Environ Dev Sustain (2008) 10:717–730
DOI 10.1007/s10668-007-9081-8

A forecast analysis on world population and urbanization process

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Received: 29 August 2005 / Accepted: 17 October 2006 / Published online: 10 February 2007

Abstract The continuous growth of world population and the intensification of urbanization process create a challenge to environment quality and sustainable development around the world. In this paper I tried to conduct a forecast analysis of near-future urbanization related population growth worldwide, based on recent demographic trends. Such an analysis can provide important insights into the prospects for changes in the size and composition of world population and in urbanization process. Optimal polynomial functions were used to fit historical trajectories of population dynamics, and the detailed forecasts of the population mainly over the period 2010–2030 were conducted and analyzed. If the past pattern continues, world total population would increase to 7.94–8.33 billion in 2030 and the annual growth is expected to continually decline in the forecast period. Global total population would stop increasing during the period 2050–2060 and would not exceed 9.5 billion in the future. The total population of Africa, Asia, Oceania, South America, North & Central America would separately increase to 1.35–1.41, 4.86–5.65, 0.04–0.05, 0.44–0.45, and 0.71–0.72 billion in 2030. Europe's total population is forecast to decline to 0.64–0.67 billion in 2030. World's rural population is expected to grow to the maximum during the period 2015–2020 and would greatly decline after that period. Global rural population would reach 3.12–3.41 billion in 2030. Rural population in Asia and Africa is estimated to increase and achieve the maximum around 2025 and decline thereafter. For other regions, the rural population would continually decline in the forecast period. Urban population in the world would continually grow and reach 4.72–5.00 billion in 2030, an increase of 48.6–57.8%. However the annual growth of urban population is expected to increase to the maximum (6.86 million/year) during the period 2020–2025 and then decline in the following years. Urban population is projected to continually grow in all regions excepting Europe. Europe's urban pop-

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ulation is expected to decline in the period 2010–2030. Urbanization process worldwide, represented by the ratio urban population versus total population (RUT) and the ratio rural population versus urban population, is expected to continue during the period 2010–2030. The RUT of the world is projected to reach 0.5 before 2010 and would continue to increase in the forecast period. Global RUT is estimated to reach 0.56 in 2030. However, the regional patterns of urbanization process would be diverse. Europe's RUT is estimated to continually decline in the forecast period and reach 0.68 in 2030. The RUT for Africa and Caribbean would continually increase before 2030, while the RUTs for Asia and South America are estimated to achieve their maximums around 2025 and decline in the following years. Oceania and North & Central America would thoroughly realize urbanization (≈1) during the periods 2020–2025 and 2025–2030. The expansion of world population and urbanization will continually exert a stronger stress to environment quality and sustainable development in a near future. However we may expect this situation would start to change from mid-21st century after total population has achieved its maximum.

Keywords World · Total population · Rural and urban population · Urbanization · Forecast

1 Introduction

World population increased in total of less than 1% before 17th century. The population began to grow faster from 17th century at the annual growth rate less than 0.5% (Jiang and Zhang, 2003; Lin, 2005). The growth was rapid after WWII and the annual growth rate reached 2% from the late 1940s to early 1970s. After that period, the population growth in the developed countries began to slow down. Meanwhile, the increase of world population began to slow down as a result of the family planning policies adopted in the developing countries like China. The annual growth rate during 1995–2000 was 1.3%, but it dropped down to 1.2% during 2000–2005 (Lin, 2005). These temporal changes in global total population may reflect the above trend: 1.0 billion in 1800, 2.0 billion in 1930, 3.0 billion in 1960, 4.0 billion in 1975, 5.0 billion in 1987, and 6.0 billion in 2000. The time spans for increasing 1.0 billion of total population in the past 200 years were 130, 30, 15, 12, and 13 years, respectively. The population growth appeared to slow down since the end of last century. Nevertheless, it is necessary to have an in-depth analysis on the forthcoming world's population. The purpose of this paper is to conduct a forecast analysis of near-future urbanization related population growth worldwide, based on recent demographic trends. Such an analysis can provide important insights into the prospects for changes in the size and composition of the world's population and in urbanization process, to inform public policies concerning environmental issues (Matson, Parton, Power, & Swift, 1997; Tilman et al., 2001).

2 Materials and methods

2.1 Data Sources

Human populations may be classified into various categories like that for gender, countries, living standards, etc. The present topic is urbanization and urbanization

related population, i.e., total population, rural population, and urban population. Total population, rural population and urban population of the world, Africa, Asia, Caribbean, Europe, North & Central America, Oceania, South America, the developed countries, and the developing countries since the year 1961, were collected from FAOSTAT (FAO, 2005) and used in the current study. The population data of Europe after 1992 were used due to the data availability.

