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Quantitatively defining and mapping rural: A case study of North Carolina

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ABSTRACT

Contemporary research has measured differences between rural and its urban/suburban counterparts on the backdrop of social, economic, political and health phenomena. However, given the ambiguity of its definition, varying meanings and applications of the word 'rural' exist. In this paper we explored three different popular uses of the term rural on the backdrop of quantitative data with findings highlighting 1) there do exist statistical differences in data depending upon how rural is defined and 2) the definition of rural provided through the USDA's Rural-Urban Commuting Areas (RUCA) best aligned with other definitions of rural.

1. Introduction

Contemporary research has measured differences between rural and its urban/suburban counterparts on the backdrop of social, economic, political and health phenomena. In the United States, multiple government policies aim to address the inequity in rural versus urban well-being, as manifested in the lack of high-speed, reliable and affordable broadband services in most rural areas, less diversity of rural economies when compared to urban economies, and disproportionately low access to hospitals and other health care facilities for rural residents (USDA, 2020; Nelson et al., 2021; Dabson and Kumar, 2021; Kolodinsky and Goetz, 2021; Morris et al., 2022). The development and implementation of effective policies requires robust and reliable data to both target the funding and assistance to the communities in need and to evaluate the success of the policies (Goetz et al., 2018; Lamm et al., 2020; Mann et al., 2021; Dabson and Kumar, 2021; Parker et al., 2022).

The analyses of rural development trends to inform policies have traditionally relied on the data about the historically main rural economic activity, agriculture (Shellabarger et al., 2019), but have been more recently taking a broader view that better reflects the contemporary industrial composition including rural manufacturing (Low, 2020) and rural entrepreneurship (Goetz et al., 2018; Dabson and Kumar, 2021; Conroy and Low, 2022). Recent research highlights the diversity of rural areas in terms of both location relative to more populated areas and changes in population dynamics over time (Lamm et al., 2020; Dabson and Kumar, 2021). For example, Goetz et al. (2018) list three distinct types of the rural environments in the United States: high-amenity regions that have attractive landscapes such as lakes or mountains, metro-adjacent rural communities that benefit from the employment and growth of a large city, and remote or extractive-industry-based rural communities that struggle economically. The authors point out the different types of rural communities have distinctly different employment and overall well-being dynamics, and to the importance of using consistent operational definitions of rural for measuring over-time changes in population well-being. Our study complements these findings by pointing to the importance of the consistency of contemporaneous quantitative operationalizations of the concept of rural.

For the rural development policies to be effective, research and policy need to be integrating federal and state government, academia,

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and private sector perspectives (Low, 2020). The importance of having reliable, consistently defined and collected data goes well beyond government planning, evaluation, and accountability. The data are equally important for start-up businesses and existing companies to identify new market opportunities, especially with the changing rural industrial base, which, depending on the specifics of the location, might include amenity-based opportunities for tourism and recreation or the overhaul of extractive-based businesses (Goetz et al., 2018; Raimi et al., 2020; Conroy and Low, 2022). Nonprofit organizations, which fill the gaps not reached by the business and government sectors are another group that needs such data (Walters, 2020).

The operationalization of the term 'rural' has reverberating consequences in practical applications. For example, a review of the quantitative measures of rurality used in the recent health services research literature revealed that out of 103 studies considered, five different geographic delineations and 11 methodological approaches were used to measure rurality, complicating and possibly invalidating the comparison of the empirical estimates of the disparities between rural and urban obtained from alternative assessments (Danek et al., 2022). Notable is the United States Department of Agriculture (USDA) summary of Rural Programs (USDA, 2020), which highlights more than 40 programs designed to support rural America in areas such as telecommunications, electricity, community facilities, water, environment, business and housing. Programs have certain thresholds on which funding is based. For example, in the Water and Waste Disposal grant program designed to provide infrastructure for rural areas, public entities, Federally-recognized Indian Tribes and nonprofit corporations can only apply if their populations are less than 10,000. However, the threshold for rural in the Distance Learning and Telemedicine grant program is 20,000. Each program defines rural in their fairly simple (population) and more complex (regions outside of contiguous urban areas) ways.

In North Carolina, a tier system is employed into various state programs to encourage economic activity in the less prosperous areas of the state. Tiers are calculated using four factors: Average Employment Rate, Median Household Income, Percentage Growth in Population and Adjusted Property Tax Base per Capita. Many of the counties classified as Tier 1 (most distressed) for the upcoming year are located in traditionally rural counties in the eastern part of the state. Forty counties make up Tier 1, another forty counties compose Tier 2 while the remaining twenty counties make up Tier 3 representing the state's least distressed counties (North Carolina Department of Commerce, 2021). These tiers are revisited every year. For 2022, the eleven counties (Alexander, Brunswick, Buncombe, Chowan, Jones, Macon, New Hanover, Polk, Randolph, Rowan and Watauga) that changed tiers were largely driven by changes in unemployment and population growth rates compared to their counterparts.

Rural-specific research as well as research that involves a rural component typically use qualitative and colloquial applications of the term 'rural'. The most common quantitative operationalization of rurality relies on population density and/or distance from metropolitan areas (Bollman and Reimer, 2018; Nelson et al., 2021), although many researchers acutally do not define rural within the confines of their work. There are up to nine different definitions of the term rural used by the U.S. federal agencies such as the United States Census Bureau, Deparment of Commerce, Federal Office of Rural Health Policy, National Center for Education Statistics, Office of Management and Budget, USDA – Economic Research Service and USDA – Business and Industy Loan Program. With the variety of quantitative definitions, the important questions arise on the consistency of the major operational definitions of rural and the practical implications of the differences in identifying rural populations based on alternative, commonly used quantitative criteria for rurality highlighted in this research. We answer these questions using the state of North Carolina as a case study.

Within each agency, quantitative definitions provide strict guidelines as to how rural is defined, allowing for the expressing and mapping of rurality in a Geographic Information System (GIS). A GIS serves as the means by which spatially-explicit data can be created, analyzed and rendered in the digital environment. In the vector GIS data model where spatial phenomena are represented as points, lines and polygons, attributes describing individual features provide enhanced dimensionality so these features and corresponding attributes can be mapped, analyzed and correlated against each other. Within particular polygonal enumerations units, information related to voting patterns, socio-economics and health outcomes can be encapsulated and stored using overlay and geostatistical GIS techniques. Furthermore, information about this enumeration unit's setting (urban, suburban or rural) can be stored as categorical or Boolean data and analyzed spatially. With the prevalence of high-quality (spatial, temporal and attribute) data, the delineation of rural regions can be easily mapped within the confines of a GIS and catered to an organization's criteria for their definition of rural.

