POPULATION NETWORK NEWSLETTER

POPNET

Wolfgang Lutz, Editor

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In 2001 IIASA, IUSSP (International Union for the Scientific Study of Population), and UNU (United Nations University) started a joint initiative to prepare a comprehensive scientific assessment of the role of population in sustainable development strategies, with the aim of producing a science-based policy statement as input to the 2002 Johannesburg World Summit on Sustainable Development.

The Global Science Panel comprises 30 distinguished scientists from various disciplines and comes under the joint patronage of Maurice Strong and Nafis Sadik. It is coordinated by Wolfgang Lutz and Mahendra Shah, and receives financial support from UNFPA (United Nations Population Fund), the government of Austria, and the MacArthur Foundation. Initial discussions were held at a meeting at NIDI (Netherlands Interdisciplinary Demographic Institute) and at General Conferences organized by the IUSSP and IHDP (International Human Dimensions of Global Environmental Change Program). Drafts were also discussed at two cyber seminars organized by the IUSSP/IHDP Population Environment Research Network (PERN). Full documentation of these seminars can be found at **www.populationenvironmentresearch.org**.

The statement here was finalized during a meeting of the Panel held at IIASA on 21–23 March 2002. It will also be printed as a brochure together with materials supporting the main points made, and will be distributed to governments, non-government organizations, the media, and the scientific community. W.L.

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IIASA International Institute for Applied Systems Analysis www.iiasa.ac.at

IIASA/IUSSP/UNU* Global Science Panel on Population and Environment reaches conclusion on science policy statement for Johannesburg Summit

Population in Sustainable Development

If we do not put the human population at the core of the sustainable development agenda, our efforts to improve human well-being and preserve the quality of the environment will fail. The Johannesburg Summit must heed the first principle of the 1992 Rio Declaration—that "human beings are at the centre of concern for sustainable development"—by taking full account of how population and society interact with the natural environment.

Sustainable development aims at improving human well-being, particularly by alleviating poverty, increasing gender equity, and improving health, human resources, and stewardship of the natural environment. Because demographic factors are closely linked to these goals, strategies that consider population have a better chance of success.

The International Conference on Population and Development in Cairo in 1994 recognized that population policy should be oriented toward improving social conditions and expanding choices for individuals. The key recognition was that focusing on people—their rights, capabilities, and opportunities—would have multiple benefits for individuals, for society, and for their sustainable relationship with the environment.

Hence in Johannesburg, consideration of sustainable development policies must include population growth and distribution, mobility, differential vulnerability, and the empowerment of the people, especially women.

*Note: This statement on Population in Sustainable Development reflects the views of the Global Science Panel and does not necessarily reflect those of the institutions that have co-sponsored the process leading to this statement.

A Demographically Diverse World

We live in a world of unprecedented demographic change. Global population increased by 2 billion during the last quarter of the 20th century, reaching 6 billion in 2000. Despite declining fertility rates, population is expected to increase by another 2 billion during the first decades of the 21st century. Nearly all of this growth will occur in developing countries and will be concentrated among the poorest communities and in urban areas.

We also live in a world of unprecedented demographic diversity. Traditional demographic groupings of countries are breaking down. Over the next 25 years increases in

population in sub-Saharan Africa, South Asia, and the Middle East are expected to be larger than in the past quarter century, and growth in North America will be substantial as well. In contrast, in most European countries and in East Asia, population growth has slowed or stopped, and rapid population aging has become a serious concern. Mortality also varies widely across regions, with the burden of infectious disease, including HIV/AIDS, being particularly heavy in Africa. In addition, levels of mobility, urbanization, and education differ substantially among and within regions, affecting economic and health outlooks.

This diversity presents different challenges requiring differentiated responses. The most urgent of these occur where rapid population growth, high levels of poverty, and environmental degradation coincide.

Population Matters to Development and Environment

Research has shown that changes in population growth, age structure, and spatial distribution interact closely with the environment and with development. Rapid population growth has exacerbated freshwater depletion, climate change, biodiversity loss, depletion of fisheries and other coastal resources, and degradation of agricultural lands. Fertility decline in high-fertility countries, by slowing population growth, can make many environmental problems easier to solve. It can also have important economic benefits by reducing the number of children relative to the working-age population, and creating a unique opportunity to increase investments in health, education, infrastructure, and environmental protection.

