ADMINISTRATIVE BOUNDARY REORGANIZATION AND THE MAPPING OF TEMPORAL CHANGE

Comenetz, J.

Department of Geography, University of Florida, PO Box 117315, Gainesville, FL 32611, USA.
E-mail: comenetz@geog.ufl.edu

ABSTRACT

Administrative boundary reorganization poses a problem for cartographic analysis of social, demographic, and economic variables because data sets created before and after reorganization are incompatible. Weighting methods are often used to translate data between different boundary configurations, but these can introduce substantial error. An alternate method called "strategic amalgamation" can resolve the problem of data conversion while adding little or no error. Strategic amalgamation creates an entirely new set of upper-level areal units based on combination of lower-level units, thus largely avoiding the need for weighting.

1. RESTRUCTURING OF NATIONAL ADMINISTRATIVE UNITS

Reorganization of internal (administrative) boundaries and demographic enumeration units occurs everywhere in the world. Countries achieving independence more recently are more likely to experience such changes. Over time, these boundaries tend to become more stable. In the USA, for example, first-level units (states) have been stable for nearly a century, while in a typical decade only a handful of second-level units (counties) experience any change. When changes do occur in "older" countries, they tend to be simple divisions or mergers of existing units, as in the recent division of Venezuela's capital territory into two regions, the creation of the capital territory in Brazil in the 1950s, and the creation of the territory of Nunavut in the Canadian Arctic. Relatively rare are wholesale restructurings without regard to existing boundaries, one case being the revamping of British counties in the 1970s.

In the past few decades, therefore, boundary reorganizations have been most common in developing nations, especially those of sub-Saharan Africa, the majority of which achieved independence between 1950 and 1990. As national statistical data such as census results are released according to the latest configuration of regions, such data become progressively less compatible with previous data. In some African nations, reorganization of political units has extended beyond the primary (provincial) level to the secondary (district or county) and even the tertiary (municipal) levels.

2. DATA CONVERSION

Conversion of older data to newer administrative regions (or vice versa) is essential in order to map changes or trends that span multiple administrative boundary regimes. A variety of weighting methods (1), based on the size of units, their population, their centroid locations, or other variables, are often used to accomplish this. Unfortunately, weighting introduces errors that are both difficult to quantify and can be large enough to call conclusions into question. This is especially true where one is mapping temporal change of relatively small magnitude. If the margin of error associated with values calculated through weighting exceeds the values being calculated (or exceeds the change in values over time), then weighting cannot produce useful results.

The use of weighting is absolutely necessary only when one cannot employ data from lower level (smaller) administrative or enumeration units. For example, I recently served as a consultant to the City of Gainesville, Florida, USA, for its political redistricting after the 2000 census. Because Gainesville's precincts (voting districts) do not coincide with even the smallest census enumeration units (census blocks), accurate estimation of precinct population could not be accomplished without weighting. This was accomplished by use of a housing unit map obtained from the local electrical utility. Where a block was split by a precinct boundary, housing units were counted on each side of the divide and the population was weighted accordingly. The resulting estimates were considerably more accurate than those obtained through the alternate method--advocated by government agencies contacted during the project--of assigning block populations to whichever precinct contained the block's centroid.

The preceding example is the extreme case, where there are no lower-level units to work with. Weighting may be avoided in whole or in part only if, during the course of boundary reorganization, administrative units remain the same at some level. That is, new upper-level units are created by re-aggregating existing lower-level units. Here, data from past and present may be compared by simply adding together the appropriate lower-level units. But one can also minimize the need for weighting in the intermediate case, when upper level units have changed and there have also been alterations to some, but not all, lower-level units.

