dot map based on the census tract. (E) Dot map based on census blocks. (F) Dot maps based on grid cells. (G) An aerial image of the tract shows a distribution of inhabited and uninhabited areas.

## 4. Discussion and Conclusions

As we pointed out in the introduction section the use of maps for the purpose of visualization is on the rise in racial segregation/racial diversity research. Our goal in this paper was to compare three different methods (percentage maps, diversity/dominant race maps, and racial dot maps) for visualization of race geography, using three different data models (census tracts, census blocks, and high-resolution grid). Through the series of examples, we demonstrated that using tract-based data may result in an incorrect assessment of racial reality on the ground regardless of the visualization method. Therefore, our first conclusion is that tract-based data should not be used to visualize racial demography, especially on the local scale. Instead, the block-based data, or even better, the grid-based data should be used.

Our second conclusion is that percentages maps are a poor method for visualizing racial geography because they require several maps to convey an overall situation. Diversity/dominant race maps and dot maps are better visualization tools because they convey a lot of information in a single, easy-to-understand map. A diversity map illustrates three variables, a level of racial diversity, a dominant race, and a population density. It is a categorical map with the resolution corresponding to census tracts, census blocks, or grid cells depending on which data model is used. As we mentioned above, the tract-based variant has frequently too low spatial resolution to reflect the actual spatial configuration of race distribution. What the diversity map does not show is shares of races in a given location (in diversity map this information is compressed into diversity measure and a dominant race). A racial dot map illustrates two variables, population density, and a racial mix; the diversity can be visually inferred from the racial mix.

Which of the two methods of visualization is to be used, the diversity/dominant race map or the racial dot map? Based on the examples in this paper we recommend using racial dot maps if the study area is small (say a single tract or few tract). Dot map provides the most specific information and is least affected by cartographic generalization. Another choice to make is the data model. Which of the three data models, census tracts, census blocks, or grid, to use? We already recommended against using census tract model, so the choice is between census block and grid models. Based on the examples given in this paper, using grid data provides an advantage especially in areas with a significant portion of sub-block uninhabited area. When no sub-block uninhabited areas are present, block-based data can be used.

How to go about obtaining a ready-to-use visualization of race geography for of a specific study area? For diversity maps, there are two choices. First, diversity maps based on census-tracts for the entire U.S. (for years 1990, 2000, 2010) can be viewed and/or downloaded (by state or metro area) from the Mixed Metro project, (http://mixedmetro.com/). Note that those maps are tract-based and may have an insufficient spatial resolution. Also, note that the MixedMetro categories are based on diversity measure and dominant race but not on the population density.

Second, diversity maps based on the high-resolution grid for the entire U.S. (for years 1990, 2000, 2010) can be viewed and/or downloaded (by county, metro area, or direct selection from the map) from SocScape, (http://sil.uc.edu/webapps/socscape_usa/). SocScape maps are based on diversity measure, dominant race and population density. Grid-based diversity maps in this paper are taken from SocScape (tract-based and block-based diversity maps in this paper did not originate from a ready-to-use repository but instead were calculated). One advantage of SocScape is that a user can navigate a map of the United States and choose the diversity map of the study area for download by means of an adjustable rectangle. This is the fastest way to get a visualization of racial diversity for any area in the conterminous U.S.

Racial dot maps can be viewed, but not downloaded, at the University of Virginia (https://demographics.virginia.edu/DotMap/) website, and at the New York Times (https://www.nytimes.com/interactive/2015/07/08/us/census-race-map.html) websites. The map offered by the University of Virginia is based on block-level data but it cannot be zoomed close enough to see details. The map offered by the New York Times is based on tract-level data. These maps were not constructed with research in mind. In order to make dot maps available to the research community, we have made available for download (http://sil.uc.edu) grid-based dot maps (2010) for each county in the conterminous U.S.

With the availability of high-resolution maps of racial diversity/dominant race and racial dot maps, the social science community has now access to resources which allows for accurate visualization of racial geography down to the sub-tract level.

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