In high-income countries, the environmental impact of population growth and distribution must be considered jointly with high consumption rates. Even in countries where little growth is envisioned, unsustainable patterns of consumption have global implications for the environment and human well-being, and must be addressed with appropriate policies.

Before the end of this decade, the majority of the world's population will live in urban areas. Urbanization can improve people's access to education, health, and other services. But it also creates environmental health hazards, such as water and air pollution, and by increasing consumption levels, can have environmental impacts in distant rural areas as well.

The mobility and spatial distribution of populations, especially at local and regional levels, is a significant determinant of sustainability. Where the population lives and works relative to the location of natural resources affects environmental quality. The expansion of the agricultural frontier and other human activity is encroaching on fragile ecosystems in many parts of the world.

Policy Must Account for Differential Vulnerability Within Populations

Deteriorating environmental conditions and extreme events do not affect all countries, populations, or households in the same way. Even within a household, the effects may differ by age and gender. Consideration of vulnerability must therefore focus not only on countries but also on the most vulnerable

segments of the population within countries.

Many factors contribute to vulnerability, including poverty, poor health, low levels of education, gender inequality, lack of access to resources and services, and unfavorable geographic location. Populations that are socially disadvantaged or lack political voice are also at greater risk. Particularly vulnerable populations include the poorest, least empowered segments, especially women and children. Vulnerable populations have limited capacity to protect themselves from current and future environmental hazards, such as polluted air and water and catastrophes, and the adverse consequences of large-scale environmental change, such as land degradation, biodiversity loss, and climate change.

Vulnerability can be reduced by promoting empowerment, investing in human resources, and fostering participation in public affairs and decision-making.

Empowerment Through Education and Reproductive Health Benefits People and the Environment

Two policies have multiple benefits for individual welfare, for social and economic development, and for the environment. One is investment in voluntary family planning and reproductive health programs. Since research has shown that many women in high-fertility countries have more children than they actually want, these programs allow couples to have the number of children they desire, thus reducing unwanted childbearing and lowering fertility rates. Lower fertility leads to slower population growth, allowing more time for coping with the adverse effects of that growth, and easing stress on the environment.

The other top policy priority is education. Education enhances individual choice, fosters women's empowerment, and improves gender equity. Better-educated people are in better health, and often contribute to greater environmental awareness. The increased economic productivity and technological advance that education induces can lead to less pollution-intensive production. It may also reduce vulnerability to environmental change by facilitating access to information and the means to protect oneself. Furthermore, in countries with rapid population growth, the fertility-depressing effect of education contributes to reducing the scale of human impact on the environment.

These two policies—education and reproductive health programs—are in high demand by individuals almost universally because their multiple benefits are clear. They also empower individuals to make informal choices. Efforts to achieve sustainable development should give them the highest priority.

Strengthening Interdisciplinary Training and Research

To facilitate the joint consideration of population, development, and environment, more interdisciplinary research and education addressing these topics is necessary at all levels. The different disciplines should also conduct their studies in ways that make the results mutually accessible. Training about the nature of these interactions is a priority issue for the policy-making community, media, and scientists.

New Initiative in European Demography

After 25 years of existence, the Institute for Demography (IFD), part of the Austrian Academy of Sciences and located in central Vienna, will be significantly expanded and internationalized. Under the leadership of Wolfgang Lutz (director) and Richard Gisser (deputy director), the IFD will grow to include some 25 scientists in four research groups: population dynamics and forecasting, comparative European demography, demographic–economic interactions, and Austrian demography. This expansion is made possible by targeted funding from the Austrian government for research in key areas. More information about the IFD can be found at **www.idemog.oeaw.ac.at.**

The IFD and IIASA's Population (POP) Project—which will continue to be led by Wolfgang Lutz—will jointly coordinate and provide the headquarters for a new consortium of major demographic research institutes in Europe. Meeting at IIASA in November 2001, the directors of INED (Francois Heran), NIDI (Evert van Imhoff), MPI-Rostock (James W. Vaupel), and IFD/IIASA (Wolfgang Lutz), with Dirk Van de Kaa serving as senior advisor, agreed to establish the European Demographic Research Ensemble (EDRE).

