The Area Adjusted Map

An Epidemiologic Device

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SPOTTING CASES of disease or injury on a map is a common procedure in epidemiology. The distribution of events on a map is influenced by variations in both attack rate and population density. In many instances variations in population density may obscure geographic patterns related to the etiology of the disease or injury, as noted by several epidemiologists (*1*, *2*). This factor may be eliminated by making the map area proportional to population rather than to actual land area. Such maps, or what have been termed "population-by-area cartograms," are well known in the cartographic literature (*3–5*).

Population-by-area cartograms were made for Massachusetts and the United States in about 1937 by F. Randolf Philbrook and Roy F. Feemster, Massachusetts Department of Public Health (personal communication 1963). However, maps of this type and their applications in epidemiology apparently have not been described in the medical literature. This paper explains the preparation and characteristics of an area adjusted map, using maps of New York State as illustrations.

Method

The map, based on the upstate New York (New York State exclusive of New York City) population, was laid out on arithmetic graph paper with 1/10-inch divisions. A scale of 500,000 people per square inch was selected to yield a total map area which would be a convenient size for use. Upstate New York is comprised of 57 counties, partitioned into towns and cities. A town contains one or more villages. The population for all counties, and each city, town, and incorporated village with 10,000 or more people was obtained from the 1960 census. Each political unit was assigned the number of 1/10-inch squares which corresponded to its population.

A major north-south geographic landmark, the Hudson River, was drawn as a straight, vertical line on the graph paper. First, the counties adjacent to this landmark were mapped, and then consecutively adjacent counties. The two Long Island counties, Nassau and Suffolk, were mapped separately from the remainder of the State. Actual shapes of counties were sacrificed to the extent necessary to retain as far as possible, common boundaries, relative locations, and the approximate contour of the State. Each county was designated by a two-letter alphabetical code.

Cities, towns, and incorporated villages with 10,000 or more people were mapped in a similar manner within county boundaries. To facilitate the use of this map with vital statistics data, these minor civil divisions were designated by the numeric code used in the analysis of the State birth and death records. In each county, nearby civil divisions with less than 10,000 people were grouped together, without designation, in their approximately relative locations.

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There is no unique solution to the topologic problem of preparing a population-by-area cartogram for a given population and its jurisdictional boundaries. Although the map areas of the various regions are fixed by their populations, their shapes and relative locations are not completely determined. This necessitates judgment and skill in the construction of such maps. In using area-adjusted maps, events are spotted within the smallest appropriate jurisdictional unit in a random fashion.