This is accomplished through a process of careful merging or "strategic amalgamation" of lower-level administrative units in both the old and new administrative systems. Strategic amalgamation results in a set of areal zones to which data gathered under both systems may be aggregated. Often the merged zones (MZs) resulting from amalgamation are comparable in size to, or smaller than, the existing political units. Precision is not only not lost but may be gained in such cases. Where the amalgamated units are too large, weighting methods can be applied, but only to split the problematic units. This minimizes the error introduced by weighting, thus maximizing the utility of the resulting MZs for temporal analysis. Strategic amalgamation will be illustrated through examples from a study of population change in Ethiopia.

3. ETHIOPIA, 1984 TO 1994

Though Ethiopia has established a regular series of decennial censuses, with enumerations in 1984, 1994, and 2004 (planned), tracking demographic change proves very difficult because the Ethiopian government thoroughly restructured its administrative boundaries twice in the decade between 1984 and 1994 (Figure 1). Statistical continuity was further affected by the independence of Eritrea in 1993, which in turn restructured its own administrative units. Thus it is impossible to analyze demographic change in Ethiopia between 1984 and 1994 without first fitting the census data for both years to a consistent set of regions.

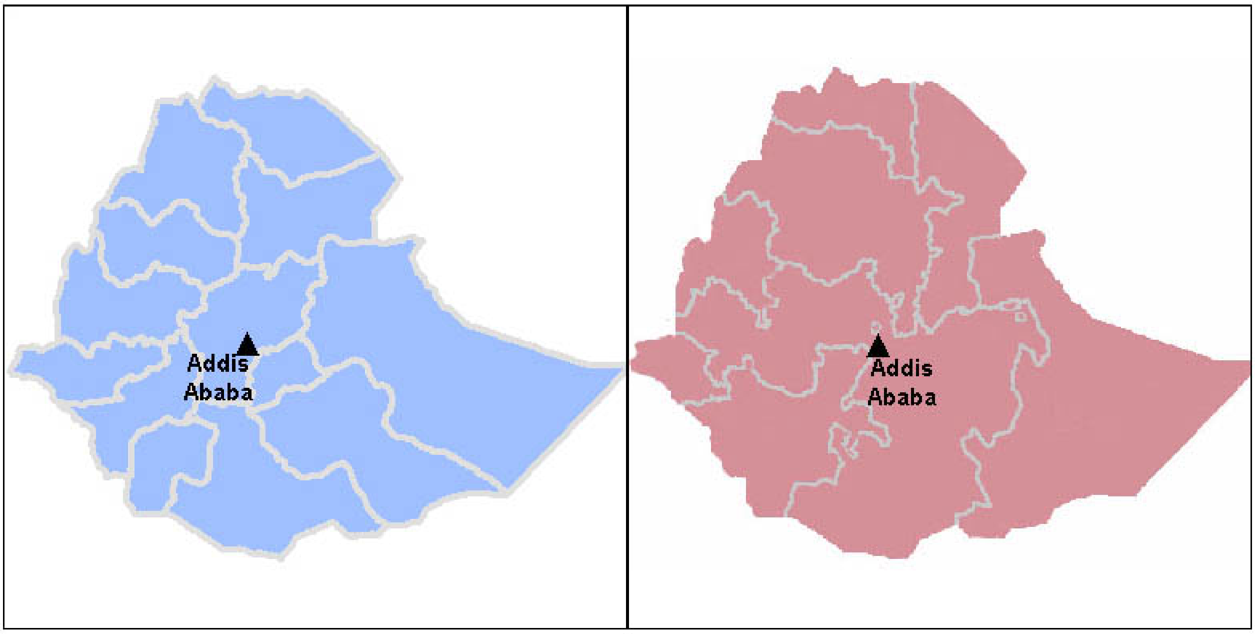

Figure 1. Ethiopian provincial boundaries in force in 1984 (left) and in 1994 (right).

Because the Ethiopian reorganization affected not only the highest-level administrative unit (provinces), but also the next level (*awrajas* or regions), the third level (*weredas*, similar to counties), and possibly even the fourth level (*kebeles*, or peasant associations), re-aggregation of data from one census into the provinces existing at the time of the other census proved impractical. Even were it possible, the number of provinces has always been too small for detailed analysis: omitting now-independent Eritrea, there were 13 in 1984 and 11 in 1994.