The European Demographic Research Ensemble (EDRE)

The goals of the EDRE are to foster comparative population studies in Europe, enhance the exchange between demographic institutes in Europe, jointly address some of Europe's key population-related challenges, and advise the European Commission on demographic substance. In these endeavors active collaboration will be sought with other demographic research centers, existing networks, and cross-national initiatives to strengthen the European demographic research base. As of the summer of 2002, more information about EDRE will be available at **www.populationeurope.org.**

Job Opening for Senior Demographer

The Institute for Demography of the Austrian Academy of Sciences is looking for an internationally experienced leader for its new research team on comparative European demography to start in 2003. Initially a fixed-term appointment, the position could become permanent after evaluation. A thorough knowledge of European population data and methods of demographic analysis is essential. English is the working language, but some knowledge of German or other European languages would be useful. Applications with curriculum vitae and supporting materials should be sent to Wolfgang Lutz (c/o Ani.Gragossian@oeaw.ac.at) by 1 September 2002.

Distinguished Visitors Program to Vienna

Funds will be available for distinguished demographers to take part in research visits of 1–12 weeks at the Institute for Demography. During the visits the guests will have the opportunity to interact with the Institute's staff and to give a lecture. For further information please contact Wolfgang Lutz (c/o Ani.Gragossian@oeaw.ac.at).

Staff Changes at IIASA's Population Project

Brian O'Neill will join POP for three years starting in June 2002. Warren Sanderson will again spend May–August 2002 at IIASA. Karina Nilsson (Sweden), Ren Qiang (China), and Salut Muhidin (Indonesia) recently joined POP as postdoctoral fellows. Anne Goujon moved from IIASA to the Institute for Demography in Vienna. Marilyn Brandl, Gui Ying Cao, Isolde Prommer, and Wolfgang Lutz continue to work at POP.

Asian MetaCentre Enters Phase 2

Wellcome Trust Award for Continuation of the MetaCentre

The Asian MetaCentre for Population and Sustainable Development Analysis, with its headquarters at the National University of Singapore (NUS), has received a major award of around S$2.7 million from the Wellcome Trust in the United Kingdom. The funding ensures a continuation of the Asian MetaCentre for a period of three years, starting from February 2002.

Development of a Health Focus

On 1 October 2001 the Wellcome Trust launched a new program, the Health Consequences of Population Change (HCPC), that replaces the Population Studies and Non-Communicable Diseases in Developing Countries Programme. The HCPC program will focus on how health is being affected by the demographic, environmental, and socioeconomic changes that are taking place in the developing world, such as population growth, migration, urbanization, lifestyle and behavioral shifts, and aging. The objective of the new program is to support research aimed at identifying and quantifying the main determinants of developing-world morbidity and mortality at the population-based level. In line with these goals, the MetaCentre will focus on demographic issues such as population–development–environment interactions, population forecasting, aging, migration, and reproductive health in Asia, with an emphasis on the health impacts of various population dynamics.

www.populationasia.org
for more information, or send an E-mail to popnasia@nus.edu.sg

People at the MetaCentre

The three principal investigators at the Asian MetaCentre, Brenda Yeoh (NUS), Vipan Prachuabmoh (Chulalongkorn University), and Wolfgang Lutz (IIASA), are the driving force behind the research efforts. Additional members of staff include postdoctoral fellows Evi Nurvidya Arifin (Indonesia) and Kannan Navaneetham (India), a research assistant, and two administrative assistants.

During its second phase, the Asian MetaCentre will be welcoming an increasing number of postdoctoral fellows, senior research fellows, and visiting scholars, who will share their intellect and research ideas with colleagues not only at the Asian MetaCentre but also out in the region.