We chose North Carolina as a case study because different definitions of rural result in strikingly different estimates of what is considered rural. GIS to the data provided by the North Carolina State Demographer (mid-2020) are used to explore the number of municipalities and rural population impacted by the different definitional thresholds used by the federal U.S. agencies. Of North Carolina's 553 municipalities, more than 95% satisfy some definition of rural. However, given the most liberal definition of rural, barely more than 20% of North Carolina's population can be considered rural. This operationalization and visualization can also be expressed at smaller scales. The USDA publishes service area datasets that are used in the grant criteria evaluation process at a smaller, national scale. Data related to rurality include 100-mile buffer regions around urbanized areas with a population of greater than 50,000, Socially Vulnerable census tracts based on 15 social factors such as poverty, unemployment, income, vehicular access, group quarters and race. Another dataset representing Frontier and Remote areas that satisfy all the following criteria are also included in Fig. 1.

15 min or more from an urban area of 2500–9999 people
30 min or more from an urban area of 10,000–24,999 people
45 min or more from an urban area of 25,000–49,999 people
60 min or more from an urban area of 50,000 or more people

In these applications of rural, North Carolina is largely excluded. As a matter of fact, only 18 areas (ZIP codes in this case) of North Carolina's 763 ZIP codes are classified as Far and Remote areas and no regions are outside of the 100-mile buffer from urbanized places with a population greater than 50,000. Several of the definitions analyzed in this study were used in the recent efforts in North Carolina to delineate between rural and non-rural counterparts across various phenomena including the work on spatial database development and analysis of the food environment (Mulrooney et al., 2017a; Mulrooney and Wooten, 2021), voting patterns (Mulrooney and McGinn, 2021), socio-economic indicators (Mulrooney et al., 2017b) and health outcomes via the recent COVID-19 pandemic (Mulrooney and McGinn, 2021; Liang et al., 2021). In this paper we explore three popular quantitatively-defined uses of the term rural, and associated implications from policy perspectives. Using spatial and statistical analysis, we 1) explore the difference among and between various applications of the term rural on the backdrop of health, demographic, voting, health and socio-economic data, 2) quantitatively determine which, if any, of the definitions applied align better with other definitions, and 3) explore the practical implications of the differences in identifying rural populations based on alternative, quantitative criteria for rurality.

2. Background: defining and quantifying rural

The definitions of rural versus urban have gained significant interest among scholars in recent years. The increasing shocks and volatility experienced globally associated with the COVID-19 pandemic, international conflicts, and climate variations have imposed unprecedented

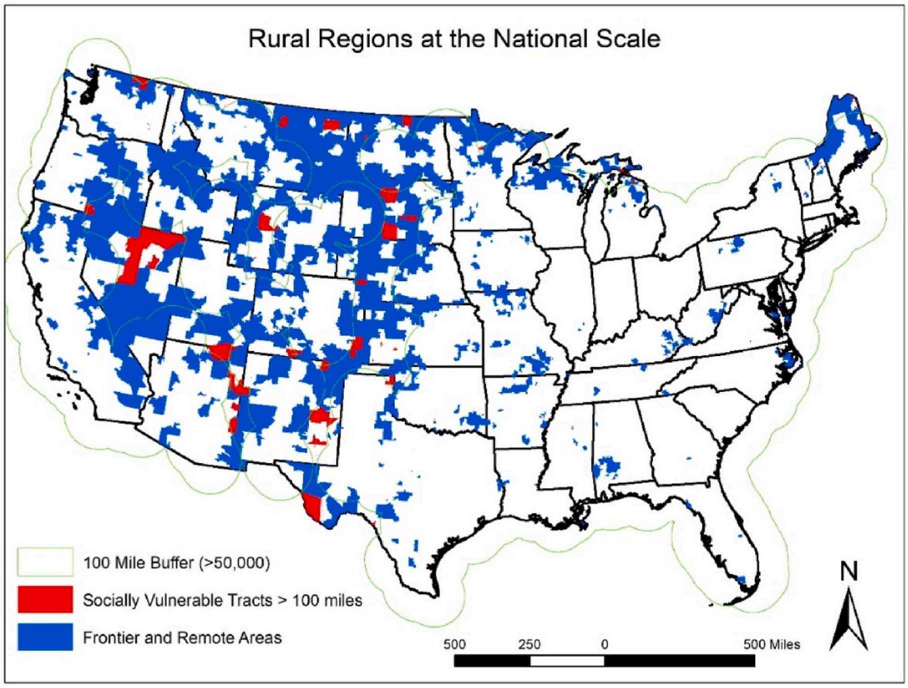

Fig. 1. Different ways to express rural within the USDA. (USDA, 2022).

impacts on rural communities. Studies have shown low-income and socially-disadvantaged populations living in rural areas seem to be more vulnerable while facing the challenges of economic stress and health disparity (U.N., 2020; Allcott et al., 2019; USDA, 2019; Coleman-Jensen et al., 2020; NAS, 2017; NAS, 2019).

From a demographic standpoint, the term 'rural' refers to regions with low populations and population densities; however, they present themselves differently. In places such as Iowa or Vermont, which have the highest proportion of rural residents (U.S. Census Bureau, 2005), a small town may occur every ten miles. However, in places such as California or Nevada where less than 10% of the population is classified as rural, vast regions of open land with little to no population due to physical barriers (deserts, mountains, etc.) also represent rural. The placement of resources and amenities as well as the implementation of policy vary greatly over these two rural places.

Many agree that there is no single definition of rural that best encapsulates the concept of rural across various applications, needs and scales (Nelson et al., 2021; Coburn et al., 2007; Coladarci, 2007; Cromartie and Bucholtz, 2008; Hart et al., 2005; Howley et al., 2005). Research by Hawley et al. (2016) notes articles which explicitly focus on rural research that provide a quantitative definition of the term. Some wonder if researchers themselves know the definition of rural within the context of their research and how it may vary from one definition to the next while Arnold et al. (2007) note there is no consensus definition of rural although the application of rural has profound implications on education policies. As a result, the interpretation of results invites unintended generalization as they highlight problems of overgeneralizing (grouping non-rural regions as rural) or underestimating (classifying truly rural regions as not rural).