Using weights convert data from one census year to the administrative structure current at the time of the other census would also introduces a large and undefined amount of error because weighting methods depend upon assumptions about population distribution within enumeration units, *e.g.* that population is concentrated in cities. As an alternative, two gridded world population data sets have been created: the Gridded Population of the World (GPW) version 2 (2) and Landscan version 3 (3). Instead of manipulating administrative units, these divide the world into standard grid squares, and assign populations to each square based on weighting methods. Unfortunately, available gridded data are not suited to the Ethiopian case due to problems of accuracy and consistency. GPW coverage of Ethiopia is based on 1984 census data, projected to subsequent years based on estimated annual growth rates. The Landscan program uses the latest available projections provided by the US Census Bureau. Thus neither data set is based on a direct assignment of actual census data, but rather on projections that introduce additional error (data quality issues are acknowledged for Ethiopia on the GPW website). Equally important, in order to detect change over the desired time period, one would need to combine GPW and Landscan because the former is based on the 1984 census while the latter is based on newer data. This is impossible because (i) grid cell sizes differ, and (ii) GPW and Landscan use different methods for assigning population to grid cells: GPW assumes that population density is constant within weredas, while Landscan uses a weighting method based on road proximity, urban area location, land cover, and other variables. Thus use of gridded data would neither improve accuracy nor encompass the desired inter-censal period (1984 to 1994).

The alternative chosen to address these problems was to design a set of new geographic units, approximating real political boundaries as much as possible but deviating where necessary due to changes in the boundaries of lower-level administrative units.

For the construction of the new map, the following data sources were used:

- Base maps of 1984 provinces, regions, and weredas in paper (4, 5) and GIS format (6)
- Base maps of 1994 provinces and weredas, in paper and graphic file format (7, 8)
- Population figures for provinces and weredas from the 1984 and 1994 censuses (6, 9)

The goal was to aggregate weredas from both 1984 and 1994 into a set of new regions whose boundaries could be held constant for the analysis of data from both censuses, thus permitting the sketching of an accurate map of population change. The task was difficult because, with the rearrangement of administrative boundaries, some weredas were split or combined, others were partly annexed to neighboring weredas, and a few changed name. As some new weredas spanned the old provincial boundaries, and vice versa, it was impossible to simply re-aggregate weredas to the other set of provincial boundaries. Use of provincial units is further complicated by the inconsistency of different sources in their delineation of Ethiopian administrative boundaries for any single time period (10).

Fortunately for this exercise, the boundaries of many weredas did remain constant between 1984 and 1994. These served as a starting point for amalgamation of 1984 weredas into a new set of 30 regions called "Merged Zones" (Figure 2), accomplished through geographic analysis using base maps and GIS. The Merged Zones (MZs) have the advantage of encompassing relatively certain populations, because they are all composed of entire weredas. No old or new wereda is split between two MZs. Every old or new wereda that crosses a new or old provincial boundary is included within a single MZ, thus eliminating the problems inherent in weighting.

