

Three Centuries of Global Population Growth: A Spatial Referenced Population (Density) Database for 1700–2000

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The Earth's surface has changed considerably over the past centuries. Since the start of the Industrial Revolution in the early 1700s, humans from the "Old World" started to colonize the "New World". The colonization processes lead to major changes in global land use and land cover. Large parts of the original land cover have been altered (e.g., deforestation), leading to extra emissions of GHG's to the atmosphere and enhancing global climate change. The spatial and temporal aspects are still not very well known. More and more global integrated environmental assessments concerning global sustainability require long time series of global change indicators, of which population is an important one. This study presents an update of the geo-referenced historical population maps for the period 1700–2000, part of the History Database of the Global Environment (HYDE), which can be used in integrated models of global change and/or global sustainability.

KEY WORDS: global spatial historical population map; HYDE; global change.

INTRODUCTION

As long as humans have lived on the face of the Earth, they have influenced the landscape they were living in. For thousands of years these

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changes were negligible, until population numbers started to increase. Worldwide, except for some already densely populated Indian and Chinese regions, the patterns of land use and land cover change followed the patterns of European settlement and economic development. At the beginning of the Industrial Revolution, a global economy started to emerge. This led to migration of people into the “New World”. New political ideas of Imperialism, combined with religious motifs and supported by new technology (weaponry, transport by ships, trains) enabled the Old Economies to explore and exploit the huge virgin lands outside the Old World.

In large parts of Europe, the end of the 17th and the 18th century was a period of great and sustained fall in mortality and followed by higher birth rates. This resulted in a large excess of births over deaths, thus producing a high natural increase of the population. Changes in agriculture and industrialism triggered migration within Europe, resulting in increasing urbanisation and also out-migration began towards the “New World”.

This study presents new global geo-referenced population density maps for the period 1700–2000. It is an update from work as described by Klein Goldewijk (2001). Improvements to the former version are the inclusion of many historical population data sources on a sub-national administrative unit level. Furthermore, population growth rates from a study of Grigg (1987) were applied to all of the administrative units where no data were given for historical time periods. In this way, a detailed historical population estimate for the last 300 years was created, with spatial components as well.

METHODOLOGY

Starting point of the historical population maps is a new global administrative boundary map on a sub-national level, developed at RIVM (Klein Goldewijk, Meijer, & Wonink, 2004). It follows, if available, the ISO3166-2 coding for all countries in the world. Small omissions were manually added and corrected. The map comprises 222 countries, divided into 3441 administrative units. The choice was to use the ISO3166-2 level globally, for transparency and consistency reasons, although it results in large administrative units in some countries (State levels in Canada, Australia, and US) and smaller units in other countries (e.g., The Netherlands, Bangladesh, Ghana). Another compelling reason is that much of the historical population data sources used in this study, are provided on

the ISO3166-2 level, and not on a more detailed one (such as NUTS 3 levels for Europe, and county levels for the USA).

This map was the base for the data collection. Where possible, historical population data were collected at the ISO3166-2 level or converted to match that level. Important sources for the sub-national population data were the Populstat database (Lahmeyer, 2004) and the Gazetteer (2004). Populstat present historical population data for almost all countries of the world on a national and sub-national level. The Gazetteer presents national and sub-national population numbers and administrative area estimates for the most recent dates. Crosschecks were done with data from Mitchell (1993, 1998a, b), Maddison (1995) and many local country studies.

Historical time series for each unit per country were used for as long as the data seemed to be more or less robust, and country totals obtained in that way were compared to other sources where possible. Gaps in data were filled through interpolation between data points. Hindcasting to the base year 1700 was done by using the regional growth rates given by Grigg (1987) where no data were available. Country, regional and world totals were compared to other sources and growth rates per continent were adjusted until they were close to the numbers found in literature.

When country totals were given for year t_{hist} but sub-national data for year t_{recent} , the ratio between all sub-national administrative units compared to the country total in year t_{recent} was applied to year t_{hist} . In other words, the spatial differentiation within a country was assumed not to have changed over time. Of course, this is probably not true in reality, but due to data constraints it seems the most reasonable thing to do.

RESULTS

Table 1 presents global estimates for the total population numbers for 1700–2000. The HYDE estimate of 626 million for year 1700 agrees well with the numbers found in literature, ranging from 410 million (Braudel, 1981) to 679 million (Biraben, 1980). Global numbers increased from 815 million in 1750 to 985 million in 1800. The first billion people inhabited the planet shortly after 1800, going up from 1297 million in 1850 to 1689 million in 1900. The two billion point was reached already just before 1930. In 1950 the total number of people on Earth really started to grow exponentially, around 2,660 million in 1950, 3185 million in 1960, 3762 million in 1970, 4,484 million in 1980, 5,278 in 1990 and reaching the 6 billion before the year 2000 (6,088 million).

TABLE 1
Total Global Population Estimates (in millions)

	1700	1750	1800	1850	1900	1950	1960	1970	1980	1990	2000
Woytinski and Woytinski (1953)					1,608	2,400					
Ox. Ec. Atlas (1972)					1,571						
Matras (1973)	694		978	1,262	1,650	2,521					
United Nations (1973)	791				1,650						
Durand (1974), lower	735				1,710						
Durand (1974), upper	805				1,600	2,400					
Thomlinson (1975), lower	600	700	900		1,580	2,490	2,980	3,630			
Tuве (1976)					1,668						
Durand (1977)	731				1,625	2,500					
McEvedy and Jones (1978)	610	720	900	1,200	1,625	2,500					
Biraben (1980)	679	770	954	1,241	1,633						
Braudel (1981)	410										
Bogue (1985)						2,524	3,037	3,696	4,432		
Merrick (1986)		760	1,000		1,630	2,516					
Winkler Prins (1987)			910		1,610	2,500	2,990	3,765			
Grigg (1987)	641		890	1,171	1,668	2,486	2,982	3,632	4,414		
WRI (1987)						2,516	3,014	3,698	4,453	5,293	
Demeny (1990)					1,650				4,430		
Richards (1990)											
Maddison (1991)	603										
United Nations (1992)						2,511	3,013	3,688	4,433	5,273	
Klein Goldewijk and Battjes (1995)					1,638	2,511	3,013	3,688	4,433	5,273	
Haub (1995)	500	795		1,265	1,656						
Tanton (1995)	600		900		1,600	2,400					
Stern and Kaufmann (1996)					1,622	2,516	3,019	3,697	4,447	5,295	

