International Institute for Applied Systems Analysis
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options

autumn 2005

Asia's Future

what research reveals

editorial

Asia in numbers

Leen Hordijk
Director, IIASA

Asia's numbers tell its story. Its population of 3.9 billion in mid-2005 accounted for over 60% of the world's population. Predictions show that it will grow even further. For example, IIASA's researchers suggest that India's population will rise from today's 1.0 billion to around 1.4 billion by 2050 (see article on page 18). This increase is significantly more than the entire population of the United States today.

The makeup of its populations is also changing. More of its people are living in cities, and Asia is home to some of the world's most populous cities (for example, Mumbai at 18.1 million inhabitants) and some of the fastest-growing cities. By 2030, over half (58%) of China's population will live in cities—up from 36% in 2000 (see article on page 24).

The continent has the world's second-largest economy—Japan, with a gross domestic product of US$4,623 billion in 2004, and as this magazine shows, with strong signs of an economic recovery (see article on page 16).

It also boasts some of the world's fastest-growing economies—gross domestic product in China, India, and Southeast Asia is expected to grow by 8.7%, 6.1%, and 5.6%, respectively, in 2006 (see article on page 26). Not surprisingly, the continent also includes two of the world's five largest consumers of energy—Japan and China.

It also suffers regularly from natural disasters. The tsunami in 2004 killed over 200,000 people along the coasts of the Indian Ocean.

These numbers give a flavor of the tremendous challenges facing the countries of Asia. Decisions that a country makes now will have a huge impact on its future, which is why it is so important that policy makers have the most accurate information at their fingertips. Here at IIASA, we provide such information through our publications, data, models, and research tools so that a country can better understand the present and its future.

This issue of *Options* highlights some of these insights from IIASA's scientists. For example, we show China's options for feeding itself, we highlight how population change affects demand for energy, which in turn impacts greenhouse gas emissions, and we argue for a more effective approach to disaster relief.

Although this issue focuses on Asia, IIASA's research covers the global changes that are affecting the whole world—from the United States to Africa and from Latin America to Russia. Lessons can be learned from other countries' successes in turning global challenges into rewarding opportunities.

Finally, I hope you like the changes that we have made to *Options*, both in its design and content. They are part of IIASA's ongoing commitment to extending the reach of its research. Inside this issue, you will find a reader survey, and we would welcome your feedback. The survey can also be completed online at www.iiasa.ac.at/Options/survey.

About IIASA

IIASA is an interdisciplinary, nongovernmental research institution.

IIASA's scientists research
- energy and technology;
- environment and natural resources; and
- population and society.

IIASA produces
- data, models, and research tools;
- refereed scientific literature; and
- policy-relevant information.

IIASA helps
- countries make better-informed policy;
- develop international research networks; and
- support the next generation of scientists.

IIASA is funded and supported by scientific institutions and organizations in the following countries:

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About *Options*

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options

A student in a factory school in Bejing, China, eating a bowl of rice (UN Photo / John Isaac)

LIFE EXPECTANCY

Reconsidering aging

Many analyses of aging populations of developed nations are incomplete and potentially misleading, according to a study in *Nature* by Warren Sanderson of IIASA and the State University of New York at Stony Brook and Sergei Scherbov of IIASA and the Vienna Institute of Demography. Current estimates of a population's age are based on the average number of years that people have been alive. Equally important, however, is the number of years they have left to live.

Sanderson and Scherbov have supplemented the traditional concept of a population's average age with a new measure, "standardized age," which takes into account how many years people have left to live. "Standardized age" is straightforward to calculate. For example, using 2000 as the reference year, if the remaining life expectancy of a 30-year-old in 2000 is 50 years and that of a 40-year-old in 2050 is also 50 years, then the future 40-year-old is assigned a "standardized age" of 30. Everyone of the same age has lived the same number of years. Everyone of the same "standardized age" has the same remaining life expectancy.

Sanderson and Scherbov estimate how the proportion of elderly people in a society will change over the 21st century for Japan, Germany, and the United States—three countries that typify different patterns of aging—when the age at which people are classified as "elderly" responds to changes in life expectancy. When the timing of life-cycle events is allowed to vary as life expectancies improve, a new perspective on aging emerges. In the United States, for example, if the age at the receipt of a full pension is increased by around two months per calendar year, the US public pension system would be sustainable without additional reforms. ■

Sanderson W & Scherbov S (2005).
Average remaining lifetimes can increase as human populations age.
Nature 435: 811–813.