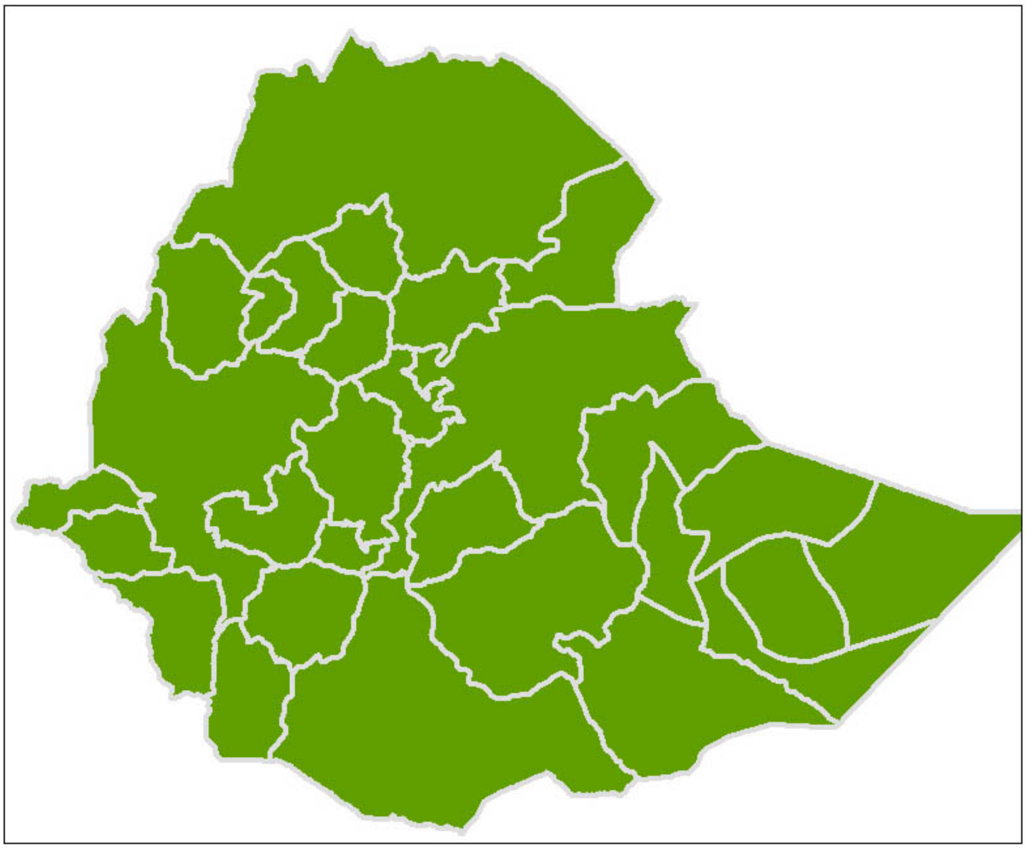

Figure 2. Merged Zones.

Creation of the MZs is illustrated in Figure 3, where fine lines indicate wereda boundaries, medium-weight lines show awraja boundaries, and heavy black lines represent 1984 provincial boundaries. No map of 1994 provincial boundaries was available in usable GIS format. Five sample MZs are numbered and shaded in color. Whenever possible, MZs were designed to be equivalent to a region/awraja (MZ 1), a province (MZ 2, equivalent to Arssi province), or combinations of awrajas (MZ 3). For example, MZ 1 is equivalent to an awraja within Hararge province, while MZ 3 is equivalent to a group of four awrajas (different shades of blue in Figure 3) within Bale province.