TABLE 1 (Continued)

	1700	1750	1800	1850	1900	1950	1960	1970	1980	1990	2000
United Nations (1996)						2,524	3,027	3,702	4,447	5,282	
Kapitsa (1997)		728	907	1,170							
United Nations (2000)						2,519	3,020	3,691	4,430	5,255	6,057
Klein Goldewijk (2001)	605	723	975	1,264	1,628	2,531	3,037	3,716	4,465	5,302	
United Nations (2002 Rev.)						2,519					6,071
Lucas (2003)		728		1,171		2,519		3,691	4,430	5,255	6,057
Lower literature estimate	410	694	890	1,170	1,571	2,400	2,980	3,630	4,414	5,255	6,057
This study	626	816	985	1,297	1,689	2,660	3,185	3,762	4,484	5,278	6,088
Upper literature estimate	679	805	1,000	1,265	1,710	2,531	3,037	3,765	4,465	5,302	6,071

TABLE 2
Regional Population Estimates (in thousands)

	1700	1750	1800	1850	1900	1950	2000
North America							
Merrick (1986)		2,000	6,860		82,000	166,000	
UN (2002)					82,500	171,550	313,987
US Bureau of Census (2004)*	953	2,057	6,082	25,659	76,094	152,271	281,422
This study					81,656	165,004	311,589
Latin America							
Sanchez-Albornoz (1974)				30,495			
Durand (1977)		14,000			63,000		
Merrick (1986)			24,500		70,000	165,000	518,809
UN (2002)					74,250	166,995	
Lucas (2003)		11,000		33,000			
This study	10,268	15,237	23,037	35,900	68,435	162,700	513,755
Africa							
Merrick (1986)		100,000			133,000	224,000	
UN (2002)			106,820		133,650	220,888	793,627
Lucas (2003)		95,000			122,000		
This study	92,289	92,339	93,059	97,664	119,947	251,090	817,352
Asia							
Durand (1977)		455,000			500,000		
Merrick (1986)**			636,020		867,000	1,292,000	3,672,342
UN (2002)					947,100	1,399,170	
Lucas (2003)		479,000					
This study, incl. Oceania	376,198	518,615	621,085	799,417	932,042	1,388,851	3,405,113

TABLE 2 (Continued)

	1700	1750	1800	1850	1900	1950	2000
Europe							
Durand (1977)		102,000			284,000		
UN (2002)						361,115	487,293
Lucas (2003)***		140,000					
This study	89,376	113,204	143,102	208,249	290,728	399,510	517,900
CIS							
Grigg (1987)		40,000	55,000	80,000	150,000	190,000	
This study	32,323	42,927	58,506	79,049	137,208	204,435	282,920

* USA only.

***Without Japan.

***Incl. USSR.

The increase was not equally spread all over the world. Table 2 presents some regional historical population estimates from different authors, and the next section will go into more detail for each specific world region.

Asia

Historically, already a large part of the global population has been living in Asia. Parts of Eastern China and the Indus Valley in India have been populated for a long time period, resulting in relatively high population densities. In the year 1700, estimates for the Indian region (India, Pakistan, Bangladesh, Nepal, Sri Lanka, Afghanistan, Maldives and Bhutan) start at 146 million people, which yield a density of 29 inh/km². The population hardly increased for a long time period to 176 million in 1800, and about 325 million in 1900, but then growth became exponential resulting in 486 million in 1950 and 1357 million in 2000. This is also reflected in the growth rates; from 1700 to 1800 it was around 0.18% per year, from 1800 to 1900, 0.62% increasing to 0.81% per year for the 1900–1950 period and a staggering 2.08% per year for the last 50 years.

The population growth of the China region (China, Mongolia, Taiwan, and Aomen – formerly known as Macau) is somewhat more rugged. Until the World War II, the population growth of China seemed to fluctuate according data of Liu and Hwang (1979). Growth rates vary considerably during that period, especially in the earlier periods. Starting at a 0.90% per year in the first five decades of the 18th century, they seem to collapse during the following 100-year period (less than 0.20%, and even negative (–0.06%) for China for 1850–1900), but increasing to 0.56% and 1.78% during the second half of the 20th century. For a long time, Chinese population growth was constrained by a ceiling set by the limitations of advanced pre-modern technology in a long applied traditional agriculture (Liu and Hwang, 1979). New dynasties led often to temporal increases in peace and order, often resulting in settlement of sparsely settled land when the traditional agriculture could not sustain larger population numbers. Dynastic decay, pestilence, famine and social disorder led in their turn to serious declines in population numbers. All this, results in a total population estimate for the China region of 141 million in 1700, 343 million in 1800, 406 million in 1900, and almost 1300 million in 2000.

The rest of Asia (Mekong region, the Korea's, Indonesia region, Japan and Oceania) showed a modest population increase during the 18th century (growth rates less than 0.20% per year). The average growth rates increased to 0.6% in the 19th century, with the exception of Indonesia, which experienced a higher average growth rate of 1.23% per year. Oceania is an

exception, due to the immigration flow towards Australia (8% per year in the 19th century). Most countries in the rest of Asia had a growth rate of more than 1% per year after 1950 (Malaysia, Philippines, Singapore and Brunei Dar El Salaam even more than 2% per year), except Japan and some smaller Pacific Islands, who showed a modest increase.