The Asian MetaCentre has forged active links with many population centers, research institutes, and networks:

- College of Population Studies, Chulalongkorn University, Bangkok, Thailand
- International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria
- National Centre for Epidemiology and Population Health (NCEPH), Australian National University, Canberra, Australia
- International Union for the Scientific Study of Population (IUSSP), Paris, France
- Asia-Pacific Migration Research Network (APMRN), University of Wollongong, Australia
- Demographic Institute, University of Indonesia, Jakarta, Indonesia
- Demography and Sociology Program, Australian National University, Canberra, Australia
- Institute of Economic Growth, Delhi, India
- Institute of Policy Studies, Singapore
- International Centre for Living Aquatic Resource Management (ICLARM), Penang, Malaysia
- Office of Population Studies, University of San Carlos, Cebu City, Philippines
- Asian Research Center for Migration, Chulalongkorn University, Bangkok, Thailand
- Institute for Population and Social Research (IPS), Mahidol University, Nakhon Pathom, Thailand
- Scalabrini Migration Center, Quezon City, Philippines
- Institute of Population Research, Beijing University, Beijing, China

Conference

2002 IUSSP Regional Population Conference on "Southeast Asia's Population in a Changing Asian Context," Siam City Hotel, Bangkok, 10–13 June 2002. Five sessions are to be organized and supported by the Asian MetaCentre. (More information at www.chula.ac.th/college/cps/IUSSP-2002/IUSSP-2002.html.) Main coordinator: Vipan Prachuabmoh, E-mail: iusspcps@Chula.ac.th.

Asian Population Network Seminars

Migration and the "Asian Family" in a Globalising World, Singapore, 16–18 April 2001.

Re-engaging the Generations: Intergenerational programming in Social Services, Singapore, 4–6 March 2002.

Fertility Decline, Below Replacement Fertility and the Family in Asia: Prospects, Consequences and Policies, Singapore, 10–12 April 2002.

Health Consequences of Population Changes in Asia: What are the Issues? Siam City Hotel, Bangkok, 13–14 June 2002. (More information at www.populationasia.org/health_consequences_of_popn_changes.htm). Coordinator: Brenda Yeoh, E-mail: popnasia@nus.edu.sg.

Health Consequences of Urbanisation, Australia, to be held in late 2002 or early 2003.

High-Level Training Workshops

Methods of Systems Analysis for Studying and Forecasting Population-Environment Interactions, Bangkok, 13–24 November 2000.

New Approaches and Methods of Population Forecasting, Singapore, 5–16 March 2001.

Methodological Issues in Family and Migration Research, Singapore, 19–26 April 2001.

New Methods in Population Dynamics, Thailand, to be held in 2003.

Reprint from *Nature**

The End of World Population Growth

Wolfgang Lutz, Warren Sanderson, and Sergei Scherbov

There has been enormous concern about the consequences of human population growth for the environment and for social and economic development. But this growth is likely to come to an end in the foreseeable future. Improving on earlier methods of probabilistic forecasting[1], here we show that there is around an 85 percent chance that the world's population will stop growing before the end of the century. There is a 60 percent probability that the world's population will not exceed 10 billion people before 2100, and around a 15 percent probability that the world's population at the end of the century will be lower than it is today. For different regions, the date and size of the peak population will vary considerably.

Figure 1 shows the probability that the world population size would reach a peak at or before any given year. It indicates that there is around a 20 percent chance that the peak population would be reached by 2050, around a 55 percent chance that it would be reached by 2075, and around an 85 percent chance that it would be reached by the end of the century.

There is around a 75 percent chance that the peak population of the European portion of the former USSR has already been reached in 2000, an 88 percent probability that it will be reached by 2025, and over a 95 percent chance by the end of the century. For the China region, the probability of

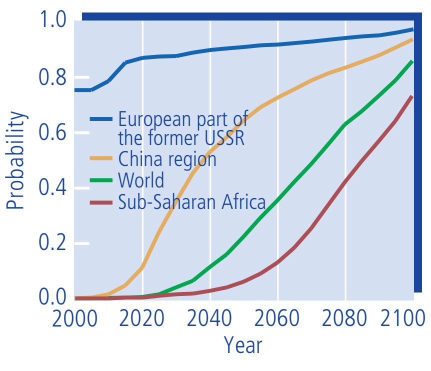

Figure 1. *Forecasted probability that population will start to decline at or before the indicated date.*