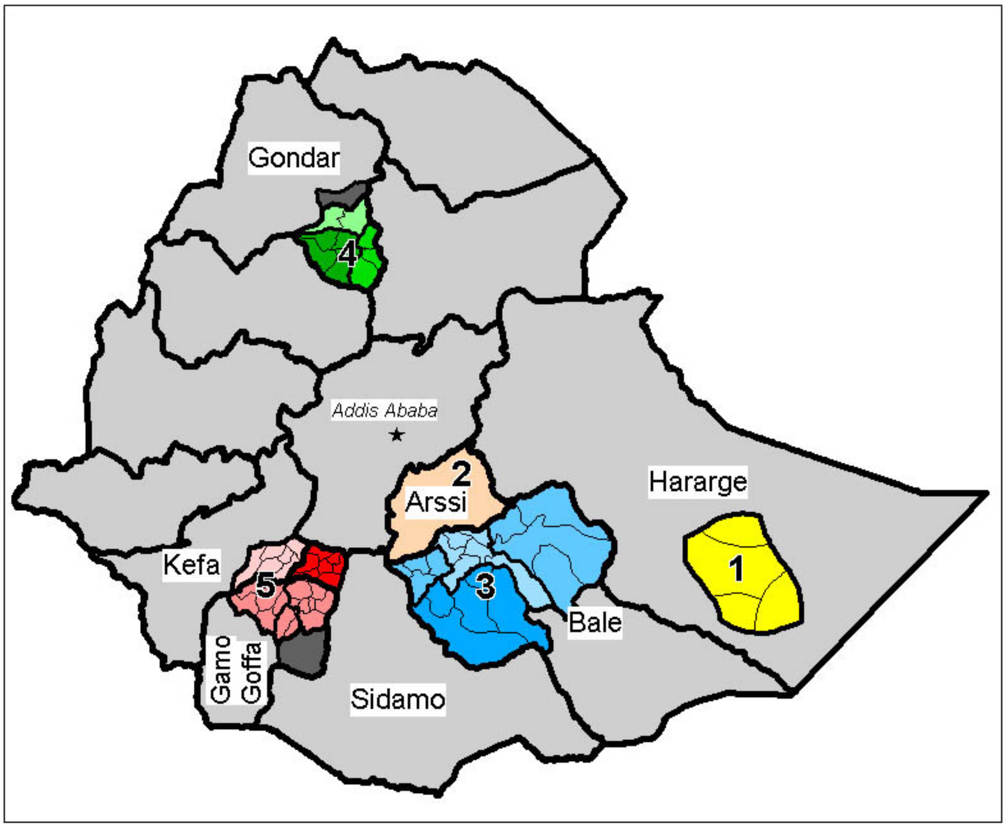

Figure 3. Creation of Merged Zones.

MZs 4 and 5 are more complex. MZ 4 lies entirely within Gondar province, but does not consist of entire awrajas. One awraja is split between MZ 4 and another MZ. The split portion of the awraja is indicated by dark gray shading. This was necessary when weredas boundaries were altered so that they crossed pre-existing awraja boundaries. In the case of MZ 5, new weredas crossed old provincial boundaries resulting in an MZ spanning parts of three old provinces, shown by shades of red. MZs 4 and 5 do, however, lie entirely within *new* provinces, and are approximately equivalent to new second-level administrative units. Finally, the largest MZs (Figure 2) represent areas where weredas could not be amalgamated within any configuration of either old or new provincial or regional boundaries and it was necessary to create more extended zones to avoid splitting weredas.

All MZ borders represent constant boundary lines–lines that served as wereda borders in both 1984 and 1994 and that were not affected by wereda splits or mergers. In Figure 4, weredas are shown in gray, with old provincial boundaries overlaid in yellow and MZ boundaries in red. From this map, it is clear that MZ boundaries often coincide with provincial boundaries. When they do not, they often follow awraja boundaries. Since MZs are largely based on existing regions or provinces, they are not arbitrary divisions of territory. Beyond the unavoidable quality problems inherent in census statistics, such as undercount, typos, and errors resulting from the estimation of population in areas not enumerated exactly at the census date, it is likely that the populations of the 30 MZs are as good approximations of their true populations as it is possible to achieve using the methods and data sources available.