This brings the total estimate for the whole Asia region at 376 million in 1700, 519 million in 1750, 621 million in 1800, 799 million in 1850, 932 million in 1900, 1389 million in 1950 and 4305 million in 2000 (see table 4).

Countries with a relative high population density in 1700 were the Maldives (285 inh/km²), Korea Rep. (108 inh/km²), Bangladesh (86 inh/km²) and some small Pacific islands states such as Tuvalu, Nauru (>100 inh/km²). This view is somewhat blurred by the sheer size of countries like China and India. Chinese provinces such as Aomen (1975 inh/km²), Xianggang (619 inh/km²) and Shanghai (227 inh/km²) and the Indian state of Pondicherry (226 inh/km²) were much more populated than other parts of the country.

Also Taiwanese cities like Chiayi, Taipei, Kaohsiung and Taichung were apparently densely populated at that time. At present, 84 provinces/states in Asia have more than 500 inh/km², and even 43 of them reaching over 1000 inh/km², all of them located in China (3), Taiwan (10) and Bangladesh (30). Sizzling exceptions are Aomen (>20,000 inh/km²), cities such as Jakarta, Seoul, Taipei, Manila (all more than 13,000 inh/km²), the states of Chandigarh and Delhi in India (>7,000 inh/km²), Hong Kong (>6,000 inh/km²), Singapore, Osaka and Tokyo (>4,000 inh/km²).

Spatially many of the population "hotspots" can be located on the fertile river deltas of the Brahmaputra and Ganges in Bangladesh, the Indus Valley in northern India, the Yangtze, the Yellow River and the Huang He in China, the Mekong in Vietnam, and the whole Island of Java in Indonesia. The paddy rice cultivation has evolved to perfection over centuries so that relative high population densities could and still can be sustained in those areas, without deterioration of the environment.

Africa

Estimates for the African continent must be treated with care. Especially before 1900, the numbers are highly uncertain, most African countries did not even have a census until the 1960s. There are some estimates for total Africa for the year 1750 to be found in the literature ranging between 95 million and 100 million people (Merrick, 1986; Lucas, 2003). This study estimates a total of 92 million people in 1700. Following the growth rates of Grigg (1987), the 18th century apparently showed hardly any increase in the total number of people of the continent (ca. 0.01% per year), in some

TABLE 3
Growth Rates per Region (in %)

	1700/ 1750	1750/ 1800	1800/ 1850	1850/ 1900	1900/ 1950	1950/ 2000	1700/ 1800	1800/ 1900	1900/ 2000	1700/ 2000
North America	1.55	2.19	2.92	2.34	1.42	1.28	1.87	2.63	1.35	1.95
Latin America	0.79	0.83	0.89	1.30	1.75	2.33	0.81	1.09	2.04	1.31
Europe	0.47	0.47	0.75	0.67	0.64	0.52	0.47	0.71	0.58	0.59
Africa	0.00	0.02	0.10	0.41	1.49	2.39	0.01	0.25	1.94	0.73
CIS	0.57	0.62	0.60	1.11	0.80	0.65	0.60	0.86	0.73	0.73
Middle East	0.50	0.49	0.50	0.30	0.80	2.02	0.50	0.40	1.41	0.77
Asia	0.64	0.36	0.50	0.30	0.80	1.81	0.50	0.40	1.30	0.74
Oceania	0.51	0.52	0.83	1.61	1.09	1.46	0.52	1.22	1.27	1.00
World	0.53	0.38	0.55	0.53	0.91	1.67	0.45	0.54	1.29	0.76

areas even a decrease occurred, probably due to the slave trade business. Famine, diseases, and tribal warfare resulted in a very low life expectancy. The average growth rate for the continent slowly increased to 0.10% per year in the first half of the 19th century, climbing to 0.41% per year for the second half (see Table 3). It really started to increase considerably in the 20th century, 1.49% per year for the pre-Second World War period, and 2.39% per year for the past five decades. The accompanying numbers are 92 million in 1750, 93 million in 1800, 120 million in 1900, 251 million in 1950 and 817 million in 2000 (Table 4). This is a gain of 725 million over the last 300 years, with a growth rate of 0.73% per year.

The countries with the highest population density in 2000, except for island nations such as Mauritius, Seychelles, Reunion and The Comoros (all over 300 inh/km²), are Rwanda (317 inh/km²) and Burundi (260 inh/km²), followed by Ethiopia (142 inh/km²) and Malawi (113 inh/km²). The islands could sustain themselves for a long time with fishery and in a later stadium generate extra income through tourism, but inland states like Rwanda and Burundi could not. These small countries have almost no natural resources and have already completely stripped their natural vegetation for agriculture, food, fuelwood and fodder. Currently there are 44 African provinces/states with more than 1000 inh/km² and 69 provinces/states with more than 500 inh/km² (many of them to be found in Nigeria, Egypt and several capital areas all over the continent). In contrast, many desert regions such as Libya, Western Sahara, Botswana, Namibia and Chad, as well as tropical rainforested countries such as Gabon and the Central African Republic are still largely uninhabited (all less than 5 inh/km²).