Scale also is an important factor. For example, at the county scale, the USDA ERS developed a classification scheme that starts with the Office of Management and Budget metro and non-metro categories but sub-divides the two categories into three and six groupings, respectively (https://www.ers.usda.gov/data-products/rural-urban-continuum-codes). The resulting rural-urban continuum codes based on population totals and adjacency to high-population counties have become a backbone of the studies that seek to quantify the differences between rural and urban for larger, such as a state or a multi-state region, geographic areas. The recent uses of the rural-urban continuum codes include the analyses of water policy impacts (Zuniga-Teran et al., 2021), flood risk (Rhubart and Sun, 2021), and food insecurity (Beverly and Neill, 2022).

Cromartie and Bucholtz (2008) recognized the use of different boundaries based on administrative, land-use, socio-economic and population metrics to express rural. They found between 17% and 49% of the United States' population could be considered rural. This wide range of numbers is based on the inclusion of enumeration units designated as ranging from small towns with less than 2500 people in one definition all of the way to counties with less 50,000 people using another definition. Challenges include the many different units in which data are collected such towns, cities, ZIP codes, census block groups, census tract and counties, as well as population thresholds which define rural. While rural is typically defined as to what is it not, especially in these cases, all of these variations impact the number of people that can be calculated as rural.

Different applications and fields of study might also define the term differently. For example, as applied to the field of education, Haas (1991) and Gjelten (1982) tried to define and identify types of rural communities such as stable rural community, depressed rural communities, high-growth rural communities, reborn rural communities and isolated rural communities. In another application, Lorenzen (2021) studied how different factors influenced the rural gentrification and touristification in Mexico by drawing reviews of studies from the United Kingdom, North America, and Latin America plus own work on rural gentrification and touristification in Mexico. An argument presented by Lorenzen is that 'direct residential displacement is not a predominant impact of rural gentrification, although it is closely connected to other forms of displacement, including exclusionary displacement, socio-cultural displacement, commercial displacement, and the displacement of other animal and plant species.'

Many scholars have shed light in how definitions of rural and urban could influence economic development. Wineman et al. (2020) discussed economic transformation based on evidence from Tanzania, pointing the absence of a universal definition of rural and importance of categorizing populations by their rural or urban status for effective policymaking to advance sustainable rural livelihoods. Authors raised important issues when it comes to defining rurality such as continuous development in a dynamic interface between rural and urban, or observed shift between population density and realized economic transformation at the domestic and global level. Authors conducted analysis by using administrative, remotely-sensed, and survey-based data sources to explore the implications of applying different urban definitions in Tanzania, and investigated how different urban definitions affect the paths of urbanization in Tanzania and impacts of welfare and economic development in rural areas. Several key indicators used in this study include administrative definition, population density, impervious surface, night light intensity, local nonfarm economy as well as a subjective assessment. Authors further discussed pros (e.g., easy to set analysis threshold and contextually specific) and cons (e.g., missing rural towns with urban characteristics, does not capture multidimensional understanding, and dated data) of each indicator that could enhance or impede the interface between rural and urban development.

Other researchers have explored specific impacts of definitions of rurality on resource allocation such as land use in agriculture. Wang (2022), for example, offered new approaches to examine farming scenarios in Taiwan as a case study. Wang (2022) introduced that 'From the perspective of Callonian performativity, spatial terms such as 'rural' or 'urban' are not static, self-evident products that exist a priori, but are continually remade, performed and enacted by a range of practices, involving social arrangements and material assemblages.' This study used a land-use dispute case in Taiwan between farming communities and economic development planning to illustrate how a relational and material approach to comparative rural study that would be more appropriate to answer questions involving rural development, resource allocation, decision making in planning, and involvement of heterogeneous actors.

Morris et al. (2022) presented a modern scenario where small and medium-sized enterprises are dealing with challenges in the digital divide and seeking solutions in rural environments during COVID pandemic. This study used a survey of 110 businesses in Wales to examine their accessibility and connectivity to high-speed broadband and the impacts on business decisions. The findings revealed rural businesses faced significant limitations on business activities and opportunities due to lack of access to broadband, while COVID has driven many businesses to engage in online platforms. This limitation further restricted the development of rural business resiliency.

Most recently, Nelson et al. (2021) presented a comprehensive systematic review of the empirical and quantitative literature related to the definitions, measurements, and uses of rurality. This study shared in-depth justification, classification, categorization, and relationships from various ways to define rurality, and their associated impacts on economic development, resource allocation, opportunity accessibility, and policies in planning. Authors also revealed the importance to define and measure rurality as a key role to governance, community sustainability, health and well-being, and equitable access to services and amenities. 'Given the diversity of quantitative rurality measures, there is a need to determine what characteristics or components of rurality, units of measurement (scale), and operationalization methods are most consistently used in order to identify the strengths and shortcomings of existing quantitative conceptualizations and operationalizations of rurality. Identification of these strengths and shortcomings will allow for the advancement of the research on measures of rurality and their application to policy and practice. 'Through this pioneering work, authors recognized that 'We focus the discussion on how advances in geospatial processing and data availability have fundamentally changed how rurality is conceptualized and operationalized quantitatively, the various metrics and techniques used to create rural indices, how these different measures of rurality have been used, and the limitations and shortcomings of the research in this area.'

This paper is an attempt to quantify how different definitions of the term rural can have a profound impact on research results analyzing the same data and further underscore the mistake of using the blanket term rural without putting it into context or defining it. We present three different definitions of rural that can be mapped in a GIS and are described in Table 1. While not an all-inclusive list, these terms are used by different agencies and utilize empirical data to quantitatively define rural and its counterparts.

3. Methodology

Using the definitions described in Table 1, spatial analysis utilizing a GIS was run to assign each of North Carolina's 763 ZIP codes a rural or non-rural designation. GIS serves as the hardware, software and techniques by which spatially-related data can be created, stored, analyzed and rendered in the digital environment. In the vector GIS data model (as opposed to the raster data model where data are store as pixels), phenomena can be represented using points, lines and polygons. Within polygons, geometric properties of perimeter and area can be calculated. Using a GIS, attribute (e.g., number of ZIP codes with a COVID-19 prevalence rate greater than 500) and spatial (e.g., number of supermarkets located within 20 miles of a city) queries can be performed on the data.