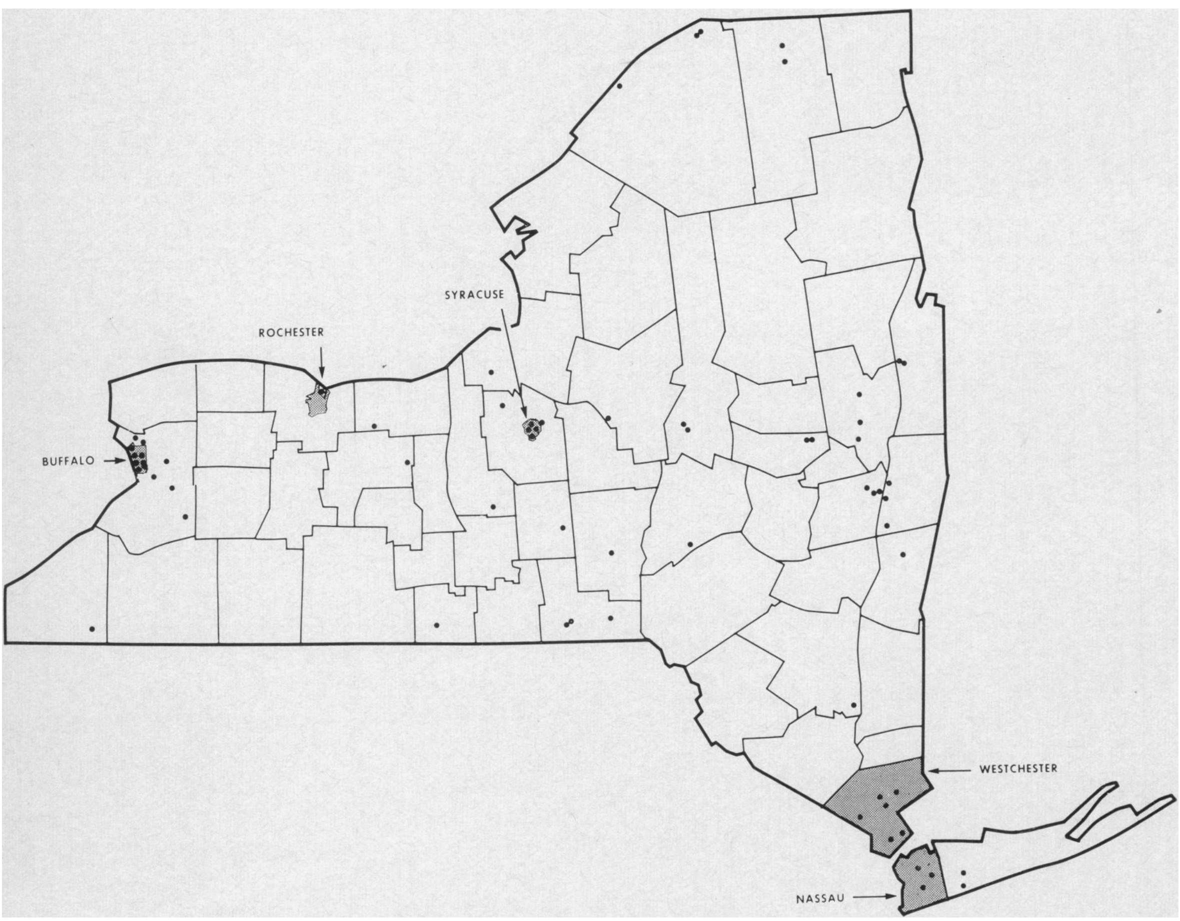
Result

The usual map of upstate New York (fig. 1) can be compared with the population-by-area cartogram of upstate New York (fig. 2). The sparsely populated northeastern section is contracted markedly in figure 2, and the shaded map areas of Nassau and Westchester Counties and the cities of Buffalo, Rochester, and Syracuse are greatly expanded. Similar changes occur in a number of other areas.

Figures 1 and 2 show the distribution by place of residence on the usual map and the population-by-area cartogram, of cases of Wilm's tumor reported to the New York State Cancer Registry in the period 1958–62 (personal communication from Vincent H. Handy, New York State Department of Health, 1963). The marked clusters of cases seen on the usual map disperse on the population-by-area cartogram. Figure 3 illustrates a clustered distribution on the population-by-area cartogram of cases of in-situ cervical carcinoma, reported to the New York State Cancer Registry in 1962.

The random distribution of cases of a hypothetical disease with an attack rate of 3 per 100,000 is shown on the population-by-area car-

Figure 1. Conventional map of upstate New York. Each dot represents one case of Wilm's tumor reported to the New York State Cancer Registry, 1958–62.



togram in figure 4. To generate this distribution, a unique 5-digit number was assigned to each $\frac{1}{10}$-inch square on the map. Two hundred and seventy 5-digit numbers were taken from a table of random numbers which corresponded to numbered squares on the map. Each selected number was spotted on the map to obtain a random spatial distribution. In figure 4, the clusters and vacuities in the population of cases of the hypothetical disease are the result of chance alone.

Discussion

The distribution of events on a map of the usual type is influenced by variations in both attack rates and population density. On the population-by-area cartogram the effect of population density variation on the distribution of events is eliminated. In figure 1 the reported cases of Wilm's tumor are clustered in several regions of high population density; in figure 2, clustering is no longer evident.

Since the map area of the population-by-area cartogram is proportional to population, the density of spots, that is the number of events per unit map area, is directly proportional to the rate. The greater densities of spots in several regions in figure 3, for example, represent high regional attack rates of reported cases of in-situ cervical carcinoma; the lesser densities of spots in several other regions represent low regional attack rates. In contrast, since the map area of the usual type of map is proportional to land area, the density of spots is proportional only to the number of events per unit of land area and provides insufficient information as to attack rates in the regions represented.

Area adjusted maps, like maps of other types, have their chief application in facilitating the rapid visualization of complex distributions. In addition, population-by-area maps make possible the rapid visualization of geographic variations in attack rates. Various types of information may be spotted; for example, cases of disease or injury, administrative services and personnel, and hospital beds. In addition, characteristics of events, including time of occurrence, may be indicated by appropriate means.

Maps with areas adjusted in other ways may be useful in some circumstances. For example,

Figure 2. Population-by-area cartogram of upstate New York. Compare the shaded regions and distribution of dots representing cases of Wilm's tumor with those in figure 1.