The Americas

The absolute increase in population in the Americas is in absolute numbers may be not so spectacular, but the temporal pace is phenomenal. When Columbus first arrived in the Americas in 1492, he did not find an empty continent. The estimates differ widely from 8 million to even up to 112 million, with a best guess of 54 million in 1492, but numbers are believed to have rapidly declined again to 8 million in 1650 (Denevan, 1992). Central America was long before Columbus arrived already (sometime densely) populated by highly civilized cultures like the Mayas, Aztecs, etc. Internal warfare and climate driven severe events (e.g., droughts, with the following diseases) already resulted in declining population numbers. On top of that, after the first settlers came to these regions, they brought with them also non-endemic diseases to the continent, and many native Americas died of the flu and other "Old World" surprises. Estimates in this study for Latin America are 10 million

TABLE 4

Population Totals and Densities per Region

	1700	1750	1800	1850	1900	1950	2000
<i>Total population (in million)</i>							
North America	1.0	2.1	6.1	25.7	81.7	165.0	311.6
Latin America	10.3	15.2	23.0	35.9	68.4	162.7	513.8
Europe	89.5	113.3	143.3	208.3	290.7	399.5	517.8
Africa	92.3	92.3	93.1	97.7	119.9	251.1	817.4
CIS	32.3	42.9	58.5	79.0	137.2	204.4	282.9
Middle East	24.2	31.1	39.7	51.0	59.2	88.1	239.4
Asia	374.9	517.0	618.9	796.2	924.8	1,376.5	3,379.6
Oceania	1.3	1.7	2.1	3.2	7.2	12.4	25.6
World	625.7	815.6	984.8	1,297.0	1,689.2	2,659.7	6,088.0
<i>% of total world population</i>							
North America	0.2	0.3	0.6	2.0	4.8	6.2	5.1
Latin America	1.6	1.9	2.3	2.8	4.1	6.1	8.4
Europe	14.3	13.9	14.5	16.1	17.2	15.0	8.5
Africa	14.7	11.3	9.4	7.5	7.1	9.4	13.4
CIS	5.2	5.3	5.9	6.1	8.1	7.7	4.6
Middle East	3.9	3.8	4.0	3.9	3.5	3.3	3.9
Asia	59.9	63.4	62.9	61.4	54.8	51.8	55.5
Oceania	0.2	0.2	0.2	0.3	0.4	0.5	0.4
World	100.0	100.0	100.0	100.0	100.0	100.0	100.0
<i>Cumulative (in millions)</i>							
North America	1.0	3.8	10.6	44.8	149.7	308.8	588.1
Latin America	10.3	29.3	44.2	68.8	127.8	296.0	948.6
Europe	89.5	221.4	280.0	403.9	559.9	778.8	1,025.1
Africa	92.3	184.6	185.9	194.2	233.7	464.3	1,436.4
CIS	32.3	83.4	113.4	154.2	258.6	398.4	565.3
Middle East	24.2	60.6	77.6	99.5	117.7	167.0	434.2
Asia	374.9	988.8	1,252.3	1,562.5	1,794.7	2,623.5	6,320.5
Oceania	1.3	3.2	4.2	6.1	13.7	23.5	48.2
Total	625.7	1,575.1	1,968.2	2,533.9	3,255.9	5,060.3	11,366.3
<i>Population density (inh/km²)</i>							
North America	<0.1	0.1	0.3	1.3	4.3	8.6	16.3
Latin America	0.5	0.7	1.1	1.7	3.3	7.9	25.0
Europe	12.4	15.8	19.9	29.0	40.5	55.6	72.1
Africa	4.0	4.0	4.0	4.2	5.2	10.8	35.3
CIS	1.4	1.9	2.5	3.4	6.0	8.9	12.3
Middle East	4.0	5.1	6.5	8.4	9.7	14.4	39.3
Asia	12.5	17.9	22.2	27.5	31.2	46.0	112.5
Oceania	0.2	0.2	0.3	0.4	0.9	1.5	3.2
World	4.6	6.2	7.6	9.8	12.5	19.6	44.8

people in 1700, 15 million in 1750, 23 million in 1800, 36 million in 1850 and 68 million in 1900 (Table 4). The 1900 value of 68 million is well in range with estimates of Sanchez-Albanoz (1974) who estimated 61 million, and Durand (1974) with 63 million and Merrick (1986) with 70 million. The total population of Latin America increased further to 163 million in 1950 and 514 million in 2000.

Growth rates continued to increase during the last century, from 0.82% per year for the 18th century, to 1.30% per year for the 19th century and a formidable 2.1% per year for the 20th century. Over the period 1700–2000 this corresponds to a growth rate of 1.31% per year, although numbers are coloured by the huge colonization of the continent.

The major change for North America (Canada and USA) began when the first settlement was established in 1607 in Virginia, and many were to follow. After the Declaration of Independence in 1776, the settlers came in, claiming the land, and so opening the continent for what turned out to be a mass exodus of Europeans. Estimates in this study for North America are 1.0 million people in 1700, 2.1 million in 1750 and 6 million in 1800. Immigration resulted in 1850 already in 26 million people. Numbers continued to increase to 82 million in 1900, 165 million in 1950 and 312 million in 2000 (Table 4).

States with high population densities at the start of the 18th century were the first colonized coastal areas such as Rhode Island and Connecticut (both more than 10 inh/km²), Delaware, Maryland and Massachusetts (more than 5 inh/km²). At the end of the 20th century the top 5 states with the highest densities are District of Columbia (3,600 inh/km²), New Jersey (438 inh/km²), Rhode Island (387 inh/km²), Massachusetts (312 inh/km²) and Connecticut (271 inh/km²). South and North Dakota, Montana, Wyoming and Alaska are still quite empty with less than 5 inh/km². Canada's Prince Edward Island with an average of 24 inh/km² is the most populated state; the rest is apart from a few larger cities still hardly populated.

Apart from many small islands in the Caribbean who have relative high population densities (e.g., Bermuda, Grenada, Guadeloupe, Martinique all more than 900 inh/km²), the bigger islands (Cuba, Jamaica, Haiti, Dominican Republic) are in the range of 100–300 inh/km². Mainland Central America is in general less densely populated. El Salvador with 293 inh/km² is an exception, but Mexico, Belize, Nicaragua, Guatemala, Costa Rica, Honduras and Panama are all under 75 inh/km². Of course, local circumstances may differ such as the Capital area of Mexico City, or the San Jose valley in Costa Rica who have much higher population densities.

South America is still not densely populated. Ecuador with 43 inh/km² is the highest in the region, Brazil has a density of 20 inh/km² but this is a distorted picture because of the vast, virtually uninhabited Amazon area, while the coastline has some large urban areas (Sao Paulo, Rio de Janeiro). Also, the Andes countries have some densely populated valleys, with a sparsely inhabited mountainous areas and lowland rainforest hinterlands.