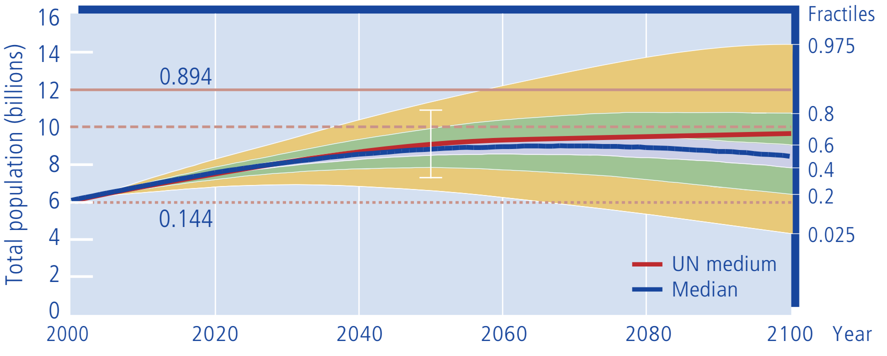

Figure 2. *Forecasted distributions of world population sizes (fractiles). For comparison, the UN medium scenario (red line) and 95 percent interval as given by the NRC[11] on the basis of an ex post error analysis (vertical line in 2050) are also given.*

reaching a peak within the next two decades is still low owing to its relatively young age structure. By 2040 the probability becomes greater than half. In sub-Saharan Africa, despite the prevalence of HIV, there is a low probability of peaking before the middle of the century. The probability reaches 25 percent by 2070, 50 percent by 2085, and almost 75 percent by 2100, owing to assumed reductions in fertility.

Figure 2 shows the distribution of simulated world population sizes over time. The median value of our projections reaches a peak around 2070 at 9.0 billion people and then slowly decreases. In 2100, the median value of our projections is 8.4 billion people with the 80 percent prediction interval bounded by 5.6 and 12.1 billion. The medium scenario of the most recent United Nations long-range projection[2] is inserted in Figure 2 as a red line. It is almost identical to our median until the middle of the century, but is higher thereafter due to the United Nations assumption of universal replacement-level fertility, i.e., two surviving children per woman.

Table 1 shows the median population sizes and associated 80 percent prediction intervals for the world and its 13 regions, indicating major regional differences in the paths of population growth. While over the next two decades the medians are already declining in Eastern Europe and the European portion of the former Soviet Union, the populations of North Africa and sub-Saharan Africa are likely to double, even when we take into account the uncertainty about future HIV trends.

The China region and the South Asia region, which have approximately the same population size in 2000, are likely to follow very different trends. Owing to an earlier fertility decline, the China region is likely to have around 700 million fewer people than the South Asia region by the middle of the century. This absolute difference in population size is likely to be maintained over the entire second half of the century and illustrates the strong impact of the timing of fertility decline on eventual population size[3].

Our findings concerning the timing of the end of world population growth are robust to plausible changes in parameter assumptions. A detailed sensitivity analysis is provided as Supplementary Information on *Nature's* World-Wide Web site (http://www.nature.com) or as paper copy from the London editorial office of *Nature*. The forecasts of the World Bank, the U.S. Census Bureau, and the medium variant of the United Nations[2,4,5] are based on independent assumptions; the median trajectory of our world forecasts is almost identical to these up to 2045. Of these three forecasts, only the UN long-range projections provide scenarios of the world's population to the end of the century. If we define the end of population growth slightly less literally,

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Table 1. Forecasted population sizes and proportions over age 60