ENERGY STRATEGIES

Experts confer

The Environmentally Compatible Energy Strategies (ECS) Program of IIASA was a co-organizer of the 2005 International Energy Workshop (IEW), which brought together over 160 global energy experts in Kyoto, Japan, to present their latest research results on global and regional energy issues. IEW meetings focus on energy assessments and analyze why views concerning energy sector development may be divergent. This year, topics included managing uncertainty and climate change, abrupt climate change, global energy resources, UNFCCC/post-Kyoto regimes, the hydrogen economy, energy prices and their economic impacts, and technological responses to climate change.

The year 2006 marks the 25th anniversary of the first IEW meeting. Preparations are under way to meet in Cape Town, South Africa, both to highlight Africa's energy issues and to raise awareness on the continent of the importance of information gathering to support energy planning, as well as the various frameworks used around the world to guide informed decision making on energy issues.

ECS welcomes sponsors for future events such as this in the energy field. ■

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RISK MANAGEMENT

Preempting disaster

Three IIASA scientists discuss their research in a special issue of the magazine *Science* on "Dealing with Disaster." In the article, "Refocusing Disaster Aid," authors Joanne Linnerooth-Bayer, Reinhard Mechler, and Georg Pflug point out that the international donor community is now in a position to help the poor cope with the economic repercussions of disasters by providing assistance before disaster actually strikes. Such assistance is possible with the advent of novel insurance instruments for transferring catastrophe risk to global financial markets. Both donors and recipients would stand to gain from such assistance, especially as the instruments can be closely coupled with preventive measures. Donor-supported risk-transfer programs would not only leverage limited disaster-aid budgets but also free recipient countries from depending on the vagaries of post-disaster assistance. However, a strong commitment on the part of the donor community and climate policy negotiators to providing expertise, capacity building, and, above all, financial support will be necessary if these programs are to make a wide-scale difference to the poor. ■

Photo: Robin Davies, AusAID

See article on pages 20–21

AIR POLLUTION

GAINS for China and India

The European Commission has awarded IIASA's Transboundary Air Pollution (TAP) Program a contract to implement the IIASA Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model for China and India. This project, which will be carried out in cooperation with the Chinese Energy Research Institute in Beijing and India's Energy and Resource Institute in New Delhi, aims to investigate cost-effective ways for China and India to control air pollution and greenhouse gas emissions.

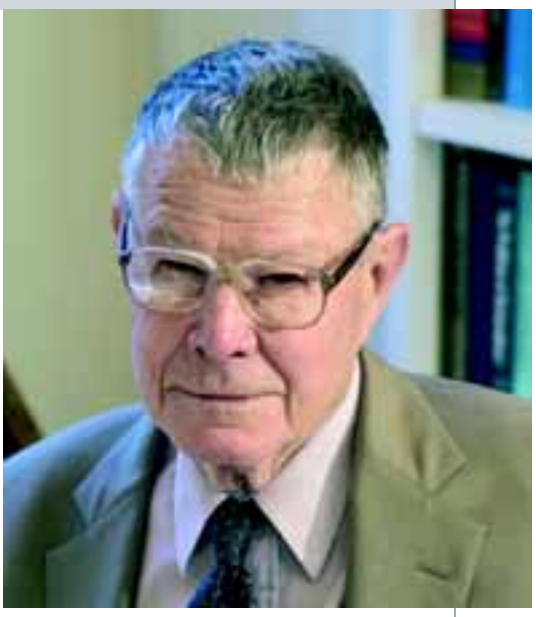
Using the IIASA Regional Air Pollution INformation and Simulation (RAINS) and GAINS models, TAP has identified several hundred specific measures that lead to lower emissions of air pollutants and/or greenhouse gases, enabling estimates to be made of the cost of controlling such emissions while taking full account of the co-benefits between air pollution control and greenhouse gas mitigation. The new project, which will implement these estimates for China and India, will allow a comparison of emission control potentials, costs, and benefits to be made between industrialized and developing countries, as well as a quantitative assessment of the scope of international economic instruments.

The estimates may also make it possible to analyze how the economic burden of emission reduction is distributed across countries and sectors, so that fair and consistent burden-sharing measures can be instituted on an international basis. ■

IIASA's Transboundary Air Pollution Program
www.iiasa.ac.at/Research/TAP

THOMAS SCHELLING

Nobel Prize goes to IIASA alumnus



Professor Thomas C. Schelling of the University of Maryland, who worked at IIASA in several research areas from 1994 to 1999, has been awarded the Nobel Prize in Economics jointly with Robert J. Aumann of the Hebrew University "for having enhanced our understanding of conflict and cooperation through game-theory analysis."

He is the fourth Nobel Prize Laureate to have worked at IIASA. A thoughtful, articulate, and often original thinker, Professor Schelling was one of the first to apply the ideas of game theory to international relations. In his classic book, *The Strategy of Conflict* (1960), he showed that even the deadliest conflicts involve essentials of common interest and cooperation between enemies.