French Guyana, Guyana and Surinam with less than 3 inh/km² are more or less still pristine.

Europe

Europe has seen an increase in population over the last three centuries of 428 million people, although the growth rate over that period is relative low (0.59% per year, Table 3). Reason for this is the fact that it was already relative densely populated in 1700, about 12 inh/km², which is comparable to the eastern part of China in that year. Only the India region has a higher population density in 1700, namely 32 inh/km². Europe witnessed the highest increase in population numbers during the first half of the 19th century (average of 0.75% per year) and they have been decreasing ever since (0.52% per year in the 1950–2000 period). Total numbers were 113 million in 1750, 143 million in 1800, 208 million in 1850, 291 million in 1900, 400 million in 1950 and 518 million people in 2000, which is comparable to the number of Latin America (see Table 4). The last decades, many European countries witness a decline in population. The aging society and declining birth rates are responsible for the so-called “greying” of many societies such as Germany and Italy, and other European countries are expected to follow. Currently, only immigration keeps the total population of The Netherlands at a—for economic reasons—desired level (CBS, 2003).

European countries with the highest population density in 1700 were Belgium and the Netherlands (55–60 inh/km²), United Kingdom followed with 44 inh/km², and Germany and Ireland (36–38 inh/km²), comparable with Eastern Europe's Czech Republic and Hungary (37 and 33 inh/km² resp.). The population density for whole Europe increased from 12.9 inh/km² in 1700 to 72.1 inh/km² in 2000. Western and Eastern Europe do not differ that much on an average population density from 16 inh/km² in 1700 for Eastern Europe (18 inh/km² for Western Europe) towards 95 inh/km² in 2000 (106 inh/km² for Western Europe). It must be noted that none of the Eastern European countries has a population density of more than 131 inh/km² (Czech rep.), Poland is second with 124 inh/km², followed by a group consisting of Albania, Hungary, Slovakia, Serbia (around 100 inh/km²).

Apart from the relative sparse populated Baltic states of Latvia and Estonia (less than 32 inh/km^2) the rest of Eastern Europe has a population density between 60 and 100 inh/km^2 .

Most densely populated countries, apart from city-states as Monaco, San Marino and Gibraltar, are Malta (1183 inh/km^2), The Netherlands (473 inh/km^2) and Belgium (335 inh/km^2). Space can still be found in Northern Europe, Iceland (3 inh/km^2), Norway (14 inh/km^2), Finland (17 inh/km^2) and Sweden (19 inh/km^2) are sparsely inhabited.

Middle East

The population growth in the Middle East region seemed relatively stable during the 1700–1850 period (0.5% per year), leading to an estimate of 24 million people in 1700, and 51 million in 1850. Then, apparently a slowing down of the growth rates took place to 0.30% per year (leading to 59 million people in 1900) and a strong recovery of the growth rates after 1900, 0.80% per year for the first half of the 20th century (88 million in 1950) and a spectacular 2.02% per year for the second half (239 million in 2000; see also Tables 3 and 4).

Dominant countries concerning total population numbers are Turkey and Iran; together they made up 58% of the total population in the region in 1700, and still add up to 54% of the total in 2000.

The population density for the whole region increased from 4.0 inh/km^2 in 1700 to 39.3 inh/km^2 in 2000. However, large differences exist between countries. Little states such as Bahrein are most densely populated (1086 inh/km^2 in 2000), followed by Lebanon (384 inh/km^2) and Israel (300 inh/km^2). The lowest densities occur in Oman (8 inh/km^2) and Saudi Arabia (10 inh/km^2).

CIS Region

The region of the former Soviet Union shows a similar trend in growth rates as Europe, with a peak in growth rates in the second half of the 19th century, although the absolute growth rates are higher than in Europe. Starting with 32 million people in 1700, 43 million in 1750, 59 million in 1800, and 137 million in 1900 (Table 4). The Famine of 1891, the First World War and the Revolution of 1917, as well as the Second World War had their significant impact on total population numbers. Estimates of casualties range from 10 million during the first episode, to 25 million in WWII, but numbers rose again to 204 million in 1950, and

283 million in 2000. After the last “revolution” in 1991, a breakdown of the economy and deteriorating health care resulted in a gradually lowering of the life expectancy and a decline in total population. The overall population density remains relative low, of course distorted by the huge size of the country itself, from 1.4 inh/km² in 1700 to 12.3 inh/km² in 2000.

Oceania

This region is dominated by Australia, a virtually empty continent in 1700. Estimates of the aboriginal population at that time range from 150,000 to 500,000 people, with a best estimate of 300,000 (Wikipedia, 2004). The first settlers arrived in 1788, and soon violent disputes over land ownership and foreign diseases (e.g., smallpox, measles) decimated the indigenous population to 100,000 in the early 20th century. Indigenous people were not classified in the official census data until 1901. The estimates for whole Oceania start with 1.2 million people (or 1.5 million incl. indigenous numbers), 2.1 million in 1800, 7.2 million in 1900 and 26 million in 2000 (of which 19 million live in Australia). Immigration has always made a large contribution to the population growth in Australia. After WWII, 5.5 million people came into the country, of which 80% stayed (Wikipedia, 2004). Still, the average population density remains very low at hardly 3 inh/km².

DISCUSSION

In summary, the largest increase in sheer population numbers over the last 300 years took place in Asia with more than 3 billion people, where the India and China regions alone added more than 1 billion people each to our planet. Africa came in second with 725 million added to the global total. Latin America ranks third with 503 million. Europe increased in population size with 428 million people, but also populated large parts of the world in the 17th and 18th century. Probably it will be the first region in the world that will decline in population size in the near future, due to the aging of many European societies, and stricter immigration laws. North America (311 million), CIS (251 million), Middle East (215 million) and Oceania (25 million) complete the list.