Method 1 (Urban Areas and Urban Cores).

In this method, the United States Census defines rural to be all territory, population, and housing units not located within urbanized areas (UAs) and urban clusters (UCs). An urbanized area consists of densely developed territory that contains 50,000 or more people. An urban cluster consists of densely developed territory that has at least 2500 but fewer than 50,000 people. GIS data for urban areas and urban clusters were downloaded at https://catalog.data.gov/dataset/tiger-line-shapefile-2019-2010-nation-u-s-2010-census-urban-area-national. After *Clipping* (creating a dataset from a larger dataset based on a spatial query) this spatial dataset to the spatial extent of North Carolina, there are 19 urban areas and 96 urban clusters located within North Carolina. Using

Table 1
Different definitions of the term rural used in this research.

Name	Agency	Definition
Urban Areas and Urban Cores	*United States Census*	All territory, population, and housing units not located within urbanized areas (UAs) and urban clusters (UCs). An urbanized area consists of densely developed territory that contains 50,000 or more people. An urban cluster consists of densely developed territory that has at least 2500 but fewer than 50,000 people
Metropolitan/ Micropolitan Statistical Areas	*Office of Management and Budget*	County-level measurement devised by the Office of Management and Budget (OMB) where rural counties are defined to be neither Metropolitan (core area with >50,000 population together with county that have a high degree of economic and social integration with that core) nor Micropolitan (urban core between 10,000 and 50,000 population plus adjacent territory with a high degree of social and economic integration with the core as measured by commuting ties.)
Rural-Urban Commuting Areas	*USDA/Economic Research Service*	ZIP code level measure sponsored by the United States Department of Agriculture delineate metropolitan, micropolitan, small town, and rural commuting areas based on the size and direction of the primary (largest) commuting flows.

GIS analysis, all ZIP codes that intersect with an urban area were denoted as non-rural and all ZIP codes which contained the centroid of an urban cluster were also designated as non-rural. The remaining 384 ZIP codes encompassing a population of 1,627,085 were defined as rural.

Method 2 (Metropolitan/Micropolitan Statistical Areas).

Metropolitan Statistical Areas developed by the Office of Management and Budget (OMB) are county-level designations where rural is neither metropolitan nor micropolitan. Utilizing data provided by the United States Census (https://www.census.gov/data/datasets/time-series/demo/popest/2010s-total-metro-and-micro-statistical-areas.html), these tabular data were *Joined* (appending tabular data to a spatial data table) to a GIS data layer of counties using the county name as a key. In the resulting join, all counties that were denoted as metropolitan and micropolitan were denoted as non-rural. The remaining 34 counties were denoted as rural. Rural ZIP codes were calculated to be a ZIP code whose centroid was contained within a rural county. Using this method, 191 rural ZIP codes were found, containing a population of 1,035,712.

Method 3 (Rural-Urban Commuting Areas).

Lastly, the United States Department of Agriculture provides Rural-Urban Commuting Areas (RUCA) through the Economic Research Service web site at the ZIP code scale. RUCA stores ordinal codes (1 through 10) to delineate metropolitan, micropolitan, small town, and rural commuting areas based on the size and direction of the primary (largest) commuting flows. Organizations such as the Health and Humas Services Administration (2021) and Rural Health Information Hub (2019) denotes rural to be RUCA codes 4 through 10. Using tabular data provide through the ERS site (https://www.ers.usda.gov/data-products/rural-urban-commuting-area-codes/), RUCA data are provided at the ZIP code scale. These data were *Joined* to a GIS data layer using the ZIP code as the key. A tabular query was run to find ZIP codes with RUCA codes 4 through 10; the result are 320 ZIP codes with a population of 2,330,220.

A summary of these methods is highlighted in Table 2 which represents the number of ZIP codes and accompanying populations for each cohort of rural and urban population.

3.1. Data

In order to determine how definitions of rural may differ across various disciplines, data transcending these disciplines were collected at the ZIP code scale (Table 3). The reasons for this are interrelated. The finest scale at which COVID-19 data are collected in North Carolina is the ZIP code. While voting data and socio-economic data are provided at finer scales (voting precincts and block groups, respectively), calculating COVID-19 rates at this scale requires the use of GIS operations such as Intersects and Clips, the inherent spatial error attached to them and the subsequent interpolation, scaling or prorating of COVID-19 data. Not only does developing data in ZIP codes maintain spatial and attribute integrity, it makes for easy non-spatial comparisons with more confidence that could not be done when combining scales.

While some of these data were relatively easy derive, others were more difficult to calculate. Income and race were extracted from the American Community Survey while COVID-19 data were extracted from the North Carolina COVID-19 Dashboard (North Carolina Department for Health and Human Services, 2021). Voting rates were calculated as the percent of voters who are registered as Democrat for the 2020 general election based on more than 7 million voter registration records provided by the North Carolina State Board of Elections (North Carolina State Board of Elections, 2020). Using ZIP code centroids and healthy food sources (supermarkets and farmer's markets) extracted from business data provided by InfoUSA (now DataAxle), the *Near* calculation was used to calculate the Euclidean distance between the ZIP code and nearest healthy food source for the variable DIST_SUPER. Other absolute measures do exist such as network distance (Pearson et al., 2005; Morland and Evenson, 2009) and travel time (Ver Ploeg et al., 2009; Jiao et al., 2012) between individual addresses and food locations, but require more data preparation and processing, thus taking from the goal of this paper.

Table 2
Summary of totals and population of rural population by method employed.

# of ZIP Codes	Method 1 (Census)	Method 2 (MSA)	Method 3 (RUCA)
Rural	384	191	320
Urban	379	572	443
Rural Population	1,627,085	1,035,712	2,330,220
Urban Population	8,789,535	9,380,908	8,086,400

Table 3
Data collected at the ZIP code scale.