Urbanization can be defined in various ways. In this study I used the ratio urban population versus total population (abbreviated as RUT) and the ratio rural population versus urban population (abbreviated as RRU) as indices for urbanization. The definition of urban can be found in FAOSTAT (FAO, 2005).

2.2 Data fitting and forecast

Unlike the linear changes of some environmental and trade variables (Zhang, Qi, & Liu, 2004; Zhang & Qi, 2005; Zhang, Qi, & Zhang, 2006), total population would follow the logistic growth in a longer period. For the purpose of the forecast, however, the estimation of upper bound of logistic growth is also a huge topic (Jiang & Zhang, 2003; Hopfenberg, 2004). Urban population and rural population, due to the migration process, would yield various trajectories. Without causing significant loss to precision, this study used the polynomial function, a flexible and adaptable model, to fit the population trajectories. The magnitude of order for polynomial function was determined using χ^2 statistic (Matlab 6.5, 2002). It was found that the optimal magnitude of function order was between 3 and 4 in almost all of the cases. For the purpose of forecast, a smaller number was chosen as the order of polynomial function. The polynomial function with a lower order could not achieve the satisfied goodness-of-fit, but the function with a higher order would over-fit the curve. For this reason, the third-order polynomial function was used to fit these trajectories:

$$x(t) = a_3 t^3 + a_2 t^2 + a_1 t + b$$

where t is year, $x(t)$ is population size (1000) or urbanization index at the year t. This study used the *polyfit* (Matlab 6.5, 2002) to fit this function and used the *polyconf* to forecast the population, the RUTs, the RRUs, and their half-widths of confidence intervals.

The empirical models, like the polynomial function, are not reliable to make a long-term extrapolation. As a result, this study conducted a mid-term forecast, e.g., the forecast mainly during the period 2010–2030. The forecasts assumed the same social, environmental and agricultural conditions in the forthcoming forecast period as the past (Tilman et al., 2001; Zhang et al., 2004; Zhang & Qi, 2005). Both forecasts and confidence intervals are important in the analysis. In a strict sense, the forecast in this study is essentially the future projection of past trend. The forecasts based on the mechanistic models with various variables would thus complement our empirical forecasts and therefore are needed.

3 Results

Generally the third-order polynomial function yielded an ideal goodness-of-fit for population growth and urbanization indices, as illustrated in Fig. 1 A to E. The