The overall picture is that Europe, CIS, the northern part of India and the eastern part of China were already more or less densely populated in 1700 and experienced since then a relative modest increase in population

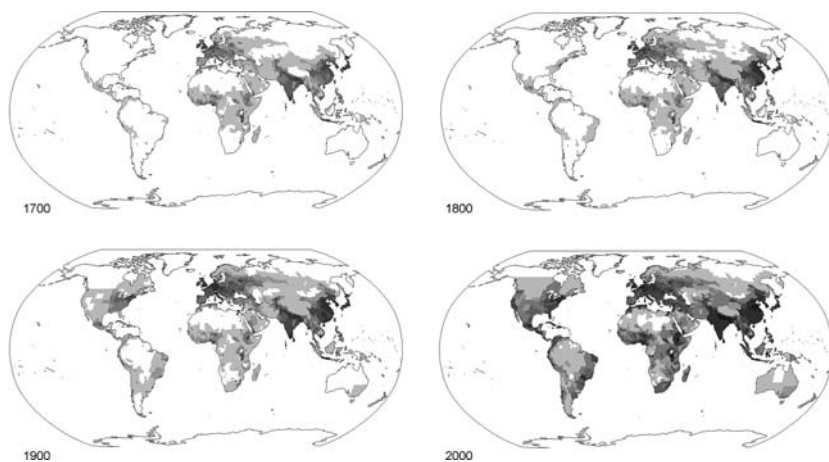


FIGURE 1.

density. Especially Europe served as a ‘springboard’ for settlers towards many virtually empty regions in the world at the end of the 17th century (see Figure 1).

The proportion of people living in Europe in 1700 was 14% of the world total, approximately the same as in Africa at that time. Oceania, North America were virtually inhabited with 0.2%, Latin America accounted for less than 2%. Middle East and CIS reached resp. just 4% and 5%. The majority of the global population did already live in Asia (60%) and this number hardly decreased to 56% in the year 2000. The share of North America increased to 5%, the share of Middle East remains unchanged (4%). Europe’s share decreased to 8.5%, while Africa first showed a decrease to around 7% around the end of the 20th century, but its share increased again to 13% in 2000.

Over the past 300 years not less than 70% of the world population lived in the less developed regions of the world. Dominated by Asia and Africa in 1700, it gradually shifted to Asia, Latin America and Africa in 2000. Looking at the last hundred years a clearer picture emerges. In 1900, Europe’s share of the world population was at its highest at 17%, the same applies to CIS with 8 to 9%. North America already reached at that time its current share of 5%, which is also true for Middle East (3.5%) and Oceania (0.4%). Latin America accounted for 4% in 1900, but gradually increased its share to more than 8% in 2000 and is still increasing. Africa shows a similar growth, from 7% in 1990 towards more than 13% in 2000.

Uncertainty

A major problem for a study like this is—not surprisingly—the lack of good historical data for many countries. Good historical census data are in general scarce, and in lots of cases of a recent date. Other sources provide sometimes patchy information, and it is hard to get a good understanding of the reliability of them. However, it is important to note, that the purpose of this study is not to present the ultimate, exact, demographic overview of the past 300 years, but a broad overview instead, useful for global change modelers, and with sufficient detail and quality.

For most countries it is defensible to use growth rates as published in literature, in combination with additional data sources found. The exact numbers could be somewhat higher or lower, depending on the growth rates used, but the general magnitude and trends are satisfactory for users as mentioned before.

The growth rates as presented by Grigg (1987) for 10 world regions are in general agreement with numbers found in other studies (UN, 2003; Durand, 1974). With no country specific information available, regional growth rates are applied to all countries within a region. Also, when no sub-national growth rates were available, the regional growth rate was applied to all administrative units in a particular country of that region. Table 3 presents the resulting average growth rates from the different regions.

Bearing the uncertainties in mind of applying one single regional growth rate to all country/province levels in that region, a plus and minus 5, 10 and 20 percent uncertainty intervals on the growth rates were computed. This yields a bandwidth in the total population numbers for each country, accumulating eventually in a regional bandwidth and a global one. Table 5 presents the upper and lower total numbers acquired in this way. The 5% bandwidth for the growth rates in 1700 results in a global lower and upper limit of 560 and 648 million people, with a best estimate of 626 million people. This is in good agreement with the bandwidth found in literature, which can be depicted from Table 5, that ranges from 410 million (Braudel, 1981) to 679 million people (Biraben, 1980). A large portion of the 10% bandwidth (521 to 692 million) is still within the range found in the literature, the 20% bandwidth ranges from 439 to 778 million people for the year 1700. It must be noted that for some regions the bandwidth is smaller than in other regions due to the fact that for some countries/regions much more historical data are available and consequently those regions are less susceptible for changes in the growth rates.

TABLE 5

Uncertainty in Population Totals per Region (in thousands)