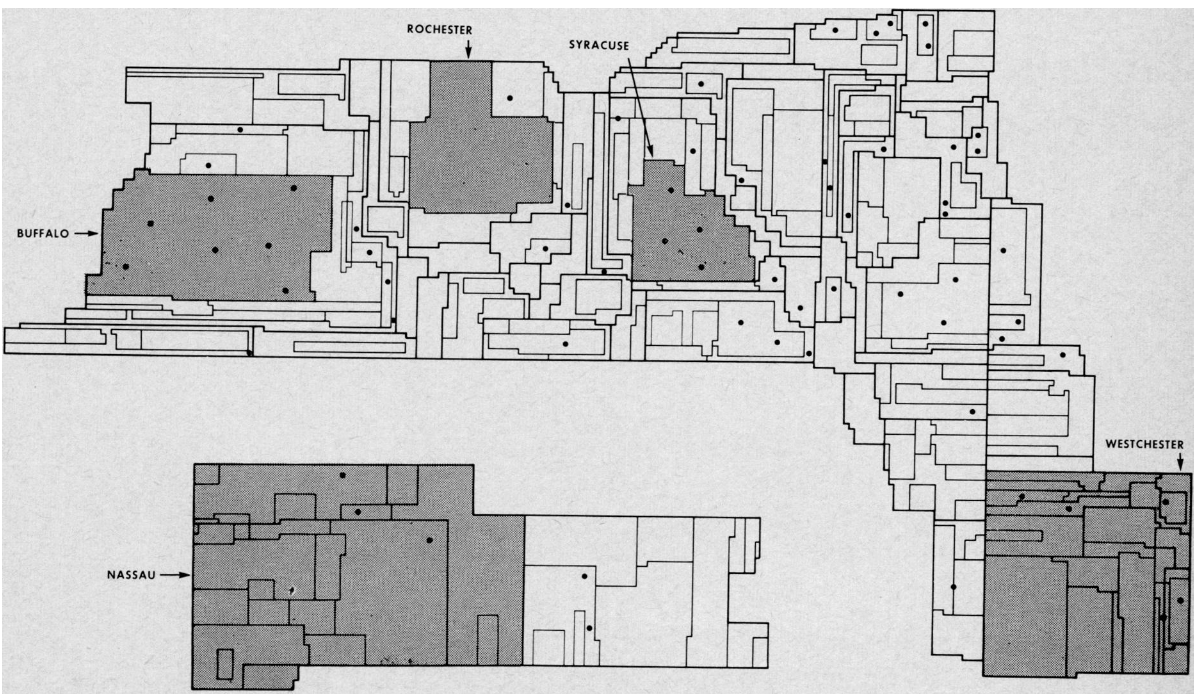


Figure 3. Population-by-area cartogram. Each dot represents one case of in-situ cervical carcinoma reported to the New York State Cancer Registry in 1962.