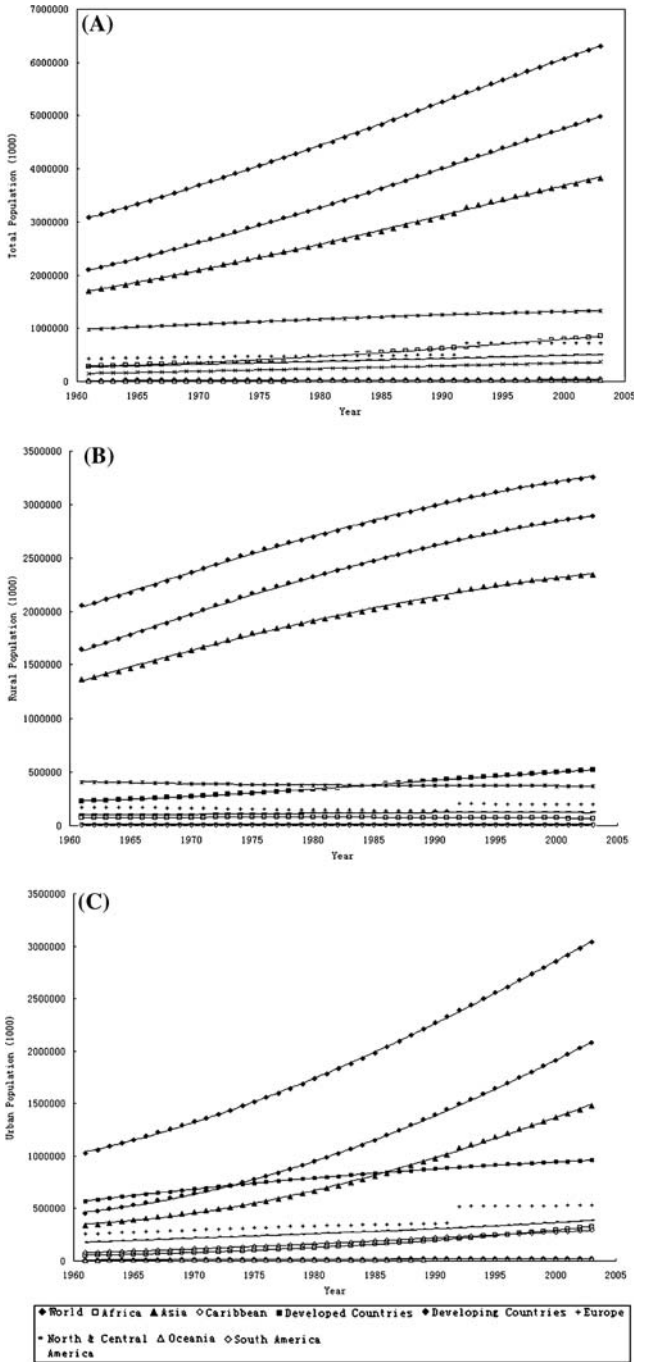

Fig. 1 Temporal changes of total population (**A**), rural population (**B**), urban population (**C**), ratio urban versus total population (**D**), and ratio rural versus urban population (**E**), which were optimally fitted by the third-order polynomial function, plotted over time

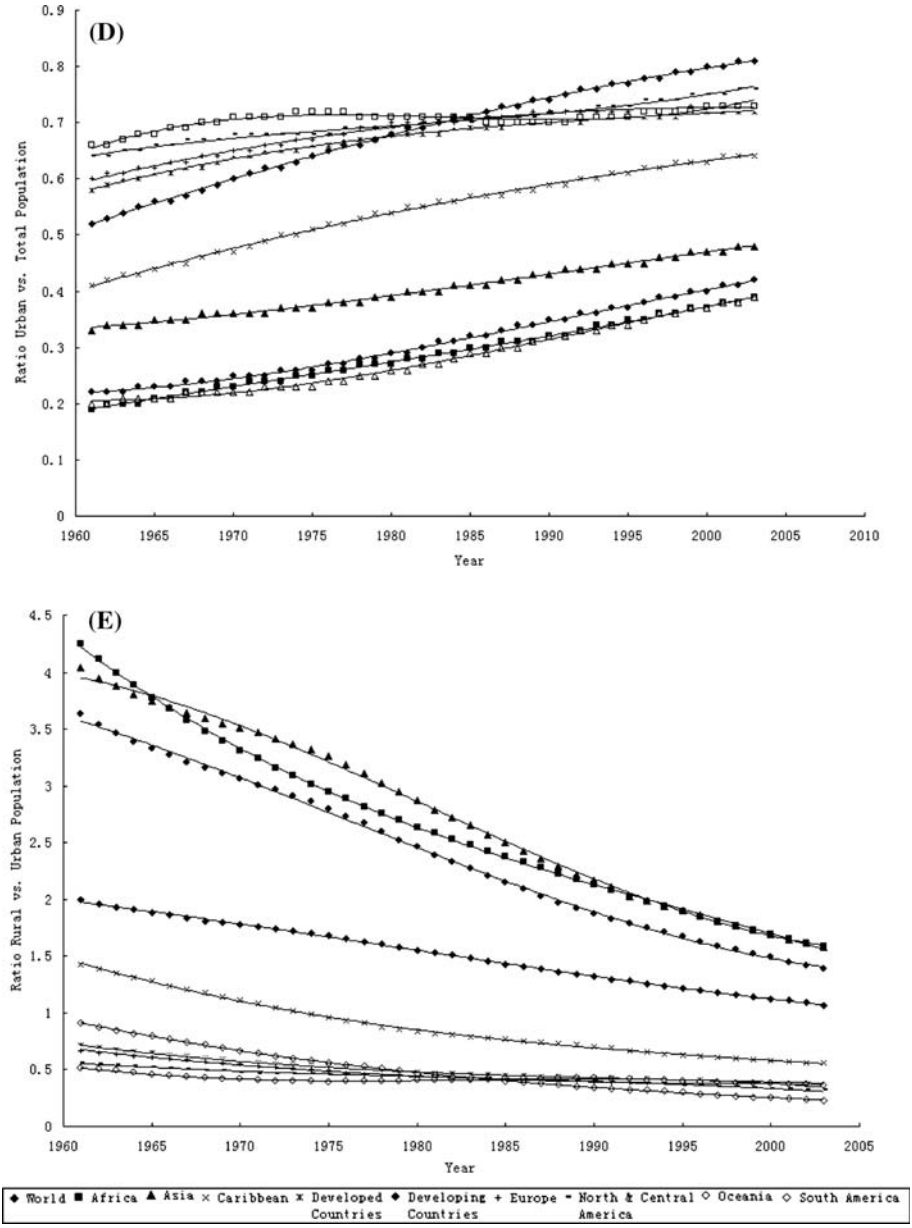

Fig. 1 continued

function may be used to describe the general trends of population growth and urbanization process.