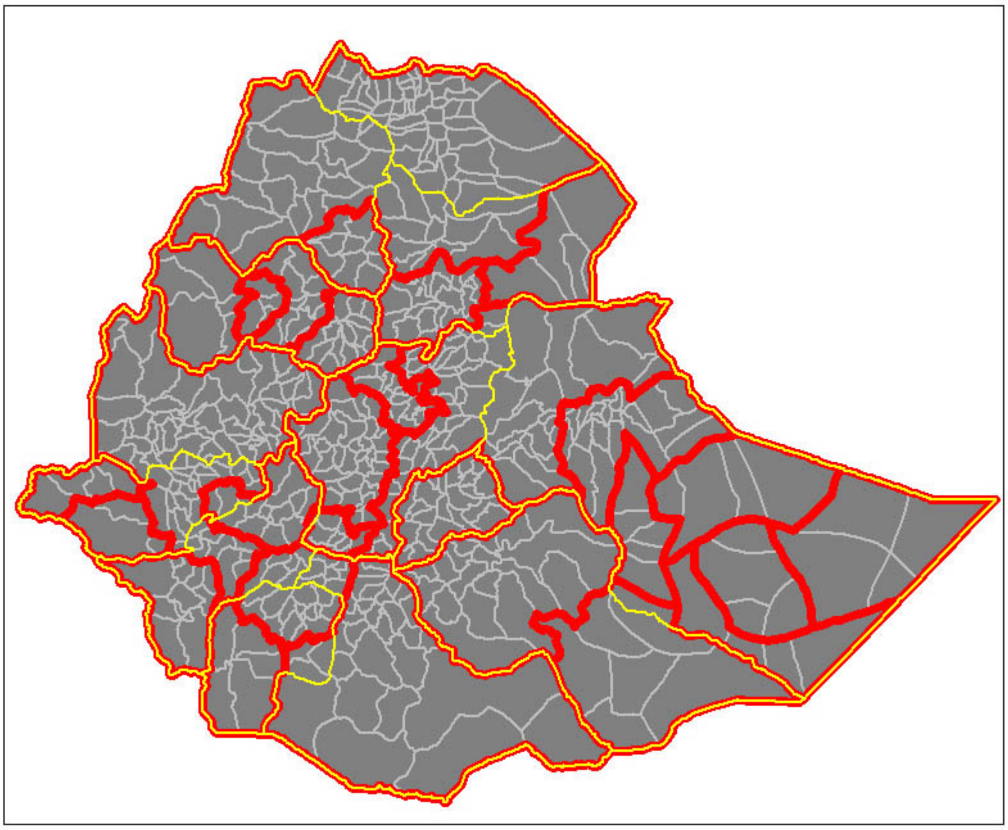

Figure 4. Boundaries of Merged Zones, old provinces, and weredas, showing coincidence of some MZ and provincial boundaries.

4. BENEFITS OF STRATEGIC AMALGAMATION

Strategic amalgamation results in a set of areal units that may be used to accurately map change in socioeconomic variables without the errors introduced by weighting methods. This technique permits relatively precise evaluation of temporal variation, allowing detection of small changes that would otherwise be missed entirely or obscured by the noise introduced by weighting. Though Merged Zones differ from "real" administrative units, they can be designed to follow existing boundaries as much as possible. If further coincidence with actual administrative units is desired, weighting may be used to split MZs along real administrative boundaries. This introduces some error but it will be of lesser magnitude than that which would result from the use of weighting across the entire map. As in the above example, strategic amalgamation can also produce a larger number of regions than is found in any real configuration designed by a national government. Strategic amalgamation permits accurate mapping of demographic change that would be impossible by other means and

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Biography of Joshua Comenetz

Joshua Comenetz has been Assistant Professor of Geography at the University of Florida since 1999. He received his PhD and MA from the University of Minnesota, holds an AB in geology from Harvard University, and has been professionally involved in cartography and GIS since 1990.

Dr. Comenetz's research spans the intersection of cartography and population geography, from cartographic theory and principle to applications of demographic mapping in many areas, including natural hazards research, the geography of religion, and ethnic segregation. Recent projects have looked at demographic change in Ethiopia related to the El Niño climatic oscillation and the spatial characteristics of the American Indian (indigenous) population of the USA.

At the University of Florida, Dr. Comenetz has developed and taught courses in cartography, data quality analysis, population geography, and the geography of international relations at the graduate and undergraduate levels.

Dr. Comenetz has also served as a consultant for political redistricting, mapping ethnic/racial groups, and demographic surveying.