June 15, 2001

Population Density vs. Urban Population:
Comparative GIS Studies in China, India, and the United States

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Paper for presentation in session S68 on "Population Applications of Spatial Analysis Systems (SIS)" at the IUSSP Conference in Salvador, Brazil, August 18-25, 2001.

Introduction

Traditional measures of urbanization based on administrative and political geographic units are inadequate to address many questions related to population settlement patterns and ecological issues that arise in recent comparative studies. National differences in the definition of urbanization and the dependence of those definitions on administrative designations of political subunits have always made cross-national comparisons difficult. In studies of the relationship between population and the environment, these differences are heightened by the ecological emphasis on the natural environment. Urbanization is usually conceptualized as a characteristic of the population or society, but in ecological studies there is equal interest in defining urbanization in terms of land use and land cover characteristics (McIntyre *et al*. 2000; Foresman *et al* 1997). While measurement differences are difficult enough to deal with when comparing the percentage of the population that is urbanized, they are much more likely to cause variation in the percentage of the land area in urban designated areas. The choice of geographic unit of analysis and definitional criteria and methodology can result in varying degrees of “overbounding” or “underbounding,” sometimes within the same area (Buckwalter and Rugg 1986). The differences in overbounding and underbounding that are annoyances in the measurement of population size become major problems for measuring the extent of urban land use.

Because ecologists often are interested in how landscapes and the environment have changed over time, changing definitions of urbanization within a given nation also pose difficulties for analysis. In the U.S., demographic data from past censuses are presented only for administrative and political geographic units. Identifying degrees of urbanization in the past is made more difficult by the paucity of population and land use data for small geographic areas comparable to the “patches,” or small study areas, that feature in ecological research (Ratcliffe and Foresman 1999). The lack of detailed population and spatial information often requires use of cartographic methods for defining urbanization; that is, reliance on mapped portrayals of urban extent (Foresman *et al.* 1997; Crawford *et al.* 1996). Lack of census geographic area boundary information also poses problems when linking historical demographic data for urban populations with information relating to environmental processes. Portrayal of populations using point data and depicting urban growth and extent through various modeling procedures (i.e., cellular automata or fractal geometry models) can overcome problems relating to lack of boundary information (Foresman *et al*. 1997).

Defining levels of urbanization is made more difficult by the fact that it is both a discrete *phenomenon* that can be observed and measured in place at a specific time, and a *process* that occurs across space and time (Galster *et al*. forthcoming). The difference between urbanization as a phenomenon and urbanization as a process creates challenges for researchers and policy makers who base conclusions and decisions on observation and measurement of something that has happened in order to affect changes and develop policies in advance of something that will happen. There is no easy solution to the tension created by this dichotomy—we must define and measure the thing in order to understand the process and its ecological effects.

This paper examines the difficulties in comparative urbanization measures among three case studies: the Pearl River Delta of China, the Indian state of Kerala, and the southern part of Florida in the United States. These areas are among the areas being studied in a forthcoming joint study of population and land use by Indian, Chinese, and U. S. National Academies of Science (National Academy of Sciences, forthcoming). It proposes a population density measure of urbanization that takes advantage of the detailed data on small area populations and land area available in modern censuses and the increasing availability of statistical manipulations in geographic information systems (GIS). The resulting density distributions offer greater potential for understanding and portraying the ecological effects of urbanization than do traditional urbanization measures with the additional advantage of comparative measures that minimize the effects of national differences in urban definitions.