Parametrical values for the third-order polynomial function are listed in Table 1. Detailed forecasts over the period 2010–2030, based on parametrical values in Table 1, are listed in Table 2 (population growth forecasts) and Table 3 (forecasts of urbanization indices). The smaller deviations suggest that the forecasts are overall

Table 1 Parametrical values of the third-order polynomial function: $x(t) = a_3t^3 + a_2t^2 + a_1t + b$, for total population, rural population, urban population, ratio urban population versus total population, ratio rural population *vs.* urban population, fitted using the software Matlab, where t is year, $x(t)$ is population size (1000) or urbanization index at the year t

		a_3	a_2	a_1	b
Total population	World	–7.212	43090.64	–85741115.90	56819622491.11
	Africa	–1.504	9104.20	–18347636.00	12313105794.64
	Asia	–3.924	23528.99	–46976669.44	31229764529.42
	Caribbean	–0.069	409.02	–808056.51	531858912.28
	Developed countries	–1.059	6225.90	–12185173.22	7943675450.48
	Developing countries	–6.152	36864.73	–73555942.68	48875947040.63
	Europe	0.284	–1787.53	3738765.03	–2600718410.50
	N & C America	0.290	–1706.99	3352041.64	–2197073934.16
	Oceania	0.064	–380.83	752395.58	–495699825.20
	South America	–0.788	4697.64	–9326097.70	6168345450.02
Rural population	World	–3.482	20451.83	–40001814.41	26057746809.05
	Africa	–2.237	13347.84	–26534397.40	17577722124.01
	Asia	–0.685	3828.25	–7074014.06	4320183794.89
	Caribbean	–0.011	61.99	–120450.34	77965382.95
	Developed countries	–1.070	6388.82	–12715171.92	8435937286.20
	Developing countries	–2.412	14063.02	–27286642.49	17621809522.85
	Europe	–0.056	325.31	–624440.98	399529439.54
	N & C America	–0.696	4128.07	–8155320.45	5370020603.38
	Oceania	–0.124	738.03	–1463412.76	967170173.49
	South America	0.060	–375.62	775933.15	–533256543.26
Urban population	World	–3.730	22640.11	–45741876.61	30763571609.62
	Africa	0.733	–4243.11	8185705.32	–5263919138.66
	Asia	–3.238	19700.42	–39902005.08	26909142378.17
	Caribbean	–0.059	348.19	–689926.69	455429601.89

Table 1 continued

		a_3	a_2	a_1	b
Urban population	Developed countries	0.011	–163.12	530416.87	–492547225.89
	Developing countries	–3.740	22803.22	–46272293.48	31256118835.50
	Europe	0.379	–2341.75	4820431.23	–3304662672.89
	N & C America	0.986	–5834.26	11505782.85	–7566047247.65
	Oceania	0.188	–1118.46	2214992.17	–1462330575.89
	South America	–0.849	5073.30	–10102139.58	6701678697.11
	World	–0.00000061	0.00365	–7.27	4827.36
	Africa	0.00000055	–0.00324	6.40	–4211.27
	Asia	–0.00000193	0.01155	–23.01	15279.25
	Caribbean	0.00000029	–0.00179	3.66	–2497.36
Urban population/Total population	Developed countries	0.00000121	–0.00724	14.49	–9663.85
	Developing countries	–0.00000162	0.00967	–19.26	12772.54
	Europe	0.00000020	–0.00128	2.70	–1890.70
	N & C America	0.00000205	–0.01216	24.08	–15899.10
	Oceania	0.00000662	–0.03937	78.10	–51633.39
	South America	–0.00000032	0.00181	–3.46	2198.06
	World	0.00000411	–0.02441	48.28	–31812.94
	Africa	–0.00002047	0.12257	–244.64	162796.99
	Asia	0.00003299	–0.19604	388.25	–256250.98
	Caribbean	–0.00000677	0.04065	–81.39	54338.86
Rural population/Urban population	Developed countries	–0.00000425	0.02546	–50.83	33834.21
	Developing countries	0.00001855	–0.10997	217.21	–142969.00
	Europe	–0.00000198	0.01198	–24.18	16263.59
	N & C America	–0.00000397	0.02363	–46.82	30937.67
	Oceania	–0.00001322	0.07865	–155.99	103122.77
	South America	–0.00000348	0.02100	–42.22	28299.63