	Median world & regional population sizes (millions)					Share of population over 60		
Region	2000	2025	2050	2075	2100	2000	2050	2100
World total	6,055	7,827	8,797	8,951	8,414	0.10	0.22	0.34
		(7,219–8,459)	(7,347–10,443)	(6,636–11,652)	(5,577–12,123)		(0.18–0.27)	(0.25–0.44)
North Africa	173	257	311	336	333	0.06	0.19	0.32
		(228–285)	(249–378)	(238–443)	(215–484)		(0.15–0.25)	(0.23–0.44)
Sub-Saharan Africa	611	976	1,319	1,522	1,500	0.05	0.07	0.20
		(856–1,100)	(1,010–1,701)	(1,021–2,194)	(878–2,450)		(0.05–0.09)	(0.14–0.27)
North America	314	379	422	441	454	0.16	0.30	0.40
		(351–410)	(358–498)	(343–565)	(313–631)		(0.23–0.37)	(0.28–0.52)
Latin America	515	709	840	904	934	0.08	0.22	0.33
		(643–775)	(679–1,005)	(647–1,202)	(585–1,383)		(0.17–0.28)	(0.23–0.45)
Central Asia	56	81	100	107	106	0.08	0.20	0.34
		(73–90)	(80–121)	(76–145)	(66–159)		(0.15–0.25)	(0.24–0.46)
Middle East	172	285	368	413	413	0.06	0.18	0.35
		(252–318)	(301–445)	(296–544)	(259–597)		(0.14–0.23)	(0.24–0.47)
South Asia	1,367	1,940	2,249	2,242	1,958	0.07	0.18	0.35
		(1,735–2,154)	(1,795–2,776)	(1,528–3,085)	(1,186–3,035)		(0.14–0.24)	(0.25–0.48)
China region	1,408	1,608	1,580	1,422	1,250	0.10	0.30	0.39
		(1,494–1,714)	(1,305–1,849)	(1,003–1,884)	(765–1,870)		(0.24–0.37)	(0.27–0.53)
Pacific Asia	476	625	702	702	654	0.08	0.23	0.36
		(569–682)	(575–842)	(509–937)	(410–949)		(0.18–0.29)	(0.26–0.49)
Pacific OECD	150	155	148	135	123	0.22	0.39	0.49
		(144–165)	(125–174)	(100–175)	(79–173)		(0.32–0.47)	(0.35–0.61)
Western Europe	456	478	470	433	392	0.20	0.35	0.45
		(445–508)	(399–549)	(321–562)	(257–568)		(0.29–0.43)	(0.32–0.58)
Eastern Europe	121	117	104	87	74	0.18	0.38	0.42
		(109–125)	(86–124)	(61–118)	(44–115)		(0.30–0.46)	(0.28–0.57)
European part of the former USSR	236	218	187	159	141	0.19	0.35	0.36
		(203–234)	(154–225)	(110–216)	(85–218)		(0.27–0.44)	(0.23–0.50)

Note: 80 percent prediction intervals are shown in parentheses.

and take it to correspond with annual population growth of one-tenth of one percent or less, the United Nations medium projection also shows the end of population growth during the second half of the century. Their medium scenario predicts that world population growth will first fall below one-tenth of one percent at around 2075.

A stabilized or shrinking population will be a much older population. At the global level the proportion above age 60 is likely to increase from its current level of 10 percent to around 22 percent in 2050. This is higher than it is in Western Europe today. By the end of the century it will increase to around 34 percent, and extensive population aging will occur in all world regions. The most extreme levels will be reached in the Pacific OECD (mostly Japan), where half of the population is likely to be age 60 and above by the end of the century, with the 80 percent uncertainty interval reaching from 35 to 61 percent. Even sub-Saharan Africa in 100 years is likely to be more aged than Europe today. The trend of our median proportion over age 60 is almost identical to that of the UN long-range projections[2] up to 2050, but shows significantly stronger aging thereafter. This confirms recent criticism that conventional projections tend to underestimate aging[6,7]. The extent of and regional differences in the speed of population aging—the inevitable consequence of population stabilization and decline—will pose major social and economic challenges.

However, population numbers are only one aspect of human impact, and in some of the world's most vulnerable regions, significant population growth is still to be expected. Nevertheless, the prospect of an end to world population growth is welcome news for efforts toward sustainable development.

Methods

The method of probabilistic population projection applied here (see Box 1) is a further development of our earlier approach[1,8,9] that allows short-term fluctuations in the vital rates[6,10] and refers to the ex post error analysis of past projections[11]. We produced a set of 2000 simulations by single years of age for 13 world regions[12] starting in 2000. Information on baseline conditions has been derived from the United Nations[2] and U.S. Census Bureau[4] estimates, and the sensitivity of our results to possible baseline errors is discussed in the Supplementary Information. World population sizes at five-year intervals for all 2000 simulations are also listed there.