Variable	Explanation	Data Source
MED_HH_INC	Median Household Income in 2019	American Community Survey
PER_MINORTY	Percent of Minority (non-White) residents in 2019	American Community Survey
COV_RT_0930	COVID-19 Rate (per 10,000 residents) as of 9/30/2020	North Carolina COVID-19 Dashboard
COV_RT_0124	COVID-19 Rate (per 10,000 residents) as of 1/24/2021	North Carolina COVID-19 Dashboard
COV_RT_0513	COVID-19 Rate (per 10,000 residents) as of 5/13/2021	North Carolina COVID-19 Dashboard
PER_DEM_2020	Percent of voters who are registered as Democrat for 2020 general election	North Carolina State Board of Elections - Results and Data: Voter Registration Data
DIST_SUPER	Distance in miles between ZIP code and nearest supermarket	American Community Survey and InfoUSA
mRFEI	Modified Retail Food Environment, which represents the percentage of supermarkets and farmers markets versus total number of food providers within a ZIP code.	American Community Survey and InfoUSA

Relative metrics such as the mRFEI (Modified Retail Food Environment Index) represent the percentage of health food providers versus all food providers (Centers for Disease Control and Prevention, 2011). Food sources were derived from the InfoUSA database via a business' NAICS (North American Industry Classification Standard) code, where supermarkets, groceries and markets were defined as "healthy" food while "less healthy" food was represented by convenience stores, limited-service restaurants and fast-food restaurants. The mRFEI was calculated using a *Spatial Join* function, which counts the number of point phenomena (cohorts of healthy and less healthy food providers) within polygonal enumeration units (ZIP codes in this case). The mRFEI is the ratio of these healthy providers to all food providers because of these functions.

$$mRFEI = 100^* \frac{\#\ Healthy\ Food\ Providers}{\#\ Healthy\ Food\ Providers + \#\ Less\ Healthy\ Food\ Providers}$$

The end-result of these analyses is a table with each of these eight variables calculated with their values ($ per year, rates, percent, COVID-19 cases per 10,000 people, distance in miles and ratio) along with three additional columns designating Boolean values (rural or non-rural) for each method as a result of the spatial analysis.

3.2. ANOVA (analysis of variance)

Since the assumption of this paper and most rural research is that phenomena will differ between rural areas and non-rural counterparts, it is generally understood economy, demographic, health outcomes and other metrics will vary based on rurality, however the term is applied. Comparing rural and non-rural populations using an independent test of two means for each of the variables in Table 3 will yield differences as shown in Table 4. Median Household Income is statistically different between rural and non-rural at $p < .01$ across all methods. However race, measured as percent minority is lower in rural areas using one method, higher using another method while no differences exist using a third method. Other differences or varying levels of significant difference also exist between COVID-19 rates (May), voting patterns and mRFEI (Modified Retail Food Environment Index). While these results are understandable given the nature of this research and the differences between significance levels for the same data across different methods are interesting, they underscore how the use of the term rural can have drastic ramifications on the results of simple comparisons and also serve as a justification to utilize a more nuanced tool to explore differences across all three cohorts.

As a result, a single-factor ANOVA (Analysis of Variance) was employed. A single-factor ANOVA is used to determine if the means of at least three groups are different. In exploring COVID-19 rates (as of 9/30/2020), 384 ZIP code values representing rural COVID-19 rates from Method 1 were compared against 191 COVID-19 rates defining rural using Method 2 lastly against 320 COVID-19 rates defining rural using Method 3. Using the means of all data sets as well as the mean for the entire group to determine if there is sufficient evidence that a statistically significant difference exists between the mean measures of the three groups across the variables collected.

3.3. Jaccard Index

The Jaccard Index or Jaccard Similarity Index is a statistic for gauging the similarity and diversity of sample sets. A Jaccard Index is useful when the values for enumeration units are Boolean or categorial, as opposed to numeric where comparisons can be made using correlation and regression techniques. In this case, a Boolean value (1 = rural, 0 = non-rural) for one ZIP code using one definition of rural was compared to another definition of rural for the same ZIP code. It measures the intersection (values that are common between two different methods) when compared to the union (all values between different methods) between all 763 ZIP codes. The Jaccard Index ranges between 0 (complete dissimilarity) to 1 (complete similarity).

$$J(A,B) = \frac{A \cap B}{A \cup B}$$

While Python programming solutions can be developed to derive these metrics since no current out-of-the-box tools exist in GIS software, this can also be done using the *Field Calculation* (calculating a new column from existing columns) and *Summarize* (counting the number of times a value appears) tools in Esri's ArcGIS Pro Software. Using loosely-coupled applications, tabular data representing these metrics and rural designations at the ZIP code level can be exported to a spreadsheet application and metrics calculated as well.

4. Results

GIS analysis was used to visualize each of the different definitions of rural as shown in Fig. 2. Overlay analysis was used to map the number of times ZIP codes satisfied the definition of rural. The 107 ZIP codes that satisfied all three definitions of rural are highlighted in red in Fig. 2. 299 ZIP codes did not satisfy rural across any of the three definitions utilized in this paper and are represented in green.

4.1. ANOVA

An analysis of variance (ANOVA) was run between three methods to represent rural across seven different variables (Table 5). ANOVA extends the pairwise independent *t*-test one step further by exploring statistical differences between three or more groups. In this case, the average for median household income was run between 384 ZIP codes using the definition of rural using.

4.2. Jaccard Index

Method 1 against the average median household income for 191 ZIP codes using Method 2 against the median household income for 320 ZIP codes using Method 3. Based on the way rural is defined, the average of median household income from the 384 ZIP codes in Method 1 is statistically different than the 191 ZIP codes in Method 2 and the 320 ZIP codes in Method 3. This process was repeated for the seven other variables. For five of the eight variables, the means were statistically different across the three different methods with varying levels of significance.

A Jaccard Index was run to find the pairwise similarity between two different methods using the ratio of the intersection versus the union of the sets in question (Table 6). Boolean classifications of rural for each ZIP code (1 = rural, 0 = non-rural) was compared between the methods. Values range from 0 (no similarities between two methods across all 763 ZIP codes) to 1 (all values between two methods are equal across all 763 ZIP codes). While values of 1 are impossible because each method has a different number of rural ZIP codes, the most similarity was found between Method 1 (Census) and Method 3 (RUCA) where almost 75% of the ZIP codes were had similar classifications of rural. Adding the Jaccard Indices for the three methods against each other highlights Method 3, underscoring the highest agreement between the two methods.