Table 2 Forecasts of world population over the period 2010–2030

		Total population (10^9)					Rural population (10^9)					Urban population (10^9)				
Year		2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030
World	$x(t)$	6.853	7.217	7.555	7.863	8.135	3.348	3.375	3.372	3.337	3.267	3.506	3.842	4.183	4.526	4.868
	$\Delta x(t)$	0.037	0.060	0.093	0.138	0.196	0.028	0.044	0.069	0.103	0.146	0.028	0.045	0.070	0.103	0.147
Africa	$x(t)$	0.987	1.085	1.184	1.282	1.379	0.564	0.585	0.598	0.600	0.590	0.423	0.500	0.586	0.682	0.789
	$\Delta x(t)$	0.005	0.009	0.014	0.020	0.029	0.004	0.006	0.010	0.014	0.020	0.002	0.004	0.006	0.009	0.013
Asia	$x(t)$	4.239	4.510	4.770	5.019	5.252	2.431	2.468	2.488	2.493	2.481	1.808	2.042	2.282	2.526	2.771
	$\Delta x(t)$	0.074	0.119	0.186	0.277	0.393	0.048	0.077	0.120	0.178	0.253	0.040	0.064	0.100	0.148	0.210
Caribbean	$x(t)$	0.041	0.042	0.042	0.042	0.042	0.014	0.013	0.013	0.012	0.012	0.027	0.028	0.029	0.030	0.030
	$\Delta x(t)$	0.000	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.002	0.000	0.000	0.000	0.001	0.001
Developed countries	$x(t)$	1.353	1.359	1.356	1.344	1.321	0.362	0.352	0.338	0.320	0.296	0.991	1.007	1.018	1.024	1.025
	$\Delta x(t)$	0.007	0.012	0.018	0.027	0.039	0.006	0.010	0.015	0.022	0.032	0.004	0.007	0.011	0.016	0.023
Developing countries	$x(t)$	5.500	5.858	6.199	6.519	6.814	2.986	3.023	3.034	3.017	2.971	2.514	2.835	3.165	3.502	3.843
	$\Delta x(t)$	0.032	0.051	0.080	0.119	0.169	0.030	0.049	0.076	0.113	0.161	0.026	0.042	0.066	0.098	0.139
Europe	$x(t)$	0.717	0.706	0.691	0.673	0.653	0.190	0.185	0.178	0.171	0.163	0.527	0.521	0.513	0.503	0.491
	$\Delta x(t)$	0.001	0.002	0.005	0.009	0.016	0.002	0.005	0.011	0.019	0.033	0.024	0.007	0.015	0.028	0.046
N & C America	$x(t)$	0.555	0.591	0.629	0.670	0.714	0.113	0.104	0.090	0.071	0.048	0.441	0.487	0.539	0.599	0.666
	$\Delta x(t)$	0.001	0.002	0.003	0.005	0.007	0.002	0.004	0.006	0.009	0.013	0.003	0.005	0.008	0.012	0.017
Oceania	$x(t)$	0.036	0.039	0.043	0.047	0.051	0.008	0.007	0.005	0.003	0.000	0.028	0.033	0.038	0.044	0.051
	$\Delta x(t)$	0.001	0.001	0.001	0.002	0.003	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.004
South America	$x(t)$	0.393	0.412	0.427	0.438	0.445	0.063	0.058	0.053	0.048	0.042	0.330	0.353	0.374	0.391	0.403
	$\Delta x(t)$	0.001	0.002	0.003	0.005	0.007	0.001	0.001	0.002	0.003	0.004	0.001	0.002	0.003	0.005	0.007

Based on the third-order polynomial functions fitted, where $x(t)$ is the forecast and $\Delta x(t)$ is the half width of 95% confidence interval for $x(t)$. $x(t) \pm \Delta x(t)$ is the confidence interval ($p < 0.05$). For example, the world's total population in 2030 would be $(8.135 \pm 0.196)*10^9$, with 95% confidence degree. If $x(t)$ is extrapolated as a negative value and $x(t) + \Delta x(t)$ is less than 0, then the forecast with 95% confidence degree should be regarded as a very small value (≈ 0)

Table 3 Forecasts of urbanization indices, ratio urban population *vs*. total population, and ratio rural population *vs*. urbanization, over the period 2010–2030