	1700	1750	1800	1850	1900	1950	2000
Africa							
Lower – 20% estimate	123,991	124,116	124,906	129,838	153,090	276,858	817,344
Lower – 10% estimate	106,933	107,048	107,830	112,699	135,634	263,907	817,344
Lower – 5% estimate	99,461	99,544	100,295	105,032	127,673	257,561	817,344
Best estimate	92,289	92,339	93,059	97,664	119,947	251,090	817,352
Upper + 5% estimate	86,894	86,918	87,612	92,162	114,259	246,128	817,344
Upper + 10% estimate	81,350	81,341	82,003	86,484	108,363	240,762	817,344
Upper + 20% estimate	69,870	69,775	70,351	74,649	95,966	228,597	817,345
North America							
Best estimate	953	2,057	6,082	25,659	81,656	165,004	311,589
Latin America							
Lower – 20% estimate	13,849	18,761	25,724	36,781	68,593	162,817	513,717
Lower – 10% estimate	11,977	17,021	24,498	36,632	68,593	162,817	513,717
Lower – 5% estimate	11,043	16,017	23,541	35,985	68,484	162,817	513,717
Best estimate	10,268	15,237	23,037	35,900	68,435	162,700	513,755
Upper + 5% estimate	8,753	13,196	20,185	32,207	63,426	161,024	513,713
Upper + 10% estimate	7887	12,139	18,974	31,062	63,232	161,024	513,713
Upper + 20% estimate	6815	10,911	17,760	30,441	63,022	161,024	513,713
Asia							
Lower – 20% estimate	444,730	604,249	726,843	865,521	958,068	1,383,474	3,379,562
Lower – 10% estimate	399,560	563,005	691,839	846,465	954,890	1,383,474	3,379,562
Lower – 5% estimate	376,446	540,213	670,314	828,860	938,061	1,379,195	3,379,562
Best estimate	374,912	516,953	618,936	796,167	924,828	1,376,457	3,379,562
Upper + 5% estimate	326,355	487,988	617,482	777,176	895,628	1,367,467	3,379,562
Upper + 10% estimate	304,226	464,092	592,413	756,361	872,745	1,358,768	3,379,562
Upper + 20% estimate	326,355	487,988	617,482	777,176	895,628	1,367,467	3,379,562
Oceania							
Lower – 20% estimate	1,708	2,207	2,854	3,917	7,773	12,612	25,551
Lower – 10% estimate	1,536	1,986	2,568	3,727	7,744	12,612	25,551
Lower – 5% estimate	1,409	1,821	2,355	3,519	7,549	12,535	25,551
Best estimate	1,286	1,662	2,149	3,250	7,213	12,394	25,551
Upper + 5% estimate	804	1,054	1,383	2,347	5,979	11,751	25,551
Upper + 10% estimate	595	792	1,056	1,838	5,328	11,345	25,551
Upper + 20% estimate	351	478	652	1,141	4,432	10,524	25,551
CIS							
Lower – 20% estimate	43,582	54,598	70,402	89,905	139,700	204,435	282,920
Lower – 10% estimate	37,762	48,656	64,446	84,311	138,483	204,435	282,920
Lower – 5% estimate	34,655	45,526	61,388	81,625	137,852	204,435	282,920
Best estimate	32,323	42,927	58,506	79,049	137,208	204,435	282,920
Upper + 5% estimate	29,644	39,886	55,068	75,345	134,443	203,659	282,920

TABLE 5 (Continued)

	1700	1750	1800	1850	1900	1950	2000
Upper + 10% estimate	26,481	36,226	50,841	71,105	130,099	202,168	282,920
Upper + 20% estimate	18,515	26,630	39,284	57,872	110,624	192,269	282,920
Central Europe							
Lower - 20% estimate	29,877	35,042	41,101	52,201	69,022	100,091	128,513
Lower - 10% estimate	25,803	30,864	36,919	48,264	65,992	99,179	128,513
Lower - 5% estimate	23892	28,865	34,875	46,346	64,375	98,664	128,513
Best estimate	21,909	26,768	32,705	44,121	62,412	98,022	128,513
Upper + 5% estimate	20,301	25,008	30,806	42,217	60,660	97,427	128,513
Upper + 10% estimate	18,616	23,137	28,756	39,928	58,709	96,768	128,513
Upper + 20% estimate	15,615	19,804	25,118	35,973	54,782	95,322	128,513
Western Europe							
Lower - 20% estimate	86,058	104,913	127,317	174,522	237,106	306,180	389,331
Lower - 10% estimate	78,574	97,966	121,641	173,507	237,106	306,180	389,331
Lower - 5% estimate	73,192	92,633	116,814	170,076	233,918	305,323	389,331
Best estimate	67,559	86,558	110,557	164,159	228,308	301,461	389,331
Upper +5% estimate	64,225	83,171	107,449	161,858	228,164	301,461	389,331
Upper + 10% estimate	59,987	78,541	102,679	158,493	227,946	301,461	389,331
Upper + 20% estimate	53,410	71,406	95,559	153,199	227,553	301,461	389,331
Middle East							
Lower - 20% estimate	32,768	40,026	48,814	59,465	66,911	91,922	239,396
Lower - 10% estimate	28,034	35,164	44,021	55,035	62,913	89,951	239,396
Lower - 5% estimate	26,228	33,248	42,054	53,350	61,331	89,136	239,396
Best estimate	24,229	31,071	39,749	51,019	59,175	88,102	239,397
Upper + 5% estimate	22,365	29,048	37,629	48,923	57,140	86,948	239,396
Upper + 10% estimate	20,681	27,242	35,780	47,019	55,510	86,106	239,396
Upper + 20% estimate	17,786	24,007	32,289	43,644	52,243	84,294	239,396
World (in millions)							
Lower - 20% estimate	778	986	1,174	1,438	1,782	2,703	6,088
Lower - 10% estimate	691	904	1,100	1,386	1,753	2,688	6,088
Lower - 5% estimate	647	860	1,058	1,350	1,721	2,675	6,088
Best estimate	626	816	985	1,297	1,689	2,660	6,088
Upper + 5% estimate	560	768	964	1,258	1,641	2,641	6,088
Upper + 10% estimate	521	726	919	1,218	1,604	2,623	6,088
Upper + 20% estimate	510	713	905	1,200	1,586	2,606	6,088

Note: Lower means lower growth rate.

Note: North America almost entirely based on real data.

What Does This All Mean?

All these numbers show that global population growth has not only been rapid over the past three centuries, but also unequally distributed, in time as well as in location. The question arises what consequences this growth has had on the global and local environment, and what it could have in the future. A think tank of scientists, economists, businessmen, international high civil servants, and (former) heads of state called the "The Club of Rome" rang the alarm bell already in 1972 with its report "Limits to Growth". They argued that the 'man-made damage to the Earth's Nature put its survival at stake'. Concerns were made that population, food production, and consumption of non-renewable natural resources was increasing at a rate, that 'the limits to growth on this planet will be reached sometime within the next 100 years. The most probable result would be a rather sudden and uncontrollable decline in both population and industrial capacity'. However, none of these concerns lived up to its promise, so far. Table 6 presents a few selected indicators which highlight the trends over the past 300 years.