At a time of emerging nuclear parity between the United States and the Soviet Union, Schelling's work was enormously influential. Schelling provided the theoretical basis for the strategy of nuclear deterrence—using the threat of nuclear attack as an instrument of political influence to actually prevent a nuclear attack—which, according to the Nobel Prize Committee, "proved of great relevance for conflict resolution and efforts to avoid war." Indeed, the resulting nuclear face-off endured until the end of the Cold War.

Professor Schelling also used game theory to develop an explanation of why segregation occurs and, more recently, on building coalitions for climate change. "Tom's talent is asking questions that go to the core of scientific and policy issues," said IIASA research program leader Joanne Bayer, who worked with the Laureate on various projects. "For example: Is it worth the trillions of euros necessary to abate climate change in the future, when these funds could be used to help eradicate poverty today?"

He joins three other Nobel Prize winners who also worked at IIASA. Tjalling Koopmans and Leonid Kantorovich jointly won the 1975 Economics Prize for their contributions to the theory of optimal use of resources. Paul Crutzen received the 1995 Chemistry Prize for his work on natural and anthropogenic processes affecting stratospheric and tropospheric ozone. ■

www.nobelprize.org

HEALTH, AIDS, AND POPULATION

Needs outstrip resources

In research supported by the Organisation for Economic Co-operation and Development (OECD) Development Centre, Landis MacKellar, leader of IIASA's recently completed Social Security Reform Project, analyzes trends in official development assistance (ODA) directed toward health, AIDS, and population (HAP) over the past decade. The resulting article, "Priorities in Global Assistance for Health, AIDS, and Population," was published in the June 2005 edition of *Population and Development Review*.

MacKellar concludes that while the share of HAP in total ODA has increased significantly over the past decade, if HIV/AIDS is excluded, HAP actually lost share. Moreover, contrary to the emphasis placed on health as a key sector in development, health subsectors generally considered pro-poor are also losing out once HIV/AIDS is removed.

The article underscores the urgency of warnings from the international public health community that international support for health development is insufficient and raises the question as to whether HAP assistance is being effectively allocated. ■

Further information is available at
www.oecd.org/dataoecd/42/39/34987795.pdf

MEGACITIES

Growing vulnerability

Densely populated, home to a high proportion of poor people, and expanding in a haphazard rather than planned fashion, megacities—cities with over 10 million inhabitants—are extremely vulnerable to hazards like earthquakes, flooding, and other natural disasters. The ability to cope with disasters is limited, resources are already stretched, and the problem is growing. By 2015, 17 of the world's 21 megacities will be in developing countries, and most will be in Asia, which experiences approximately 60% of the world's major disasters annually.

IIASA's Risk, Modeling and Society (RMS) Program has begun a four-year program to assess the indirect social and economic consequences of disasters for megacities and suggest ways of reducing and alleviating the effects of natural hazards. The challenges are that different megacities have different vulnerabilities, their exposure to hazards is increasing rapidly, and the risk parameters are constantly changing.

The first case study for RMS will be Istanbul, probably the most severe seismic hot spot in the world, with an estimated 0.41 probability of a severe earthquake, and possible tsunami, occurring over the next 30 years.[1] Turkish policy makers will use the information provided by RMS as a basis for new regulations, for example, on seismic retrofitting in high-risk areas and earthquake insurance.

Following its work on Istanbul, RMS plans to continue with case studies of megacities exposed to severe natural hazards in India and China. ■

1. Parsons T (2004). Recalculated probability of M 7 earthquakes below the Sea of Marmara. *Journal of Geophysical Research* 109: B05304.

IIASA's Risk, Modeling and Society Program
www.iiasa.ac.at/Research/RMS

EURASIA

Natural gas for China

IIASA's Environmentally Compatible Energy Strategies (ECS) and Dynamic Systems (DYN) Programs are currently developing the GASCOM model of competition in natural gas markets. Designed to provide answers to commercial, logistical, timing, and pricing questions so as to optimize investment in natural gas provision and payback times, GASCOM has recently been used to examine the rational dynamics of potential gas pipeline projects connecting major gas fields with demand centers in Northeast Asia.

Special attention was given by researchers to increasing the share of environmentally friendly natural gas in primary-energy use in China, which can be expected to grow vigorously, given predicted annual economic growth rates of around 7% and pressing environmental challenges. Future suppliers could include Russia, where vast natural gas resources have recently been discovered in the country's Eastern Siberia and Far East regions. Conveniently located and subject to intensive exploration, deposits there could be considered as a resource base for satisfying growing natural gas demand in China for several decades to come.