		Urban/Total					Rural/Urban				
Year		2010	2015	2020	2025	2030	2010	2015	2020	2025	2030
World	$x(t)$	0.507	0.524	0.538	0.550	0.560	0.974	0.927	0.902	0.903	0.933
	$\Delta x(t)$	0.013	0.021	0.033	0.049	0.069	0.031	0.050	0.079	0.117	0.166
Africa	$x(t)$	0.434	0.469	0.508	0.550	0.597	1.207	0.905	0.543	0.106	–0.421
	$\Delta x(t)$	0.012	0.020	0.031	0.046	0.065	0.053	0.086	0.134	0.199	0.283
Asia	$x(t)$	0.424	0.442	0.455	0.460	0.455	1.558	1.702	2.015	2.522	3.248
	$\Delta x(t)$	0.014	0.023	0.036	0.054	0.077	0.118	0.190	0.297	0.441	0.625
Caribbean	$x(t)$	0.667	0.681	0.695	0.707	0.719	0.482	0.423	0.351	0.260	0.147
	$\Delta x(t)$	0.014	0.022	0.035	0.052	0.074	0.029	0.048	0.074	0.110	0.156
Developed countries	$x(t)$	0.734	0.744	0.757	0.773	0.794	0.350	0.316	0.271	0.211	0.132
	$\Delta x(t)$	0.012	0.019	0.030	0.044	0.063	0.013	0.021	0.033	0.049	0.070
Developing countries	$x(t)$	0.451	0.469	0.481	0.485	0.482	1.341	1.407	1.582	1.880	2.315
	$\Delta x(t)$	0.013	0.020	0.032	0.047	0.067	0.084	0.136	0.213	0.316	0.448
Europe	$x(t)$	0.724	0.717	0.707	0.695	0.680	0.379	0.385	0.392	0.398	0.402
	$\Delta x(t)$	0.014	0.023	0.036	0.054	0.076	0.021	0.034	0.053	0.078	0.111
N & C America	$x(t)$	0.808	0.850	0.903	0.968	1.046	0.228	0.151	0.055	–0.065	–0.21
	$\Delta x(t)$	0.015	0.024	0.037	0.055	0.078	0.022	0.036	0.057	0.084	0.119
Oceania	$x(t)$	0.808	0.887	0.997	1.144	1.332	0.208	0.048	–0.176	–0.471	–0.849
	$\Delta x(t)$	0.019	0.030	0.048	0.071	0.100	0.030	0.049	0.077	0.114	0.162
South America	$x(t)$	0.835	0.847	0.854	0.857	0.854	0.188	0.156	0.121	0.081	0.033
	$\Delta x(t)$	0.011	0.018	0.029	0.043	0.061	0.013	0.022	0.034	0.050	0.071

Based on the third-order polynomial functions fitted, where $x(t)$ is the forecast and $\Delta x(t)$ is the half width of 95% confidence interval for $x(t)$. $x(t) \pm \Delta x(t)$ is the confidence interval ($p < 0.05$). If $x(t)$ is extrapolated as a negative value and $x(t) + \Delta x(t)$ is less than 0, then the forecast with 95% confidence degree should be regarded as a very small value (≈ 0). However, the upper limit of the forecast should be considered to be a larger value less than 1 (≈ 1), if $x(t) + \Delta x(t) > 1$

acceptable. It can be found that the deviation increases with the year, which means the long-term forecast would yield a greater width of confidence interval. For example, global total population in 2050 is forecast to reach 8.2–9.3 billion ($p < 0.05$), which could be regarded as the estimation with a wider confidence interval in some cases.

An outline on the quantitative forecasts in Table 2 and Table 3 is also beneficial for a more reliable estimation. In the following, I discuss growth percentages and confidence intervals of the forecasts for 2030 against the current values, in order to discuss similarity and variability. Current values are based on temporal extrapolation from the data available, as done in other forecast analysis (Tilman et al., 2001). The growth percentages and confidence intervals of the forecasts for 2030 are outlined in Table 4.

3.1 Population forecasts

3.1.1 Total population

Global total population is forecast to continually increase to 7.94–8.33 billion in 2030, increasing 22.7% to 28.8% based on the current population. The annual increase of global total population, averaged on every five years from now on, would be 76.7, 72.7, 67.7, 61.6, and 54.3 million respectively. As a consequence, the annual

Table 4 Growth percentages (e.g., the growth percentage 25.73% for world total population) and their 95% confidence intervals (for instance, the confidence interval (22.70–28.76%) for 25.73%, the growth percentage of world total population) of the forecasts for 2030 based on the current populations

	Total populations	Rural populations	Urban populations
World	25.73 (22.70 28.76)	–0.79 (–5.23 3.65)	53.22 (48.61 57.84)
Africa	54.93 (51.68 58.18)	10.21 (6.45 13.97)	122.31 (118.70 125.92)
Asia	32.54 (22.64 42.45)	4.25 (–6.38 14.89)	75.08 (61.79 88.36)
Caribbean	6.62 (3.05 10.18)	–16.06 (–29.93 –2.19)	18.75 (15.23 22.27)
Developed countries	–1.33 (–4.22 1.56)	–19.61 (–28.20 –11.03)	5.61 (3.25 7.96)
Developing countries	32.79 (29.49 36.09)	1.58 (–3.92 7.07)	74.17 (67.87 80.47)
Europe	–9.91 (–12.14 –7.68)	–16.28 (–33.06 0.49)	–7.32 (–15.98 1.34)
North & Central America	37.17 (35.86 38.47)	–60.05 (–70.85 –49.25)	66.10 (61.96 70.24)
Oceania	53.13 (44.18 62.09)	–100.00 (–100.00 –84.52)	104.39 (90.44 118.33)
South America	19.91 (17.97 21.85)	–38.10 (–43.60 –32.59)	32.70 (30.56 34.84)

The value–100 (i.e., 100%) means all of the population would change into other type

growth of global total population is expected to continually decline in the forecast period. The annual decrease of total population growth, estimated from these annual rates, would be about 1.0–1.2 million in the period 2010–2030. Following this trend, global total population would stop increasing during the period 2050–2060. In other word, world total population would reach its maximum in the mid-21st century and will not exceed 9.5 billion. This maximum is less than the planet's population capacity, 15 billion, calculated by Jiang and Zhang (2003). This would be much beneficial to sustainable development and environmental protection in the world.