5. Discussion

Deriving data using quantitative definitions presents a unique set of challenges. Given the OMB's requirements for urban cores in Metropolitan and Micropolitan Statistical Areas (MSA and μMSA, respectively), larger counties containing higher populations may be classified as rural when in fact they do have elements of their non-rural counterparts. For example, Sampson County, with a population of 63,991, ranks 43rd in the state for population, but is classified as rural. Its population is largely dispersed over an area of 962 mi^2 whose largest town (Clinton, population 8596) is slightly below the threshold for an urban core. ZIP codes in 30 counties with lower populations than Sampson County are classified as metropolitan or micropolitan based on their proximity and/or adjacency to counties that contain urban cores. In support of this, Perquimans County, part of the Elizabeth City Micropolitan Statistical Area (pop. 53,693), has the 11th lowest population in the state (13,740), yet is classified as non-rural according to the OMB based on its proximity to Elizabeth City.

Table 4
Results of two-tail *t*-test comparing rural and non-rural metrics at the ZIP code scale in North Carolina.

	MED_HH_INC		PER_MINORITY		COV_RT_0513		PER_DEM_2020		mRFEI	
	Rural	Non-Rural	Rural	Non-Rural	Rural	Non-Rural	Rural	Non-Rural	Rural	Non-Rural
Method 1	$42,918***	$52,471***	26.81***	31.07***	778.74***	902.33***	28.72	28.85	17.31***	11.31***
Method 2	$40,259***	$50,136***	31.95**	27.92**	821.22	846.45	31.56***	27.86***	14.20	14.38
Method 3	$41,047***	$52,443***	28.52	29.23	810.48**	861.55**	30.13**	27.81**	16.00*	13.12*

Statistically different at *ρ < 0.1 **ρ < 0.05 ***ρ < 0.01.

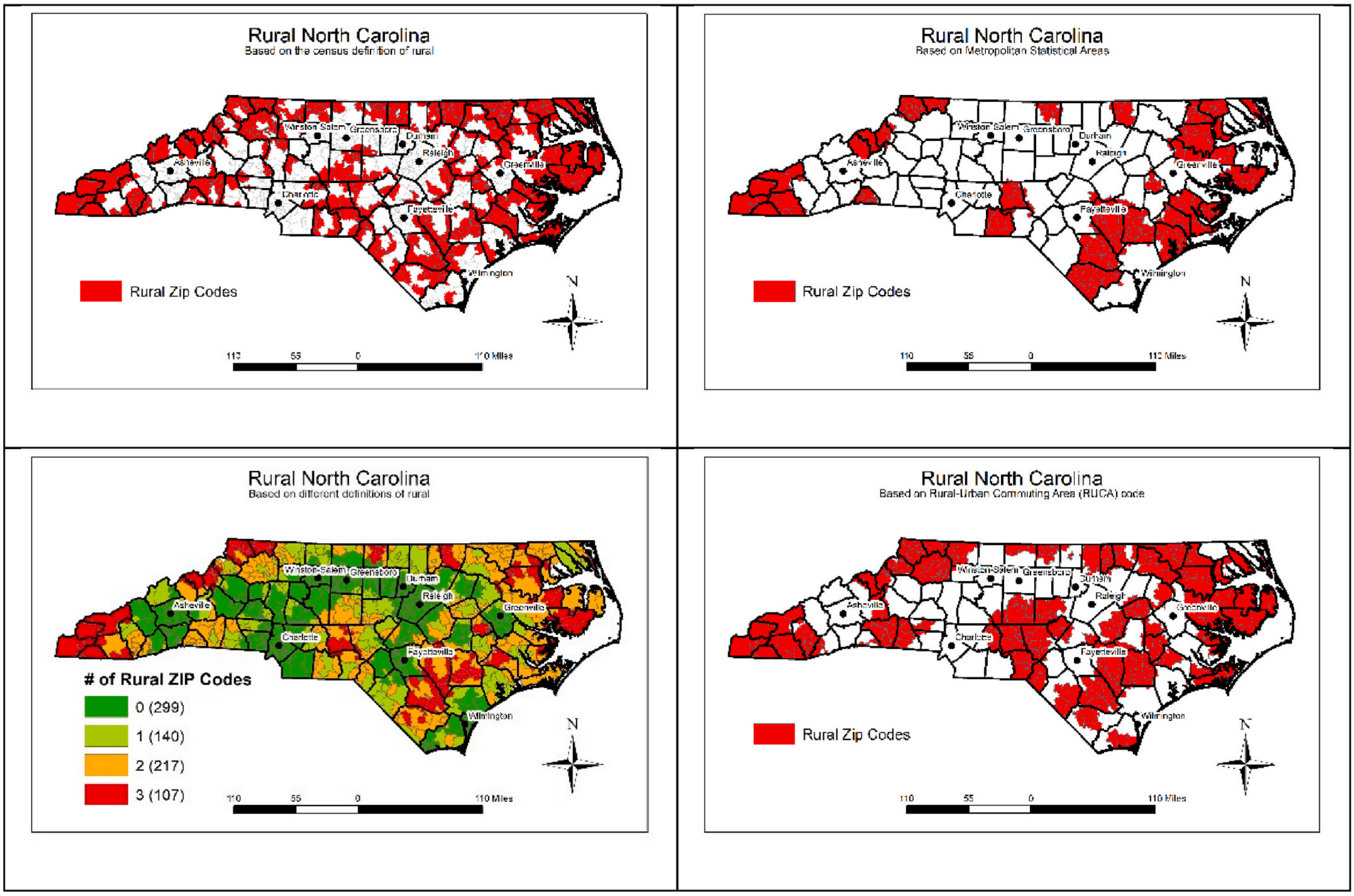

Fig. 2. Different definitions of rural in North Carolina. From top left, rural ZIP codes are highlighted in red based on 1) Census definition of rural (Method 1) 2) County-level metropolitan and micropolitan statistical areas (Method 2) 3) Rural-Urban Commuting area (Method 3) and 4) ZIP codes based on the definition of rural as applied from the three methods. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 5
Results from ANOVA analysis.