However, a major conclusion of the study was that after 2030—and in cases involving high growth in gas demand, the planned development of China's own natural gas production plus full-capacity supply from neighboring countries—some supply shortages could still arise in China. ■

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INDIA

Investment in energy

IIASA's Environmentally Compatible Energy Systems (ECS) Program has begun working with the Indian Institute of Management in Ahmedabad, Gujarat, to closely review the financial implications of different scenarios of future energy demand for India. The scenarios, which take a long-term view to 2100, focus on the next 30 years in particular.

How much investment could be available will play a paramount role in determining the choice of a long-term development pathway that delivers access to clean, climate-friendly, sustainable energy sources for a rapidly increasing population in India. The IIASA study will examine in detail the drivers and constraints for investment, such as what national climate change policies are already in place or planned, the cost of implementing the various scenarios, potential investment availability, and how scenarios can be achieved if optimal resources are unavailable. ■

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in the pipeline

EMERGING ECONOMIES

Forest sector development

IIASA's Forestry (FOR) Program is starting a major project on the global impacts of forest sector development on the emerging economies of China and India.

For a couple of years, FOR leader Sten Nilsson has been working with the Center for Chinese Agricultural Policy of Beijing, Forest Trends of Washington, DC, and the Center for International Forestry Research (CIFOR) of Bogor, Indonesia, to create a unique knowledge base on the Chinese forest sector that is now serving as a platform for the establishment of the new forest sector project in China.

The long-term outlook for China is bright. *The Economist* estimates economic growth rates of 7–8% during the next decade, which is expected to cause an escalating gap in the supply/demand balance for Chinese forest products. Although the Chinese government has taken major steps to modernize its forestry sector, additional measures are necessary.

Addressing these problems will be difficult, however, given the incomplete, non-transparent, and often conflicting data with respect to the Chinese forest sector. In a special issue of the Commonwealth Forestry Association's *International Forestry Review*, Sten Nilsson, together with Gary Bull of the University of British Columbia, Andy White of Forest Trends, and Jintao Xu of the Center for Chinese Agricultural Policy, identify the major policy issues facing the Chinese forest sector and make recommendations for future action. The publication, which will interest policy makers, commercial forestry organizations, and researchers, also describes the results from the partnership activity in China. It can be downloaded for a fee from the Commonwealth Forestry Association Web site: www.cfa-international.org/archive.html.

In addition, and in order to help establish the new study, the FOR Program organized a workshop with Chinese and Western experts in May 2005 on how to tackle the policy and knowledge deficit pertaining to the Chinese forest sector.

With respect to the Indian forest sector, Nilsson made a first rough identification of the most important policy issues, which were then discussed at the IIASA days in October 2004 in New Delhi. A workshop on the Indian forest sector, structured similarly to that of the Chinese forest sector workshop, will be held in early 2006 in New Delhi with Indian and Western experts.

Both workshops are serving as a tool for planning the new project at IIASA. ■

IIASA's Forestry Program
www.iiasa.ac.at/Research/FOR

BUILDING CAPACITY

Young scientists study Asia

More young scientists spent the summer conducting research at IIASA than ever before. And Asia was a popular area of research for the 62 scientists who came from 27 different countries.

Over 60 young scientists spent the summer at IIASA to develop their research projects, gain international experience, and enhance their research skills.

For example, Zhan Tian, from the Chinese Academy of Sciences, is using climate change projections and crop models to understand the impacts of climate change on Chinese agriculture. Amit Kumar, of the National Institute of Construction Management and Research in India, is investigating the benefits and feasibility of seismic mitigation in Khandwa in central India.

These two researchers were part of IIASA's annual Young Scientists Summer Program, which brings young scientists to the Institute for three months during the summer. Here, the young researchers, with the help of IIASA's scientific staff, develop new research ideas, expand their research network, and contribute to ongoing research activities. ■

IIASA's Young Scientists Summer Program
www.iiasa.ac.at/yssp

SUSTAINABLE COASTAL DEVELOPMENT

Post-tsunami pact signed

Following the tsunami disaster of 26 December 2004, IIASA has signed an agreement of scientific collaboration with Chulalongkorn University in Bangkok, Thailand, to conduct a joint research program on population–environment interactions in the coastal regions of Asia. The research will seek strategies for sustainable coastal reconstruction and development.

The collaboration will take place in the context of the Asian MetaCentre for Population and Sustainable Development Analysis, of which the World Population (POP) Program at IIASA was a founding partner in 2000. ■

Khunying Suchada Kiranandana, president of Chulalongkorn University, and IIASA Director Leen Hordijk sign an agreement to jointly research sustainable coastal reconstruction.

EVOLUTION

Shrinking fish

Fisheries-induced evolution in the Yellow Sea

Ongoing research indicates that undesirable genetic changes are taking place in Yellow Sea fish stocks as a result of commercial exploitation. These findings are the outcome of collaborative research between IIASA and the Yellow Sea Fisheries Research Institute (YSFRI) in Qingdao, China.