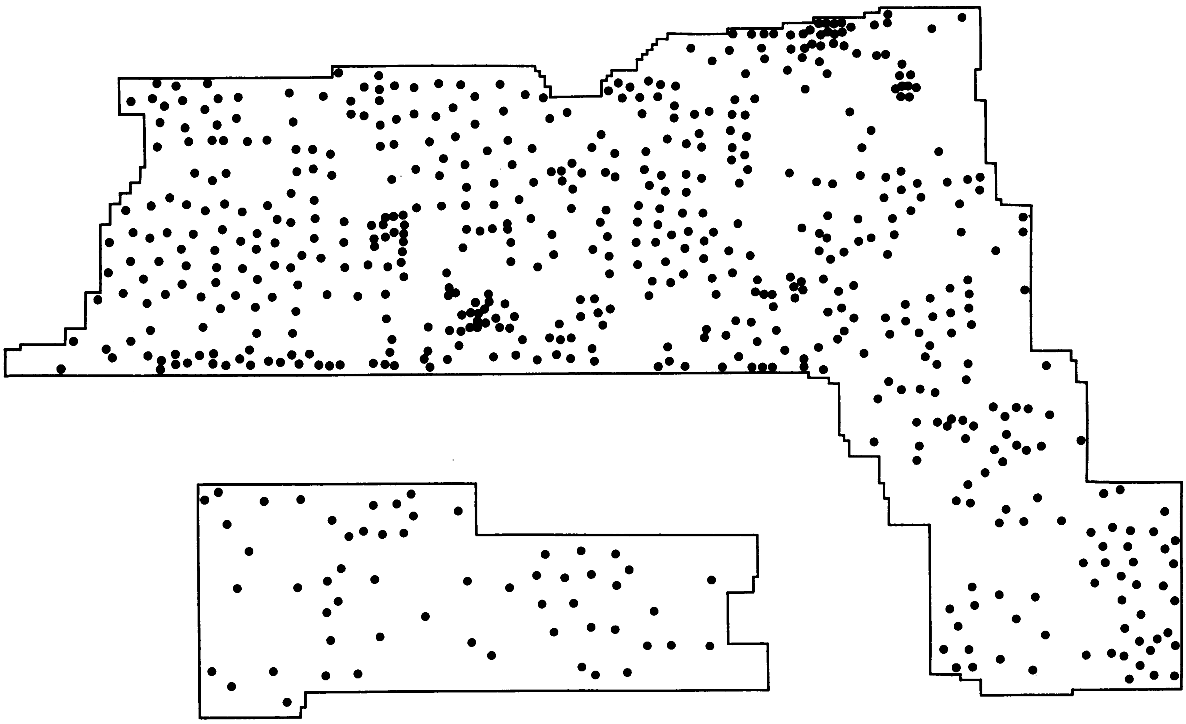
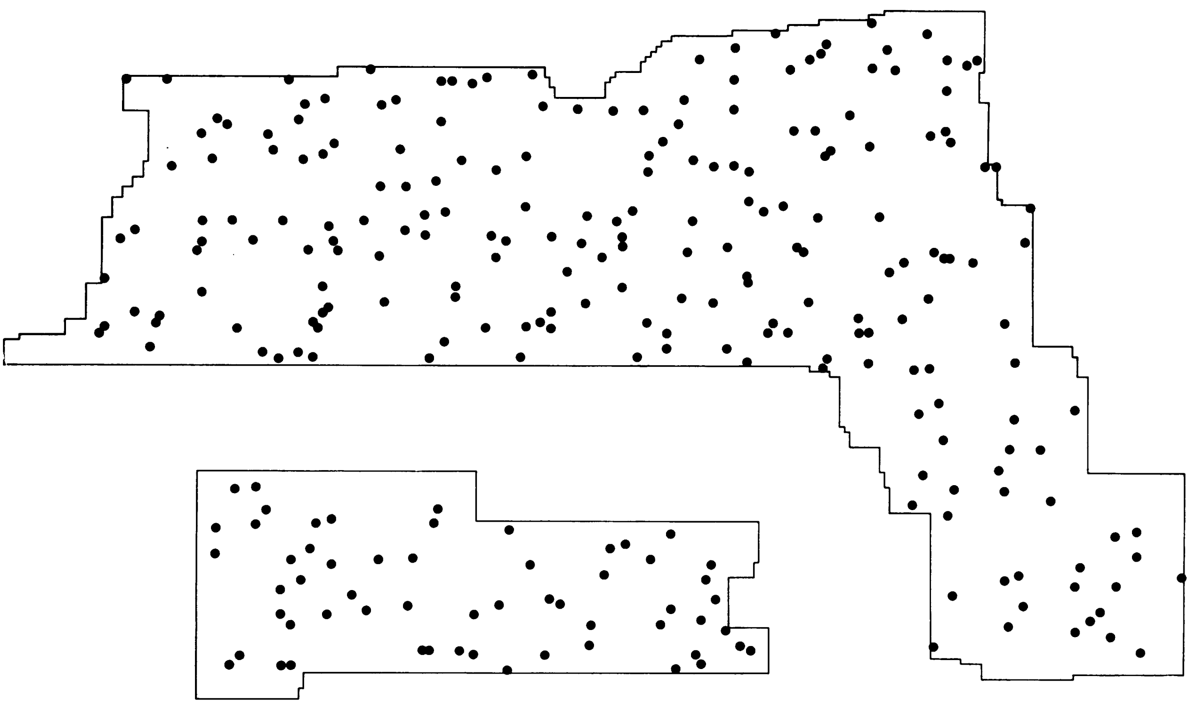


Figure 4. Random distribution of cases of a hypothetical disease on the population-by-area cartogram



the map area may be proportioned to any segment of the total population. Thus, if childhood diseases are to be studied, the map area may be proportioned only to the child population. Other characteristics of the population may also serve as the base for adjustment; for example, sex, race, parity, socioeconomic level, or immune status.

Cluster identification, a topic of much recent interest, especially in leukemia research (*6–8*), is facilitated by the use of area adjusted maps. However, an impression of clustering can be easily produced by a random distribution of events (fig. 4). The main difficulty then becomes distinguishing a random anomaly in distribution from one that cannot reasonably be attributed to chance alone, a statistical problem beyond the scope of this paper. Nonetheless, the task of determining whether cases are clustered sufficiently to justify more sophisticated scrutiny is greatly facilitated by the use of area adjusted maps.

Summary

The distribution of events on a map is influenced by variations in both attack rate and population density. The influence of the latter can be eliminated by using a population-by-area cartogram, a map in which the areas are adjusted in proportion to population.

The adjustments may correspond to the total population or to any of its segments, such as the child population. Other types and characteristics of events may be indicated as on a conventional map.

Population-by-area cartograms facilitate the rapid visualization of geographic variations in attack rates. They are especially useful as a practical screening device to identify events sufficiently clustered to warrant further investigation. To illustrate these applications, cases of in-situ cervical carcinoma and Wilm's tumor were plotted on a cartogram of upstate New York prepared to a scale of 500,000 people per square inch.

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Cleft Palate Clinical Research Center

The largest clinical research center in the United States for the study of cleft lip and palate will be established at the Lancaster Cleft Palate Clinic, Lancaster, Pa., under a grant from the Public Health Service's National Institute of Dental Research.

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