Population and Land Area

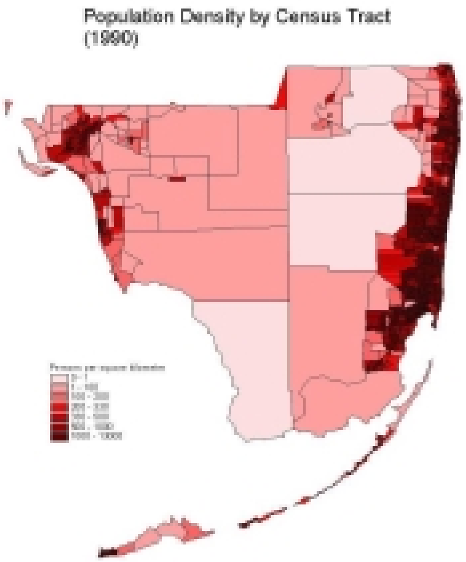
The countries in this study, China, India, and the United States of America, are the world's three most populous countries. In the year 2000, China had an estimated population of 1.261 billion; India had 1.014 billion people; and as of April 1 the population of the United States had reached 281,421,906 (U. S. Bureau of the Census, 2000). While the combined population of these three countries accounts for approximately 42 percent of the world's population, the countries occupy only 15 percent of the world's land area. How these countries handle their land and population relationships will have a major impact on how all nations cope with population pressures on environmental resources.

The crudest measure of that relationship is a simple population density measure, that is total land area divided by total population. The three countries differ substantially on their level of population density. In 1998, the world's population density was almost 40 persons per sq. km. The U. S. population density was only 28 persons per sq. km., a level substantially below the world average. The population density in China at 130 people per sq. km. is more than three times the world average, even though vast arid areas in the western part of China are sparsely populated. India is one of the more densely populated countries of the world. Its density of 307 people per square km. puts it at almost eight times the average world population density.

Simple population density can be modified by accounting for low density land set aside for non-residential urban uses, such as industrial, commercial, and retail uses as well as parklands. Calculation of net residential densities yields a more accurate depiction of population densities, but does not present an overall depiction of the extent of urbanization. In addition to accounting for different kinds of land uses and land covers in the definition of urbanization and calculation of population densities, we should also consider that patterns of urbanization differ from one location to another depending on local topography, land use regulations, cultural preferences, and so forth. To be truly useful for ecological researchers, definitions and measurements of urbanization should be multi-dimensional, taking into account patterns of urban development from one place to another resulting in differences in levels of population density, concentration of residential or commercial uses within specific areas, mixing of residential and commercial land uses, amount of intervening land devoted to non-urban uses, and so forth (Galster *et al*. forthcoming).

More important than the density of each country as a whole is the spatial variation within the country. To illustrate differences between population density calculated for administrative units and small statistical geographic areas, we have chosen one site in each country that is at or above the average population density of the nation in which it is located. The Pearl River Delta area including the major districts of Guangdong province surrounding Hong Kong, Macau, and the Pearl River has a density of 893 persons per square kilometer and an official urban population of 70 percent. South Florida is 96 percent urban but much of the population is clustered along the coast while much of the inland area reserved for national parks and conservation areas. As a result, the average density is only 172 persons per sq. kilometer (See Figure 1). At the other extreme, Kerala with an urban percentage of only 26 percent has a dense system of village settlement that leads to a high average population density of 749 persons per sq. kilometer.

Figure 1: Tract-level population densities for South Florida: 1990.



Source: U. S. Census Bureau, 1990 Census of Population.

Administratively-based Measures of Urbanization --

Most urban definitions take as a starting point the population living in “urban places.” These urban places are primarily administratively defined areas generally with recognized municipal governments. These municipal entities can vary markedly in character as well as in size between nations, within nations, and over time. For example, in the United States, laws pertaining to incorporation and annexation vary from state-to-state. In states with relatively liberal annexation laws, municipalities can annex lands with relatively low population densities, lands that otherwise would be considered rural. Such situations tend to result in overbounding of urban population and land area. On the other hand, in states with restrictive annexation policies, state laws make it difficult for municipalities to annex adjacent densely populated territory. As a result, when this occurs outside of Census Bureau-defined urbanized areas, the extent of urbanization often is underbounded in census publications.