Today, fishing is the dominant source of mortality in most commercially exploited fish stocks. According to the United Nation's Food and Agricultural Organization (FAO), world capture fisheries have reached a ceiling, with three stocks out of four being maximally exploited or overexploited. Since all fish species were genetically adapted to the environmental conditions experienced prior to intensive exploitation, the current, drastically altered conditions cannot possibly leave their life-history patterns unaffected.

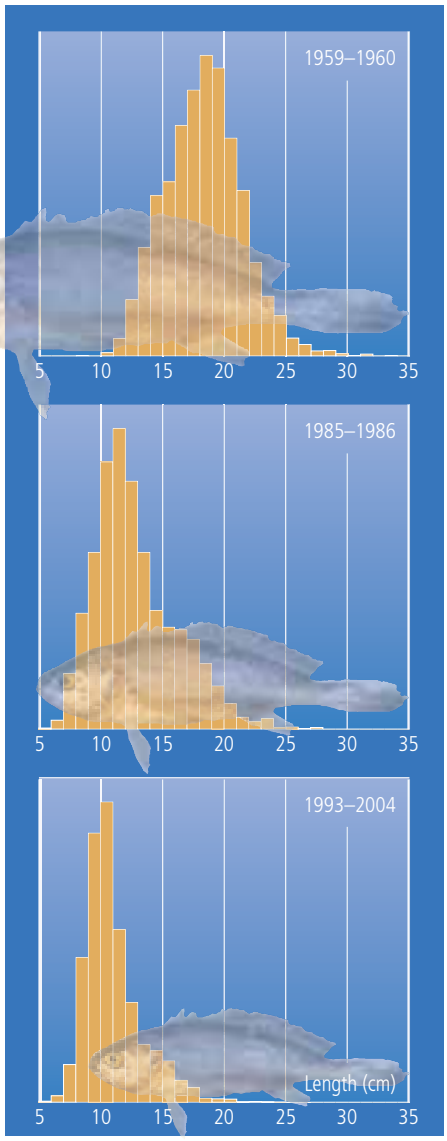
Consequently, fishing is not merely changing the numbers of fish in the sea but is also altering their genetic composition. Together with its network of international collaborators, IIASA's Adaptive Dynamics Network (ADN) Program has found indications of fisheries-induced genetic changes in more than 10 exploited fish stocks in the North Atlantic Ocean. This evolutionary dimension of fisheries has been overlooked or downplayed for decades, so that fisheries scientists and managers are just now awakening to the formidable risks posed by further unmanaged, fisheries-induced evolution.

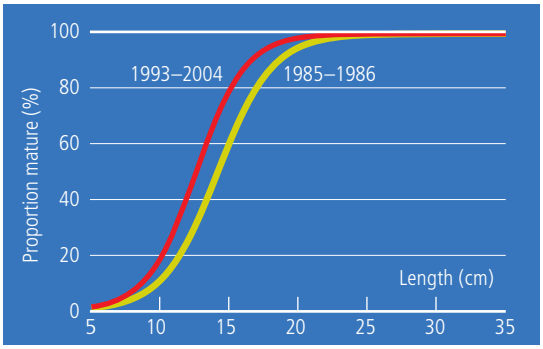
Based on contacts initiated by the National Natural Science Foundation of China in 2002, YSFRI's Xianshi Jin and IIASA's Mikko Heino and Ulf Dieckmann are examining whether fisheries-induced evolution is occurring in the Yellow Sea (map). Exploitation pressures in this region have been high throughout the past few decades. Stocks like that of small yellow croaker nowadays comprise much smaller fish than in earlier years (bar charts). Also, the stock's proportion of mature fish at any given length has increased considerably (line chart). The latter observation agrees well with predictions of fisheries-induced evolution: exploited fish are under selective pressure to leave offspring as early in life as possible, before being removed from the gene pool by the fishery.

Implications of fisheries-induced evolution for sustainable yield, stock stability, and recovery potential are grave. Once this blind spot in perceiving the consequences of human exploitation is overcome, a new generation of fisheries scientists and managers will need scientific tools to cope with the threats of undesired fisheries-induced evolution. ■

Further information IIASA's Adaptive Dynamics Network Program at www.iiasa.ac.at/Research/ADN

Dr Ulf Dieckmann is the leader of IIASA's Adaptive Dynamics Network Program. **Dr Mikko Heino** is a research scholar at IIASA's Adaptive Dynamics Network Program. **Dr Xianshi Jin** is a professor at the Yellow Sea Fisheries Research Institute.