The substantive assumptions about future trends in the three components fertility, mortality and migration, and the associated uncertainty ranges are based on revisions and updates of our earlier work[12] and the extensive analyses summarized in the recent U.S. National Research Council (NRC) report[11].

Fertility

The key determinant of the timing of the peak in population size is the assumed speed of fertility decline in the parts of the world that still have higher fertility. On this issue there is a broad consensus that fertility transitions are likely to be completed in the next few decades[11]. For the eventual size of the population and the question of whether or not world population will begin a decline by the end of this century the key variable is the assumed level of post-transitional fertility. The thorough review of the literature on that subject by the NRC states that "fertility in countries that have not completed transition should eventually reach levels similar to those now observed in low fertility countries" (page 106 in ref. 11). Our fertility assumptions are consistent with this view.

The trends in the means of the regional fertility levels have been defined for the periods 2025–29 and 2080–84 with interpolations in between. The total fertility rates (TFR) assumed for 2025–29 are similar to those chosen by the United Nations[2], but for 2080–84 they are assumed to range between 1.5 and 2.0, with lower levels for regions with higher population density in 2030. The variances in the total fertility rates are assumed to depend on the level of fertility. If the TFR is above 3.0 there is an 80 percent chance that fertility would be within one child of the mean. When it is below 2.0, the same probability is attached to a range within one half a child of the mean. Between the two TFR levels, the variance is interpolated.

Life expectancy

We assume that life expectancy at birth will rise in all regions, except sub-Saharan Africa, where HIV/AIDS will lower life expectancies during the early part of the century. In general, we assume that life expectancy increases by two years per decade with an 80 percent probability that the increase is between zero and four years; but there are a number of exceptions to this rule based on specific regional conditions. These assumptions reflect the very large uncertainty that exists regarding future mortality conditions. On the one hand, significant bio-medical breakthroughs are likely to be made; on the other, AIDS could still become a major issue outside Africa, and new and unexpected threats to human life can emerge.

Autocorrelations

Migration is treated as a random vector on the basis of recent interregional migration patterns. The autocorrelation chosen for all components is based on a 31-year moving-average process that seemed the most plausible after we had experimented with 21-, 31- and 41-year moving averages, and is close to existing national level figures[10]. We assumed an interregional correlation of 0.7 for fertility and 0.9 for mortality deviations with no correlation between fertility and mortality deviations from the assumed trend, and perfect correlation between male and female life expectancy. These choices followed extensive sensitivity analyses as documented in the Supplementary Information. The main rationale behind our choice is that under post-transition conditions, correlations between deviations from assumed fertility and mortality trends are unlikely to be large, while globalization of communication is likely to bring correlated fluctuations of rates among world regions. Mortality correlations will be higher than fertility correlations owing to the faster communication of medical technology and the faster spread of new health hazards. The sensitivity analysis documented in the Supplementary Information shows that our main conclusion, that there is around an 85 percent chance that a peak in world population size will occur in this century, is quite robust to plausible changes in those correlations.

Supplementary Information is available on *Nature's* Web site (http://www.nature.com) or as paper copy from the London editorial office. Correspondence and requests for materials should be sent to Wolfgang Lutz at lutz@iiasa.ac.at.

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Box 1. Different approaches to probabilistic population projections

The cohort component method of projection is taken as a standard; thus the differences between alternative approaches discussed in this box refer only to the modeling of future fertility, mortality, and migration rates. Here we can distinguish between the specific process chosen for representing the time series of rates and the basis for the specific assumptions made about the future range of uncertainty.

Model

In the literature there are essentially two methods of specifying the series of vital rates: (1) processes with annual fluctuations[10,13,14,15]; and (2) piece-wise linear scenarios[1,8,16]. Whereas method (2) has the advantage of conforming to the current practice of scenario definition in statistical offices around the world (including the UN)[2], method (1) can produce realistic annual fluctuations given that the possible levels are bounded. We have chosen the following moving-average model with annual fluctuations, in order to avoid the argument that our model underestimates variance[10].