The total population in the developing countries is estimated to increase by 29.49–36.09%, while in the developed countries it would decline by 1.3% in 2030 as compared to the current value. World total population growth would thus be maintained by the population growth in the developing countries during the period 2010–2030.

Africa's total population would increase by nearly 55% relative to the current level, and would reach 1.35–1.41 billion in 2030. The total population of Asia, Oceania, South America, North and Central America would increase to 4.86–5.65, 0.04–0.05, 0.44–0.45, and 0.71–0.72 billion in 2030. The total population in Caribbean would only grow by 6.6% in 2030. For Africa and Oceania, the population growth may be considered as ''explosive'' in this period. The only exception is Europe. Europe's total population is forecast to continually decline to 0.64–0.67 billion in 2030.

Generally it is expected that Africa and Oceania would have the greatest population growth in the world. Having the largest population size in the world, Asia's annual rate of total population is estimated to be 5.42, 5.20, 4.98, and 4.66 million, at 5-year interval from 2010–2030. The projected lower population growth in Asia and projected declining population size in Europe are positive signs for slowing down the growth of world population in the future.

3.1.2 Rural and urban population

Global rural population is expected to increase and achieve the maximum during the period 2015–2020 (Table 2 and 4). The annual rates of rural population are esti-

mated to be 2.70, –0.30, –3.50, and –7.00 million in the period 2010–2030, with 5-year interval. It is obvious that world rural population will greatly decline from 2015. By the year 2030, the world's rural population would reach 3.12–3.41 billion.

In the developing countries, rural population is estimated to grow to the maximum in the period 2015–2025 and then decline to 2.81–3.13 billion in 2030. Rural population in developed countries would continually decline in the forecast period, with the annual rates of 0.20, 0.28, 0.36, and 0.48 million in the period 2010–2030 (at 5-year interval).

Rural population in Asia and Africa is expected to increase and achieve the maximum around 2025 and decline thereafter. For other regions the rural population would continually decline in the forecast period.

From the above results, we can conclude that the increase of rural population would mainly occur in the developing countries, particularly in Asia and Africa, while in developed countries and some developing countries in South America, Caribbean, and Oceania, the rural population tend to decline in the forecast period.

If the past pattern continues, the urban population in the world would continually grow and reach 4.72–5.00 billion in 2030, an increase of 48.61–57.84% as compared to the current value. Other the other hand, the annual growth of urban population is expected to increase to the maximum, 6.86 million/yr, during the period 2020–2025. In the developed countries, urban population would continually grow but only increase by 5.61% in 2030. Urban population in the developing countries is projected to greatly increase by 74.17% in 2030 (Table 4).

Urban population is projected to continually grow in all regions excepting Europe. Europe's urban population is expected to decline in the period 2010–2030.

According to these estimations, we may find that Africa and Oceania would achieve the greatest growth in urban population when compared to the other regions, as indicated in Table 4. Europe's population would totally decline in the future. We may expect that as the advance of social and economic development, more and more regions would follow the similar pattern of population reduction in Europe. Global total population would decline after achieving its maximum. From that time the environment quality around the world could thus be improved substantially.

3.2 Forecasts of urbanization process

3.2.1 Ratio urban versus total population (RUT)

Urbanization process worldwide, represented by the RUT, is expected to continue in the forecast period (Table 3). The RUT of the world is expected to grow to 0.5 before 2010 (Table 3), and would continue to increase in the forecast period. Global RUT is estimated to reach 0.56 in 2030, equivalent to an increase of 14.5% as compared to the current level. It means that by 2030 the urban population would account for 56% in total population.

In the developed countries, the RUT would grow during the period 2010–2030 and reach 0.79 in 2030, increasing by 9.5%. The RUT in developing countries is estimated to grow and would see the maximum after 2025.

Regional RUTs are projected to show various patterns. The RUT for Africa and Caribbean would continually increase before 2030, while the RUTs for Asia and

South America are expected to reach their maximums around 2025. For Oceania and North & Central America, their RUTs would approximately reach 1 in the periods 2020–2025 and 2025–2030. Europe's RUT is estimated to decline in the forecast period and reach 0.68 in 2030 (Table 3).