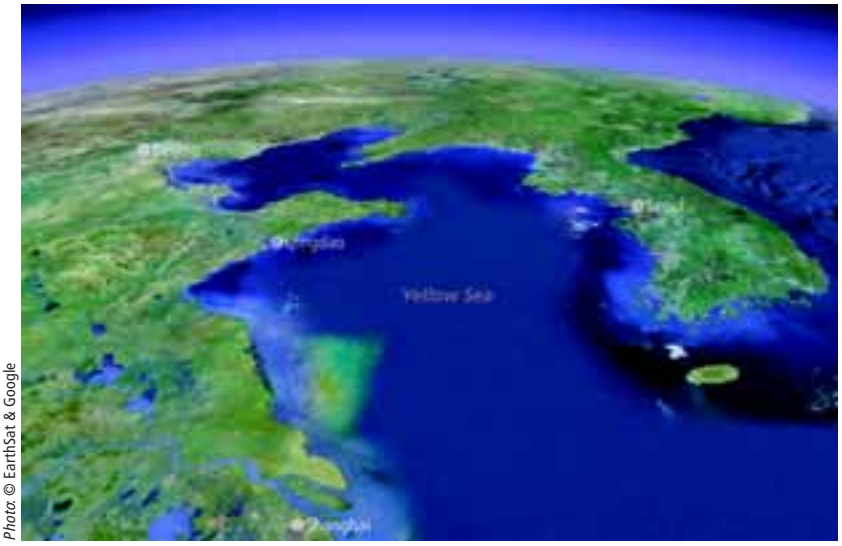


Photo: © EarthSat & Google

(Bar charts) During the past 40 years, the length distribution of small yellow croaker has shifted toward much smaller fish, evidencing heavy exploitation and, presumably, fisheries-induced evolution. The images of the fish represent the declining average length from 19.2 cm to 13.8 cm to 11.9 cm.

(Line chart) During the past 20 years, the proportion of mature small yellow croaker at any given length has increased considerably, a trend highly suggestive of fisheries-induced evolution.

(Map) The Yellow Sea is situated between China and Korea. Its shallow depths of up to 80 meters are home to about 300 fish species. During the second half of the 20th century, overfishing led to the replacement of highly valued larger species such as small yellow croaker by less-valued smaller species such as anchovy.

FLOODS AND EARTHQUAKES

Reducing vulnerability

What the Chinese and Japanese can learn from the Hungarians

China's huge Dongting Lake is one of the country's most serious flood areas. Despite recent measures by the Chinese government, such as relocating people and crops out of the highly exposed reclaimed land, dredging the lake, and reforesting large areas of cropland, severe flooding is still expected.

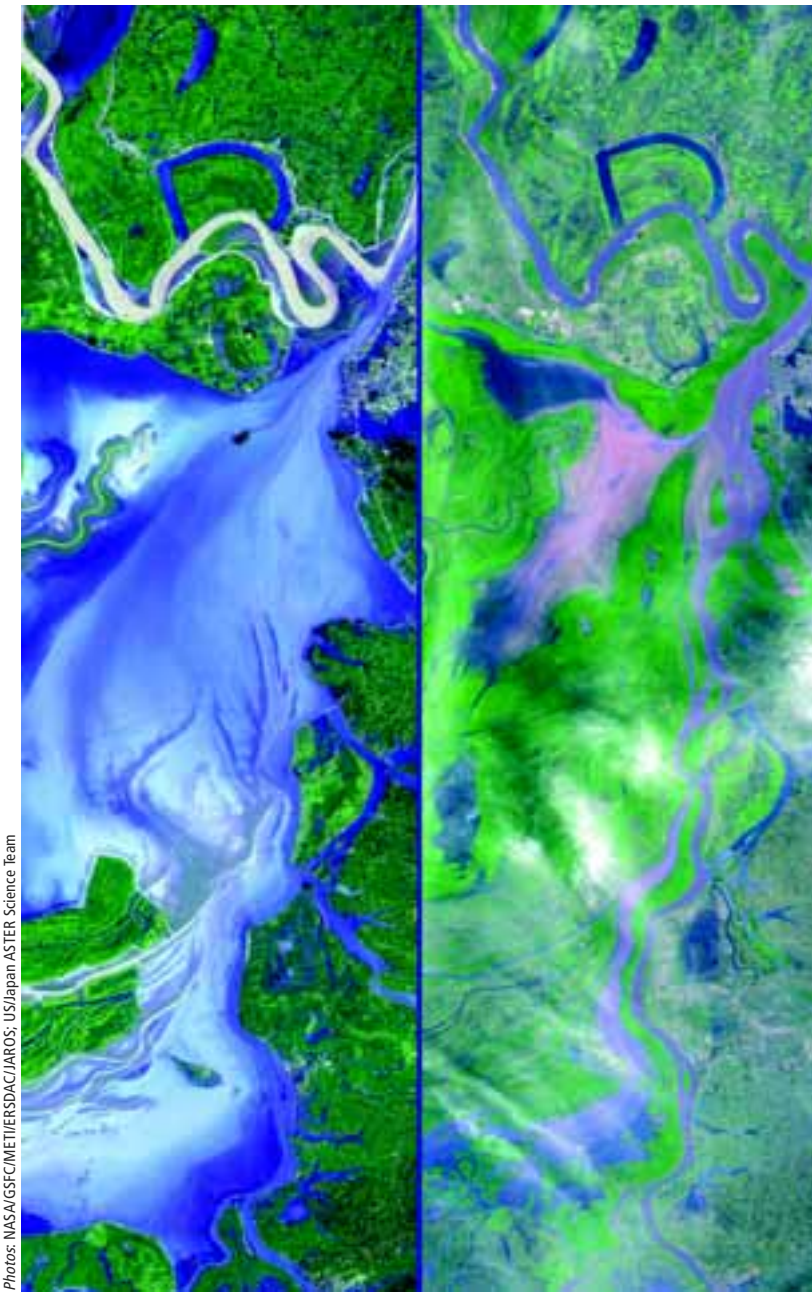
Flooding in this and other basins has led to a "spiral of poverty," with farmers losing harvests and being forced deeper into debt to survive. The Chinese government wishes to decrease the vulnerability of farmers and urban centers in the region by improving the pooling and transferring of flood losses. In partnership with Beijing Normal University, IIASA's Risk, Modeling and Society (RMS) Program is helping to design a stakeholder-involved process that aims to provide efficient and equitable options for insuring public and private assets.

