

DEMOGRAPHY IN GLOBAL CHANGE STUDIES

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ABSTRACT

Demographic information is usually provided on a national basis, but we know that countries are ephemeral phenomena. As an alternate scheme one might use ecological zones rather than nation states to organize environmental data. But there is no agreement as to what these zones should be. By way of contrast, global environmental studies using satellites as collection instruments yield results indexed by latitude and longitude. Thus it makes some sense to assemble information on the terrestrial arrangement of people in a compatible manner. This alternative is explored in the work described here, in which latitude/longitude quadrilaterals are used as bins for population information. This data format also has considerable advantage for analytical studies in which spatial series can be thought of as a two dimensional extension of time series, or for simulation modeling, etc. The result of our recent work is a five minute by five minute raster of estimated 1994 world population generated from over nineteen thousand administrative unit boundaries and covering 221 countries. The number of people in the total countries is estimated to be 5.618×10^8 , spread over 1.32×10^8 square kilometers of land. The full report details the methods used, problems encountered, applicability to urban areas, movement modeling and other uses, and needed extensions.

DESCRIPTION

The Global Demography Project at the National Center for Geographic Information and Analysis in the Geography Department of the University of California at Santa Barbara recently completed an inventory of world population by 5 minute quadrilaterals of latitude and longitude. The choice of 5 minute quadrilaterals is intended to be compatible with other global data compilations, and is intended for medium resolution studies not detailed local investigations. The detailed report is available from NCGIA and the data are available on FTP from CIESIN. The project involved the assembly of population estimates from 19,032 administrative units (defined by polygons using latitude, longitude coordinates) from countries of the world. Since the census dates vary, from 1979 to 1994, we extrapolated the global number of people to a common date; this was chosen to be 1994. The 5 minute raster, 1548 rows (57S to 72N latitude) by 4320 columns (360 East-West degrees) in size covers 9.27 by 9.27 km (85.8 km^2) at the equator to 3.1 by 9.27 km (28.7 km^2) at the northern limit (Table I). The quadrilaterals at the southern limit are approximately 49 km^2 in area. These numbers define the resolution, and, from the sampling theorem, also the minimal patterns which can be detected at each latitude. The resolution is thus 12 times that of the previously available data, and a decade more current (Matthews, 1983). A polygon to raster program reassigns the population numbers from the sub-national administrative unit polygons to the spherical quadrilaterals. This is followed by a pycnophylactic areal smoothing, described elsewhere (Tobler, 1996), to yield a more realistic

*The complete report by W. Tobler, U. Deichmann, J. Gottsegen, & K. Maloy, "The Global Demography Project", Technical Report 95-6, NCGIA Geography Department, University of California, 75pp + PC diskette, is available from NCGIA Publications, Geography Department, University of California, Santa Barbara, 93106-4060. Or contact NCGIAPUB@NCGIA.UCSB.EDU

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TABLE I

Difference in quadrilateral area using the exact ellipsoidal formula and using a mean radius sphere, in square kilometers. Based on a quadrangle area of 5 minutes in latitude and 5 minutes in longitude.

Latitude (Degrees)	Ellipsoid Area	Spherical Area	Diff. Sq km	Percent Diff.	E-W km Distance
0.00	85 480	85.863	-.384	-.449	9.266
5.00	85.158	85.531	-.374	-.439	9.230
10.00	84.204	84.548	-.344	-.408	9.124
15.00	82.625	82.922	-.296	-.358	8.949
20.00	80.430	80.664	-.234	-.291	8.705
25.00	77.631	77.792	-.162	-.208	8.395
30.00	74.245	74.329	-.083	-.112	8 021
35.00	70.295	70.299	-.004	-.006	7 587
40.00	65.805	65.735	0.070	0.107	7.094
45.00	60.806	60.670	0.136	0.223	6.547
50.00	55.332	55.114	0.188	0.340	5.951
55 00	49.422	49.198	0.224	0.452	5.309
60.00	43.118	42.878	0.241	0.558	4.627
65.00	36.469	36.231	0.238	0.653	3.910
70.00	29.526	29.308	0.127	0.736	3.163
75.00	22.342	22.163	0.179	0.802	2.392
80.00	14.976	14.849	0.128	0.851	1.602
85.00	7.487	7.421	0.066	0.881	0.801

Latitude refers to the southwest corner of the 5' by 5' quadrangle. The radius of 6371.007178 kilometers gives a spherical surface area of 510,065,621 km² equal to that of the WGS 1984 ellipsoid. Authalic latitude has not been used.

population distribution. An additional product is a tabulation of sub-national administrative unit names by 5 minutes in latitude and longitude. This can be used to assign other socio-economic variables to the spherical raster without significant computational cost. The centroids of the 19,032 polygons are also known by coordinates, and are given in the full report. Proprietary restrictions by a few countries prohibit our distribution of some of the sub-national boundary coordinates. The initial raster sizes required nearly 47 Mb of storage, but, since much of the earth's surface contains virtually no people this could be compressed to just over 5 Mb.

The accompanying viewgraphs illustrate the results for several regions, either by showing the boundary polygons used or by centroid locations or by displaying some of the resulting population distributions.

ANALYSIS

The data lend themselves to several kinds of analysis. The raster format has considerable advantage for analytical studies in which spatial series can be thought of as a two dimensional extension of time series, or for simulation modeling, etc. Population density, for example, can be defined using the finite difference approximation to the gradient of the population given by the grid. Only two simple results are presented here: The population distribution by latitude, and by longitude, using a data aggregation to 30 minutes is shown on viewgraphs. The latitudinal distribution of people is a peu pres unimodal with a peak around 30 degrees north. The longitudinal distribution shows 4 peaks, one for the Americas (120W to 30W), one bimodal bump representing Europe and Africa (7W to 52E), with the two largest peaks for India (67E to 90E) and China-East Asia (102E to 135E). A second simple computation gives the total number of people near water areas, by 30 minutes of latitude and by 30 minutes of longitude (also on view graphs). The cumulative number of people adjacent to water, for example is 465 million, using the 4 neighboring 30 minute cells, and 817 million using an 8 neighbor criterion. These numbers represent 8.3% and 14.5%, of the total world population. The use of 30 minute data rather than the 5 minute data is because these results are more easily comprehended and because this size easily fits within a DOS program on a PC. The computation is simplified because water is represented in the raster by a negative number.

CITATIONS

Matthews, E. (1983) "Global Vegetation and Land Use: New High-Resolution Data Bases for Climate Studies", *J. Climate & Applied Meteorology*, 22:474-487.

Tobler, W. (1996) "Converting Administrative Data to a Continuous Field on a Sphere", in *Proceedings, Third International Conference/Workshop on Integrating GIS and Environmental Modeling*, Santa Fe NM, Jan 21-26, 1996. NCGIA compact disk, Santa Barbara.