Klein Goldewijk (2001) presented historical land use estimates for the last 300 years, with a global cropland area of approximately 266 Mha in 1700, a pasture (grazing land for livestock) area of 524 Mha and a forest area of 540 Mha. This yields a global cropland area per capita of 0.42 ha/cap in 1700, resp. 0.84 ha pasture area/cap and 0.86 ha forest area/cap. Although global cropland and pasture areas have expanded since 1700 at an stunning rate (ca. 1500 Mha cropland and 3400 Mha pasture in the year 2000), the population growth has indeed surpassed that. Resulting numbers for the year 2000 are 0.25 ha cropland/cap, 0.56 ha pasture/cap and 0.07 ha forest/cap (see Table 6). These numbers are a bit blurred by the global average, they can change considerable when one would examine different regions of the world. For example, large regions with relative low population densities (USA, Russia, and Australia) show quite different densities than highly populated regions (India, parts of China, Java, The Netherlands, and Rwanda).

So, apparently the majority of mankind has been able to feed itself, despite the growing pressure on resources. Studies (e.g. Heilig et al., 1999) have shown that (parts of) the world can sustain far more people than today, provided that economic resources and technology are committed to this goal. It's not the amount of food that must be produced which is the bottleneck, but the distribution across the planet which is failing nowadays.

Another point of concern is the increasing damage and pollution to the natural environment. Estimates of the UN Population Division (2004) project the world's population to peak at 9.22 billion people in 2075 (ranging between roughly 7 and 11 billion, depending on assumptions about fertility

rates), and stabilise to less than 9 billion in 2300. Regions like Africa and Asia will continue to increase in population, while Europe/Russia will decline/stabilise, thus most people will be added in the poorer countries. If all those future humans would claim the same standard of living/development as the developed world has today (and why not?) then it is very likely to have consequences on Earth's future climate.

For example, Marland, Boden, and Andres (2003) showed that the average global carbon dioxide emissions, stemming from combustion of fossil fuels, has increased from almost zero in pre-industrial times to almost 4 metric tons CO₂ per capita at present (Table 6). If the rest of the world would catch up with the 'modern' standards of living, the aggregate amount of carbon that would be put into the atmosphere would be very substantial, in the order of a 4 or 5-fold increase compared to the 6 Gt C of today (Cohen, 1996). These resulting emissions could lead to an (unwanted) further enhancement of the global climate (change) effect, and other phenomena such as sea level rise (IPCC, 2001), see also Table 6.

Cohen (1996) already stated that it seems to be a matter of choice and of natural constraints, of how do we wish to live, do we accept

TABLE 6

Selected Indicators of Global Trends

Indicator	Unit	1700	1800	1900	2000	Sources
Population	Millions	626	985	1,689	6,088	HYDE, United Nations
GDP	1990 G/K \$/cap*	615	658	1,262	6,012	Maddison (2003)
Number of cars	cars/1,000 cap	n.a.	n.a.	0.01	109	HYDE, WRI
Forest area	ha/cap	0.87	0.53	0.27	0.07	HYDE, FAOSTAT
Cropland area	ha/cap	0.43	0.41	0.48	0.25	HYDE, FAOSTAT
Cattle	Head/cap	0.18	0.23	0.27	0.21	HYDE, FAOSTAT
Pigs	Head/cap	0.08	0.10	0.12	0.16	HYDE, FAOSTAT
Goats	Head/cap	0.06	0.08	0.09	0.12	HYDE, FAOSTAT
Coal production	toe/cap	n.a.	0.01	0.29	0.39	HYDE, IEA
Oil production	toe/cap	n.a.	n.a.	0.012	0.59	HYDE, IEA
Gas production	toe/cap	n.a.	n.a.	0.003	0.36	HYDE, IEA
CO ₂ emissions	metric ton CO ₂ / cap	0.00	0.03	1.16	3.78	Marland et al. (2003)
CO ₂ concentration	ppmv	n.a.	280.80	279.72	369.39	IPCC (2001)
CH ₄ concentration	ppbv	n.a.	n.a.	974.10	1,774.68	IPCC (2001)

*Note: G/K = international Geary/Khamis dollars.

poverty for example or should every human on earth have access to all the resources, space for living, etc? Do we all want to eat meat, or is a vegetarian diet also acceptable? These and other choices do have direct effect on the way we influence our environment. With the current global economy goods are transported almost without barriers all over the world. But questions arise such as do we allow migration of people from regions with many people but no/little natural resources towards regions with resources but not enough labor force (and what about national borders and immigration laws ?).

CONCLUSION

This study presents a geo-referenced global historical population (density) data base for the past 300 years. Human population numbers have increased all over the world at an incredible pace, temporally as well as spatially. Large parts of the world were virtually uninhabited three hundred years ago, but are now under some form of human influence. Europe and parts of Asia were already relative densely populated at the start of the 18th century, and served as a springboard for colonization of areas of the virtually uninhabited world.

It is clear that this colonization of the world has left its mark on the environment. In many areas huge amounts of natural land cover have been converted into agricultural land, resulting on one hand in an enormous increase in food production, but on the other hand also in environmental damage and pollution, and loss of biodiversity. Question remains if population growth will continue to strengthen this trend or that with the right technology and the right choices we can achieve a more sustainable development. The technology seems already there, so it looks like a matter of choice of how we wish to live with so many people on our planet.

Although many uncertainties are attached this analysis, the level of detail and sheer number of data sources is satisfactory enough for the intended use in integrated models of global change. The data base will be made available through the internet (<http://www.rivm.nl/env/int/hyde>).

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