Anticipating a powerful earthquake in the wealthy To-Nankai region, Japan is asking how best to reduce the region's vulnerability. Here, the focus is not on pooling losses but on preventing them. One simple and cost-effective measure, compared with expensive retrofitting of the wooden housing, is to fasten furniture to the floors and walls, which few Japanese have done. RMS is working with Kyoto University's Disaster Prevention Research Institute to develop participatory methods, appropriate to Japan, to promote furniture fastening and other cost-effective risk-reduction measures in this region.

Both projects will benefit from the lessons of a Swedish-funded IIASA study that implemented a model-based participatory procedure aiming to reduce the vulnerability of farms and households in the Tisza River region in Hungary. Driving this three-year project was the Hungarian government's inability to continue its traditional role of investing heavily in levees and rebuilding the homes of flood victims. Such problems plague countries throughout the world, and there are many conflicting views on how to resolve them. How much responsibility should individuals in poor regions or their governments take for such risks? How can citizens be motivated to take affordable measures to reduce their own vulnerability? What is the role of the private market? How can conflicts be resolved?

The Tisza study can provide insights even in the differing social and political contexts of the Chinese and Japanese projects. The study, which resulted in a stakeholder consensus on flood-risk-reduction measures and a national public–private insurance program, showed how stakeholder involvement can expedite the successful design and implementation of policy measures and the importance of respecting the different, and often irreconcilable, values of the participants. Contested policy options are an essential part of any participatory process, and the challenge is to construct a terrain of agreement that does not compromise deeply held values.

Dramatic change in the water at Dongting Lake in Hunan province, China The image on the right is from 19 March 2002, before the flooding began. The image on the left shows the extent of the flooding on 2 September 2002. The images cover an area of 39 × 119 km.



Photos: NASA/GSFC/METI/ERSDAC/JAROS; US/Japan ASTER Science Team

The Tisza study also showed the potential for interdisciplinary teams to provide expertise to inform policy processes. The project combined Hungarian, Swedish, and IIASA expertise in hydrology, modeling, economics, sociology, insurance mathematics, and even anthropology; and the participatory process was informed by an RMS-designed catastrophe flood model that uniquely combined Monte Carlo simulation with adaptive stochastic optimization. The Chinese and Japanese studies will take a similarly integrated approach to examining measures to reduce vulnerability to extreme geophysical and hydrological events. ■

Further information IIASA's Risk, Modeling and Society Program at www.iiasa.ac.at/Research/RMS

Dr Joanne Linnerooth-Bayer is the leader of IIASA's Risk, Modeling and Society Program.

SAFEGUARDING SWEDISH FORESTRY

"Shared Responsibility"

IIASA's Sten Nilsson settles a bill

Among critical thinkers in Sweden there has been concern during the past few decades about declines in the development of the Swedish forest sector. From being a forestry leader in the early 1960s to the late 1980s, Sweden had, according to some, lost its competitive position, international visibility, and formidable reputation amid dramatic changes in the world forestry sector and a rush to increased internationalization and globalization.