Variable	Method 1 (n = 384)	Method 2 (n = 191)	Method 3 (n = 320)
MED_HH_INC	42,918.40***	40,258.79***	41,046.84***
PER_MINORITY	26.81**	31.95**	28.52**
COV_RT_0930	165.61**	193.56**	186.68**
COV_RT_0124	625.01	594.67	631.27
COV_RT_0513	821.22	810.48	778.74
PER_DEM_2020	28.72*	31.56*	30.13*
DIST_SUPER	4.99**	5.51**	4.68**
mRFEI	17.31	14.20	16.00

Statistically different at *$\rho < 0.1$ **$\rho < 0.05$ ***$\rho < 0.01$.

Table 6
Matrix results of Jaccard Index analysis.

	Method 1 (Census)	Method 2 (MSA)	Method 3 (RUCA)	Sum
Method 1	–	0.653	0.746	1.398
Method 2	0.653	–	0.666	1.318
Method 3	0.746	0.666	–	**1.412**

Furthermore, the Rural-Urban Commuting Area (RUCA) codes use ordinal values to classify levels of urbanity based on population and commuting patterns. Values range from 1 (Metropolitan area core: primary flow within an urbanized area (UA) to 10 (Rural areas: primary flow to a tract outside a UA or UC) representing the most rural ZIP codes. While this research represented rural as RUCA values 4 (Micropolitan area core: primary flow within an Urban Cluster of 10,000 to 49,999 (large UC)) through 10 as some prior research had done, other definitions of rural could be utilized. For RUCA values 4 through 10, 320 ZIP codes were classified as rural. If rural was classified as greater than 5 (Micropolitan high commuting: primary flow 30% or more to a large UC) or 6 (Micropolitan low commuting: primary flow 10%–30% to a large UC), 263 and 194 ZIP codes, respectively, would be classified as rural. This may change results.

The impact of the operational definition of rural has a profound effect on the distributional aspects of the public policies aiming to support rural development. Rural Development programs of the USDA have invested $31 billion, $28 billion, and nearly $40 billion in rural areas in 2018, 2019 and 2020, respectively (https://www.rd.usda.gov). In the portfolio of these programs, rural business and cooperative programs have the highest community threshold, up to 50,000, while rural utilities programs have smaller thresholds, up to 20,000 (six programs), up to 10,000 (three programs, or up to 5000 (one program) (USDA, 2020). The largest in terms of the overall budget program funded under the USDA Rural Development umbrella of loan programs in 2020, Single-Family Housing Loan Guarantees program, invested $23.1 billion in the communities up to 20,000 (in special cases the communities of up to 35,000 were also eligible). In contrast, the third largest in spending, Business and Industry Loan Guarantees, invested $1.7 billion with the eligibility threshold of up to 50,000. Our findings about the significant impacts of the differences in definitions on identification of rural areas imply a careful consideration needs to be given to the design of the policies to ensure that intended communities have indeed been served.

6. Conclusions

The differing quantitative definitions of rurality result in conflicting narratives about over-time changes in population well-being (Goetz et al., 2018), local business opportunities (Conroy and Low, 2022), and the roles of nonprofit organizations in the society (Walters, 2020). This ambiguity, in turn, might lead to conflicting understanding of the rural-urban inequity and the needs of the rural communities. We found the concept of rural presents itself differently throughout the state of North Carolina. Rockingham County, part of the Greensboro-High Point Metropolitan Statistical Area (MSA), contains ZIP codes that satisfy none, one or two definitions of rural. To its east, Caswell County contains 13 ZIP codes; four of them satisfy all definitions of rural while another four satisfy no definitions of rural, largely due to their proximity to Burlington as shown in Fig. 3.

Eight variables related to income, demographics, health (COVID-19 rates across three different dates), voting patterns and the food environment were collected at the ZIP code scale. Using each quantitative definition of rural, ZIP codes were classified as rural or non-rural according to each of the three agencies. An independent test of two-means was used to highlight differences between rural and non-rural across these eight variables. While some variables such as median household income highlighted significant differences between rural and non-rural across all three methods as expected, others did not. In one instance, percent minority were higher in rural regions with statistical significance at the $\rho < .05$ level according to the OMB, lower according to Census at the $\rho < 0.01$ level and not statistically different according to the USDA - ERS.

Disparity between rural and non-rural is expected; however, this inconsistency was not expected. An ANOVA was performed to explore differences in means between three different cohorts. In this case, an ANOVA was used to calculate the mean of median household incomes for rural ZIP codes according to their Census, OMB and USDA definitions, returning a level of significance regarding these differences. Of the eight different variables explored, one (median household income) was different at the $\rho < .01$ level; median household income displays distinct and statistical differences based solely on the way rural is expressed. Another three variables were different at the $\rho < 0.05$ level and another one was different at the $\rho < 0.1$ level. This underscores how the use and application of the term 'rural' can have drastic impacts on research results.

A Jaccard Index was used to run a pairwise comparison to compute the similarity between different definitions of rural. The most similarity was found between Method 2 (OMB) and Method 3 (RUCA), where almost 75% of elements matched. A Jaccard Index was run between the two other permutations (Method 1 vs. Method 2 and Method 1 vs. Method 3) and the sums of the indices were added. Across all three permutations, the Jaccard Index for Method 3 (RUCA) had the highest sum, indicating the most similarity between the other two in terms of defining rural. These similarities may exist for a few reasons to include 1) a more restrictive definition of rural based on both population density (basis for urban clusters/cores) and commuting patterns 2) more granularity in RUCA designations (10) versus their census (3) and OMB (3) counterparts and 3) the ZIP code scale, which is better than OMB (county). This can be expanded out to explore all definitions of rural that can be expressed in a GIS.

As applied to the aforementioned tiers as shown in Fig. 4, while differences in income should be obvious since they are analyzed as part of the tier designation, ANOVA analysis of these tiers highlight distinct differences between the other seven variables as shown in Table 7.

Further reinforcing these numbers are a breakdown of the rural population by Tier and method explored in this study. As shown by Table 8, both the highest population, as well as percentage of rural population (% of rural population across all tiers by method), belonged to Method #3. Rural populations defined by Method #3 in Tier 1 counties number more than 1.2 million. This is 476,000 more than Method #1 and 685,000 than Method #2 for just rural population along among Tier 1 counties. These numbers provide ample justification how the application of this method to justify rural population via the tier system can have major policy-making decisions across significant rural populations in our state.