Let v be a vital rate to be forecasted for periods *1* through T and v_t the forecasted value at time t. $v_t = \bar{v}_t + \varepsilon_t$, where the mean of v, $\bar{v}_t$, and its standard deviation at time t, $\sigma(\varepsilon_t)$, are determined according to the assumptions in the text. Let $\{x_{2-n},\ldots,x_T\}$ be the values of $T+n-1$ independent draws from a standard normal distribution and n be the number of periods in the moving average. Then $\varepsilon_t = \frac{\sigma(\varepsilon_t)}{\sqrt{n}} \cdot \sum_{i=t-n+1}^{t} x_i$.

A more detailed description of the model is given in the Supplementary Information (see box above).

Assumptions

The literature suggests three approaches for deriving assumptions about the future range of uncertainty of the components: (1) to compute a measure of the future error from the ex post analysis of past projections[17,18,19]; (2) to apply time series models[10,13]; and (3) to have well-informed experts make assumptions based on explicitly stated substantive arguments[9]. These three approaches are not mutually exclusive, and approaches (1) and (2) also include expert judgement.

Here we use a synthesis of the three approaches. Our process specification uses a time series model. We have explicitly considered existing national-level parameter estimates[13,14] given that, at the level of world regions, empirical estimation is impossible owing to lack of data. The ex post analysis of past errors enters our study in two ways: the substantive assumptions made on fertility and mortality changes are informed by the analysis of past errors in those components[11,18], and our results at the regional level have been compared to the results of an ex post error analysis of global UN projections documented in the NRC report. Because we preferred to err on the side of higher variance (i.e., lower probability of population growth ending this century), we followed the general rule of producing intervals that are at least as large as those in the NRC report at the level of major world regions[11]. Combining this with argument-based expert judgement[12], we saw substantive reasons for assuming a larger uncertainty in many regions as a result of new factors such as HIV/AIDS, the new situation in the former USSR, and the indeterminancy of long-range post-transitional fertility levels that will affect an increasing number of countries.

The 95 percent interval resulting from that ex post error analysis is inserted in Figure 2 as a vertical line in 2050 (the latest year given in the NRC report). It corresponds to roughly 80 percent of our distribution, which clearly indicates that our method produces a broader uncertainty range than the ex post error approach.

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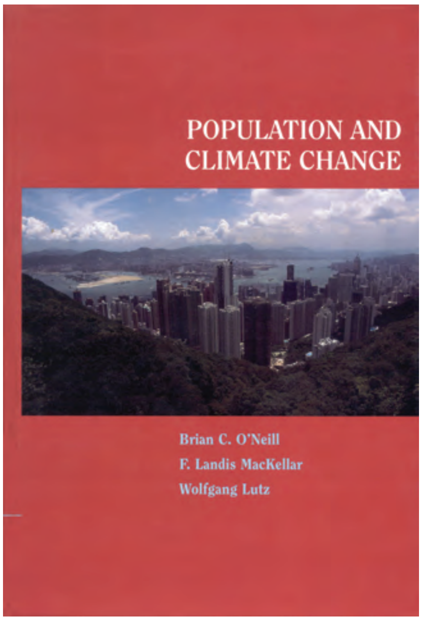

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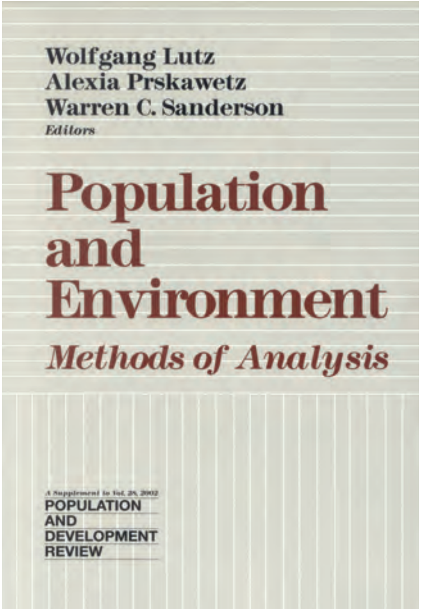

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