We may conclude from the above forecasts that Oceania and North & Central America would thoroughly realize urbanization during the period 2020–2030.

3.2.2 Ratio rural versus urban population (RRU)

The RRUs for the world is projected to show a ''U'' type of dynamics during the period 2010–2030, with a lowest RRU in 2020–2025 (Table 3). For the developing countries the RRU would grow while for the developed countries it would decline in the forecast period. By 2030 the RRUs in the developing and developed countries would separately reach 2.32 and 0.13, which mean that in 2030 the rural population would be 2.32-fold of urban population in the developing countries.

Regional RRUs are expected to yield different patterns. The RRUs for Asia and Europe would increase but for other regions the RRUs are estimated to decline. Asia's RRU would be 3.25 in 2030, which is the greatest in all regions.

By taking the RUTs and RRUs together, we may find that there are great differences among various regions in terms of these indices. Diverse patterns are suggested resulting from the historical backgrounds and development stages for different regions. In general, the urbanization process in the world would continue in the forecast period.

4 Conclusions and discussion

If the past pattern continues, world total population would continually grow and reach 7.94–8.33 billion in 2030. The annual growth of global total population is estimated to decline in the forecast period, with the annual rate of 72.7, 67.7, 61.6, and 54.3 million for the period 2010–2030 (averaged on 5-year interval). Following this trend, global total population would stop increasing during the period 2050–2060 and would not exceed 9.5 billion. Global rural population is forecast to increase to the maximum during the period 2015–2020, and greatly decline from this period. By the year 2030, the world's rural population would reach 3.12–3.41 billion. Rural population in Asia and Africa is expected to increase and achieve the maximum around 2025 and decline in the following years. Rural population would continually decline in other regions.

World urban population is projected to continually grow and reach 4.72–5.00 billion in 2030. Nevertheless the annual growth of urban population would increase to the maximum during the period 2020–2025. Urban population is projected to grow in most regions, with the exception of Europe. Urban population in Europe is forecast to continually decline during the period 2010–2030.

In general, global urbanization process, represented by the RUT and RRU, is forecast to continue during the period 2010–2030. The RUT of the world is estimated to continually increase in the forecast period and reach 0.56 in 2030. Urbanization process for different regions would show various patterns. The RUTs for Oceania and North & Central America are projected to approximately reach 1 during the

periods 2020–2025 and 2025–2030. In Europe, the RUT is estimated to decline in the forecast period and reach 0.68 in 2030. The RUTs for Africa and Caribbean would continuously increase before 2030, while the RUTs for Asia and South America are expected to reach their respective maximums around 2025.

Totally 46% of consumption of natural resources has been attributed to the population growth and 54% of that resulted from the improvement of living standards. In other words, nearly half of the resources consumption worldwide is simply caused by the population growth. Two-thirds of the natural resource on the planet have been exhausted by human beings (Ministry of Science and Technology of China, Bureau of Environmental Protection of China, 2005). Over-exploitation and competition of natural resources, deterioration of environmental quality, and global climate changes aroused from the population growth and urbanization had become the major challenges of the 21st century (Daily et al., 1998; Hu, 2003; Matson et al., 1997;Tilman et al., 2001; Andriesse & Windmeijer, 2004). Up till now, population strategies in the developed countries are successful to maintain a lower or even negative growth in some countries. Most of the countries in the developing countries, due to the excess growth in population and the rapid urbanization process, had created various troubles in education, jobs, living standards, and social security, etc. According to a report from the world population conference, ended on 23 June, 2005, China, India, United States, Indonesia, Brazil, and Pakistan are the most populous countries in the world. Most of these countries come under the developing countries or Asia. Fortunately, due to the social and economic development more and more countries are recognizing the importance of population control and fundamental changes are taking place in the developing countries (Yuan et al., 2003). A positive sign is the slowing down of population growth in recent years. As estimated in this paper, world total population would not exceed 8.5 billion in 2030 and not exceed 9.5 billion by 2050. Although this is a hopeful result as compared to the estimated 15 billion people that the world can possibly support (Jiang & Zhang, 2003), we still need to promote the public awareness for controlling the population growth and urbanization process.

Young structure would have a significant impact on population growth both in the urban and rural areas. For example, this young structure is the prime reason that the Chinese population is increasing despite a policy of 1 child per couple. The present forecast has implicitly assumed the similar young structure of human population in the forecast period as the past. However, the studies on the impact of young structure on population trend are further needed in the future.

Acknowledgments This project was partially supported by the ''948'' project of China, through 2006-G32, and the ''973'' project of China, through 2006CB102005. The author thanks five anonymous reviewers for their comments and suggestions on this paper and thanks Mrs Hasen for her help in preparation of this paper.

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