The dependence on administratively defined geography to define urban populations makes comparisons of levels of urbanization difficult across the three sites. Additional problems are posed by changing definitions over time. In China the municipal definition has been changed repeatedly—the most recent change resulting in the inclusion of a large number of municipal districts with boundaries that extend well into the countryside (Goldstein 1990; Zeng Yi and Vaupel 1989). In India, urban population includes the population of all "towns" defined as places with a municipal corporation, municipal area committee, town committee, notified area committee, or cantonment board. In the U.S., the Census Bureau's definition of urban areas includes "incorporated places" with populations of 2,500 or more (see the section below for a fuller description of the Census Bureau's urban area definition).[1]

Statistically-based Measures of Urbanization

Statistical agencies have dealt with the limitations imposed by administrative units by modifying urban definitions in various ways. In India, there has been a definitional attempt to include other areas outside of "towns" that met the following qualifications: places having 5,000 or more inhabitants, a density of not less than 1,000 persons per square mile (390 per square kilometer), pronounced urban characteristics, and at least three fourths of the adult male population employed in pursuits other than agriculture (United Nations 1980). In the United States, the Census Bureau expanded its urban definition in 1950 to include the population in unincorporated places of 2,500 or more and in "urbanized areas" consisting of a central place and the adjacent continuously built-up area (containing a population density greater than 1000 persons per square mile and having a total population of 50,000 or more).

In the United States and other countries there have been attempts to account for decentralization of settlement and economic activity by defining "metropolitan areas" that include not only urbanized areas and outlying urban places but also surrounding counties that are integrated with these urban centers as measured by substantial amounts of daily commuting, even if many of these areas have densities far too low to be classified as urban. In the U.S., the metropolitan area concept does not represent an alternative urban area definition, but rather identifies a functional area influenced by an urban center of significant population size.

[1] The U.S. does not have a "standard" definition of "urban." As a result, various Federal agencies define "urban" in different ways depending on program requirements or statutes. For example, the U.S. Department of Transportation defines an urban place as any place containing a population of 5,000 or more. Some telecommunications-related programs use a population threshold of 10,000 to identify urban places. The Rural Health Clinics Act defines "urban" as all population and territory within Census Bureau-defined urbanized areas; as a result, any place located outside an urbanized area regardless of population is considered rural for purposes of the rural health clinic program.

Density as a Comparative Measure for Environmental Studies

These different administrative and statistical definitions make international and temporal comparisons of urban populations difficult. The measures of urbanization, average density, and land use give very different pictures of the three case study areas. In fact, given our interest in the relationship between land and population, the traditional measures of urbanization are not sufficient to represent the spatial distribution issues. The concepts of urbanization differ between the countries, over time within each country, and between researchers (Parish 1987).

Urbanization can be viewed as a characteristic of the population, as a characteristic of particular kinds of land uses and land covers, as well as a characteristic of social and economic processes and interactions affecting both population and land (McIntyre *et al*. 2000). Social scientists—demographers generally, but also urban policy analysts, geographers, and others—generally define levels of urbanization in terms of population densities. Physical scientists—ecologists especially—generally approach definitions of urbanization from the standpoint of the built environment. To these researchers, density of buildings and impervious surfaces is just as important, if not more important, as population—indeed, urban ecologists often are concerned with changes to the environment as a result of human alteration of the landscape. McIntyre *et al.* (2000) note, however, that among ecologists a wide variety of urban definitions have been used in research, ranging from any human alteration of the landscape to more precise definitions based on density and specified land use characteristics.

Alternatively, regional economists, labor analysts, and related researchers might define urban in terms of the functional area integrated with an urban center. For these researchers, urban becomes more of a sociological and functional definition than a structural (density-based) phenomenon. Reconciling these different perceptions of what constitutes urbanization within a single definition poses challenges for any researcher or statistical agency.

Although the authors do not have the access to the detailed level of census tabulations necessary to refine this method for all sites, an example using South Florida can serve as an exposition of how the method might function. In the U. S. decennial censuses, populations are tabulated by small-area geographical units known as census tracts as well as by administrative boundaries such as counties and towns. Census tracts are drawn so as to include approximately 4000 inhabitants and are thus smaller in densely settled areas than in less densely populated areas. The census results by tract include information on both the population and the land area of each tract. Consequently, it is possible to tabulate density distributions of both the population and the land area.