In this study, we compared only the measures based on the same, most common approaches, population density and distance to urban areas. However, other ways to operationalize urban vs. rural are also possible. For example, Nelson et al. (2021) found a sizable portion of the recent literature defined rural/urban based on land cover; i.e., by identifying the land cover that is attributable to populated areas (developed land) vs. agricultural, forested or natural land. In recent years, multiple GIS-based, consistently maintained and updated databases on land cover and use become easily accessible to both researchers and practitioners (Yang et al., 2018; Lark et al., 2021). An investigation of the implications of using the population density approach versus land cover approach for quantification of rural would be an exciting future research topic.

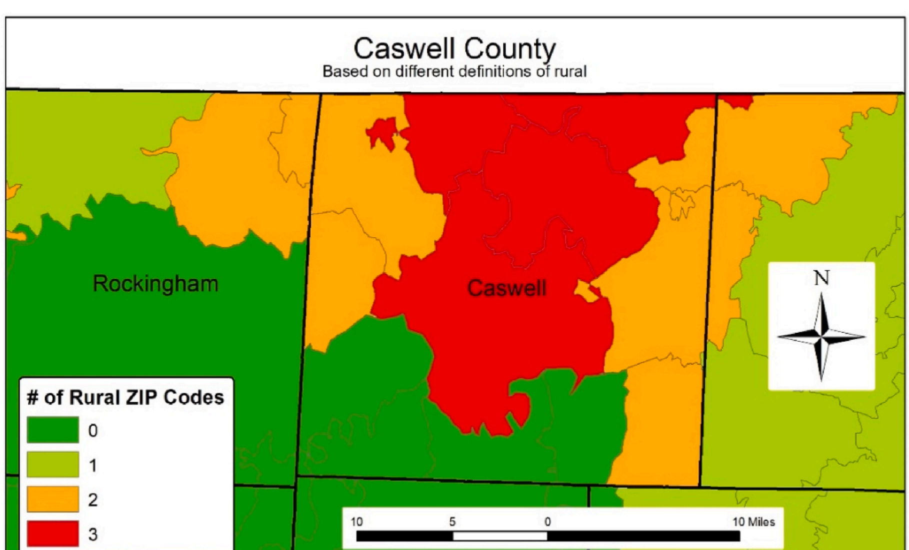

Fig. 3. The different number of definitions of rural in Caswell County.

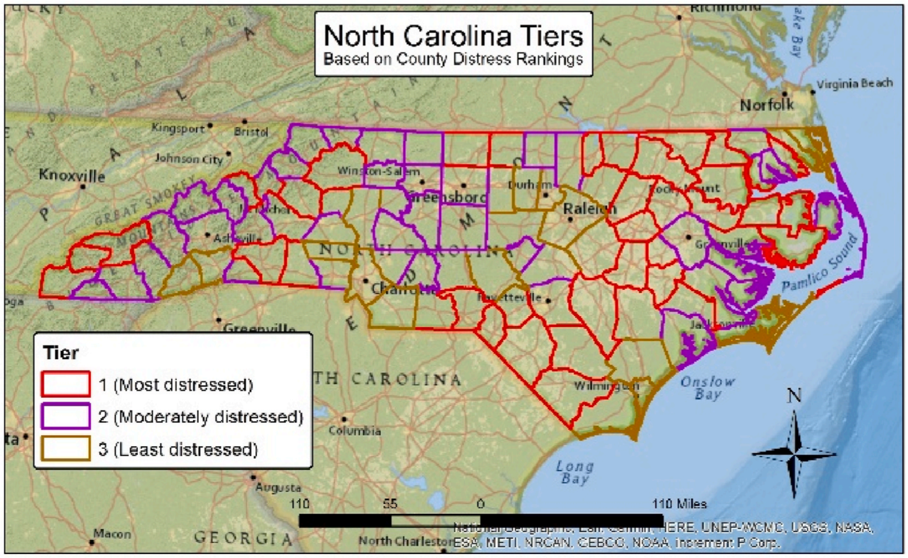

Fig. 4. County-level tiers defined by the North Carolina Department of Commerce.

Table 7
Results from ANOVA analysis based on tiers.

Variable	Tier 1 (n = 242)	Tier 2 (n = 290)	Tier 3 (n = 222)
MED_HH_INC	38,736.76***	46,750.44***	58,623.69***
PER_MINORITY	41.87***	21.28***	25.13***
COV_RT_0930	223.17***	152.60***	157.41***
COV_RT_0124	707.59***	601.27***	548.02***
COV_RT_0513	925.24***	822.08***	771.66***
PER_DEM_2020	36.50***	24.35***	26.22***
DIST_SUPER	4.33***	3.68***	2.74***
mRFEI	16.58***	15.14***	10.79***

Statistically different at *$\rho < 0.1$ **$\rho < 0.05$ ***$\rho < 0.01$.

Table 8
Summary of method and rural population by tier.

	Method 1 (Census)	Method 2 (MSA)	Method 3 (RUCA)
Rural population in Tier #1 Counties	744,176	534,347	1,220,212
Rural population in Tier #2 Counties	617,868	479,686	747,069
Rural population in Tier #3 Counties	265,041	21,679	362,939

In conclusion, the designation ‘rural’ at any scale has serious and reverberating economic, political, policy and social implications. Various definitions of rural exist. This paper is an attempt to quantify, map and highlight the difference in how rural is expressed across various agencies using the state of North Carolina as an example. While readily-available population, transportation and economic data at different scales allow one to also define and map rural as they see fit, this paper explored definitions of rural used by three separate agencies: the United States Census Bureau, the Office of Management and Budget and the USDA – Economic Research Service. More definitions for rural exist and merit further research, but in this paper the research team found:

- While there are obvious differences between rural and non-rural across all variables studied, differences were highlighted at various levels of significance.
- Using ANOVA analysis, distinct and statistical differences based solely on their definition of rural were found for more than half of the variables studied.
- Using the Jaccard Index and comparing pairwise t-tests between each method across all seven variables, the definition of rural as per the Rural-Urban Community Areas (RUCAs) utilized by the United States Department of Agriculture – Economic Research Service best aligned with the other definitions of rural.

In order to perform rural research, researchers need to have a clear and explicit understanding of the term rural and atriculate this understanding throughout their research. As shown in this work, different definitions of rural exist which can severely impact research results as well as managerial decisions and policy implications targeting various socio-economic characteristics.

Author statement

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Data availability

Data will be made available on request.

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