

Characterizing Rugged Terrain in the United States

Elizabeth A. Dobis, John Cromartie, Ryan Williams,
and Kyle Reed

What is the Issue?

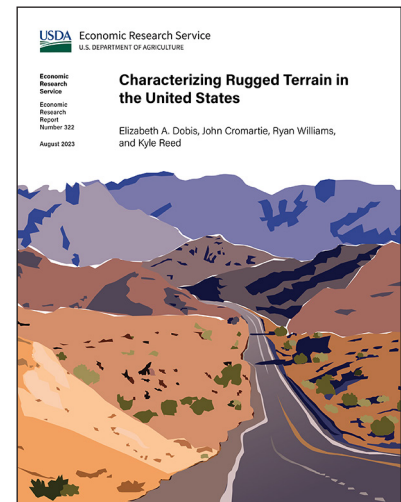
Rugged terrain affects communities and their residents in complex and often contradictory ways. Whether made up of mountains, canyons, or other landscape features with variable elevation, research has shown that rugged terrain bestows benefits on long-term residents and may spur economic growth through tourism and migration. Rugged terrain may also be a barrier to settlement and travel, limiting the amount of land available for development and making it more time-consuming for residents living in or traveling through rugged terrain to access needed goods and services. However, the role of rugged terrain as a barrier remains understudied, in part because of the lack of a geographically detailed measure of ruggedness.

In this report, we introduced two nationwide classifications of census tracts: the Area Ruggedness Scale (ARS) and the Road Ruggedness Scale (RRS). To our knowledge, these are the first detailed ruggedness measures with full nationwide coverage for the United States and the first to provide a roads-only version to help study the impact of rugged terrain on travel by car. These scales have the potential to contribute to research on the linkages between the geography and well-being of individuals, especially those living in rural areas.

What Did the Study Find?

In this report, we analyzed how population, population density, and income vary by ruggedness and rurality both nationally and across regions. To do this, we developed two census tract-level ruggedness scales:

- The Area Ruggedness Scale (ARS) has six categories based on the changes in elevation for all terrain and classifies census tracts as: (1) level; (2) nearly level; (3) slightly rugged; (4) moderately rugged; (5) highly rugged; and (6) extremely rugged.
- The Road Ruggedness Scale (RRS) has five categories based on the changes in elevation beneath roads and classifies census tracts as: (1) level; (2) nearly level; (3) slightly rugged; (4) moderately rugged; and (5) highly rugged.



ERS is a primary source of economic research and analysis from the U.S. Department of Agriculture, providing timely information on economic and policy issues related to agriculture, food, the environment, and rural America.

Analyzing by RRS categories, we found that nationally:

- In 2010, 11.6 percent of U.S. residents (35.7 million people) lived in slightly to highly rugged census tracts, and 1.4 percent (4.5 million people) lived in highly rugged census tracts.
- Population density was highest, on average, for nearly level census tracts (5,514 people per square mile) and lowest for highly rugged census tracts (3,390 people per square mile).
- As ruggedness increased, the share of the population living in rural areas increased from 16.1 percent for level census tracts to 29.7 percent for highly rugged areas. However, ruggedness is distinct from rurality as most people live in urbanized census tracts, even in the top ruggedness categories.
- Nearly 60 percent of residents in highly rugged, rural locations lived in low-income census tracts compared with about 42 to 48 percent of rural residents in less rugged census tracts.

Introducing regional variation to the ruggedness analysis, we found:

- The region with the largest share of its population living in highly rugged census tracts in 2010 was Hawaii (10.2 percent), followed by the Appalachian Mountains (6.1 percent). The Pacific Coast was the most rugged region for road travel, with 37.0 percent of its land classified as highly rugged.
- Among States, Washington had the largest share of highly rugged land (29.9 percent), but West Virginia had the largest share of people living in highly rugged census tracts (15.0 percent).
- The rural share of residents in highly rugged census tracts was much higher in the Intermountain West and the Appalachian Mountains (57.7 and 45.7 percent, respectively) and much lower in the Pacific Coast (18.6 percent). Thus, not only is the correlation between ruggedness and rurality low overall but regionally variable as well.

How Was the Study Conducted?

We used the Terrain Ruggedness Index (TRI) method of measuring topographic variability to develop two nationwide grid-cell datasets from the high-resolution, 0.15 square mile Global Multi-resolution Terrain Elevation Data 2010, which was developed by the U.S. Department of the Interior's U.S. Geological Survey and the U.S. Department of Defense's National Geospatial-Intelligence Agency. Two TRIs were developed—one using all grid cells nationwide (the Area TRI) and one using just the subset of grid cells that contain roads (the Road TRI). The TRI results were then aggregated to census tracts to create the ARS and RRS ruggedness scales.

Analysis of rurality, population, and population density across census tracts was conducted using data available from the USDA, Economic Research Service's (ERS) 2010 Rural-Urban Commuting Areas (RUCA) data file. Census tracts and population counts from the 2010 decennial census were chosen over the more recent 2020 data to match the current RUCA code classification. A list of low-income census tracts was obtained from USDA, ERS's 2010 Food Access Research Atlas (FARA) for the income analysis. The criteria used to identify low-income census tracts is from the U.S. Department of the Treasury's New Markets Tax Credit program.