To illustrate such a method, we arranged the 800 census tracts for the seven counties of South Florida (Dade, Broward, Palm Beach, Monroe, Hendry, Collier, and

Lee) by their 1990 population density (U. S. Census Bureau 1993). In table 1 we compare the urban and rural populations that are above various density levels to see which level would give a reasonable proxy for the urban population in terms of density. At 300 persons per sq km., 5.8 percent of the urban population and 12.4 percent of the rural population would be misclassified by this simple density cutoff. At 400 persons per sq. km., 8.7 percent of the urban population and 4.4 percent of the rural population would be misclassified. In fact, for this particular case, a cutoff of about 360 persons per sq. km. gives a result in which the percentage of the rural and urban population misclassified is equal at roughly 7.5 percent each.

Table 1: Distribution of Census Tracts (n=800) for Counties of South Florida by Density

Population density per sq. Km.	Percent of urban population above this density	Percent of rural Population above this density	Percent of total population above this density	Percent of total land area above this density
100	98.4	42.6	96.1	17.4
200	96.2	25.9	93.2	13.7
300	94.2	12.4	90.8	11.9
400	91.3	4.4	87.6	10.4
500	87.9	3.6	84.3	9.1
600	85.6	2.4	82.1	8.38
700	82.4	2.1	79.0	7.5
800	80.8	1.7	77.4	7.2
900	77.3	1.5	74.1	6.5
1000	73.	1.3	0.1	5.7

Source: U. S. Census Bureau, 1990 Census of Population.

To compare across areas, however, a higher density level might be preferable to reduce the likelihood that high density agricultural areas might be included in the high density category. We propose a level of 500 people per sq. km. as a round level that would reduce the chance of misclassifying rural populations as high density. In the South Florida case, a cutoff of 500 people per km. sq. would lead to classifying 84 percent of the population in “high density” areas.

Unfortunately, data with which to assess settlement patterns at similar levels of geographic detail in India and China are limited. However, a very crude idea of how this method might work is across countries can be obtained by using the method for the larger levels of geography (districts) that are published for all three countries. Table 2 shows that a population density of 500 people per sq. mile applied to the large scale district geography would yield 89.9 percent of the population and 74.8 percent of the land area in high density areas. Table 3 shows similar results for the Pearl River Delta with 84.2 percent of the population and 62.2 percent of the land area in high density areas.

Table 2: Distribution of Districts (14) by Density for Kerala, India: 1991.

Population density per sq. Km.	Percent of total population above this density	Percent of total land area above this density
100	100.0	100.0
200	100.0	100.0
300	96.3	87.1
400	94.0	81.6
500	89.9	74.8
600	78.0	58.2
700	78.0	58.2
800	70.3	50.5
900	53.4	35.7
1000	35.7	21.5

Source: Census of India, 1991, Kerala.

Table 3: Distribution of Districts (13) by Density for Pearl River Delta, China, 1990.

Population density per sq. Km.	Percent of total population above this density	Percent of total land area above this density
100	100	100
200	100	100
300	95.4	84.3
400	84.2	62.2
500	84.2	62.2
600	73.8	48.0
700	73.8	30.6
800	58.8	30.6
900	51.4	24.0
1000	35.6	24.0

Source: Guangdong Statistical Yearbook, 1998.

Given the availability of data for smaller levels of geography for the India and China sites, this measure of high density areas could be useful in making comparative studies that are less influenced by administrative and statistical differences between the countries located in high density areas that are usually thought of as “urban”—and could provide useful information on the percentage of the land area as well as the percentage of the population. This greater detail on the spatial complexity of each area measured at similar levels of spatial disaggregation could begin to supply the comparative data needed for ecological and other studies across many different societies and landscapes.

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