From the 1990s there was inertia in the Swedish forest sector and a lack of strategic debate about the sector's future. Swedish forest companies had become fewer and larger, multinational rather than Swedish, were expanding rapidly abroad and investing less in the country. Moreover, the set yearly sustainable harvest was insufficient to fulfill domestic forest industry and energy demands. Over 10 million cubic meters needed to be imported each year to satisfy the annual demand of 95 million cubic meters, a situation likely to worsen under existing policies. International competition had also increased strongly, and many of the new players had substantial cost and production advantages over Sweden.

Sten Nilsson, leader of the Forestry Program and deputy director of IIASA, saw these changes as a threat to Sweden, a small country where the forest sector was the prime contributor to the balance of payments. Thus, in 2004 he took the unprecedented step of writing a "mock" governmental bill on forest sector development in Sweden based on a similar 2003 governmental bill adopted on sustainable development.

In his bill, Nilsson proposed a coherent Swedish policy for the equitable and sustainable development of the forest sector, with the different forestry policy areas based on an integrated economic, ecological, and social framework. "Development does not depend on one or two factors alone," Nilsson wrote, "but on the positive interaction of a wide range of factors": on collaboration, coordination, dialogue, and "shared responsibility," a phrase that Nilsson ultimately chose as the title of the mock bill. Among the policies he recommended were substantial increases in the value added of forest industrial products, evaluation and reformulation of current environmental policies for forestry, and reorganization of ministerial departments and agencies.

Nilsson also underlined the Swedish forest sector's strong dependence on global forest sector development and the national policies needed to deal effectively and forcefully with transboundary issues.

"Shared Responsibility": the key to the future strength of Sweden's forestry sector

Photo: © ulf.cunha@home.se

The "disappearance" of Sweden from the international arena with respect to forest sector policy making, Nilsson added, had been "devastating."

Moreover, as the traditional academic community had failed to deliver relevant input for forest sector development in Sweden, he urged the establishment of a new independent Institute for Strategic Studies of the Forest Sector to develop solid and holistic knowledge about developments in the national and international forest sectors.

With these policies in place, Sten Nilsson believes that Sweden will regain its leading role in the global forest sector, enabling it not only to compete more equitably but also to further the cause of environmental responsibility and sustainability it pioneered in the past. ■

Further information Professor Sten Nilsson's "mock" governmental bill is available at www.iiasa.ac.at/Research/FOR/papers/sn-swegovbill.pdf.

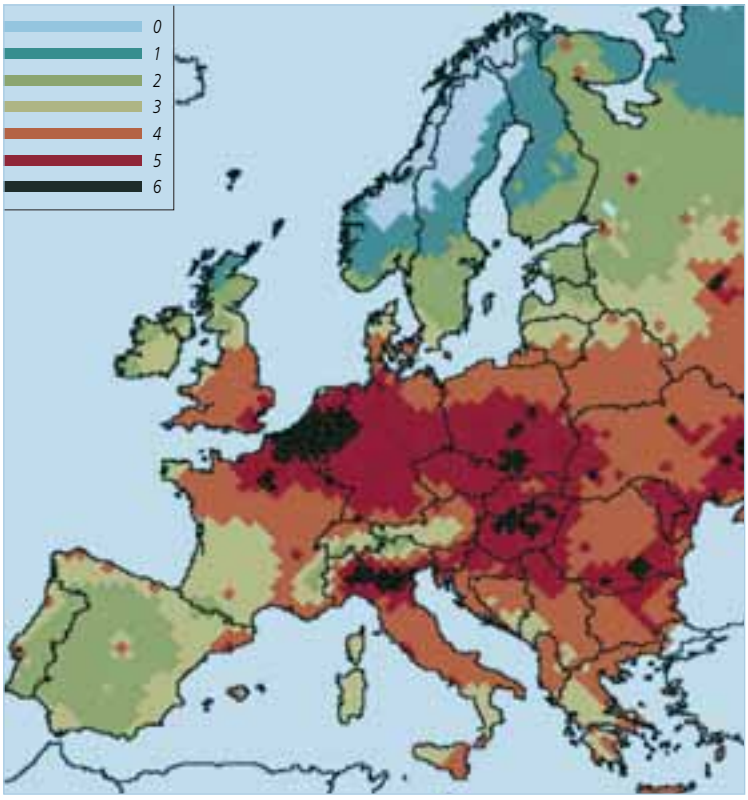
Professor Sten Nilsson leads the Forestry Program and is deputy director of IIASA.

AIR POLLUTION

A breath of fresh air

IIASA's scientists help Europe control emissions

In September 2005, after intense political discussions on the weight given by European Union (EU) policy to environmental issues, consensus was reached by the 25 EU Commissioners on a clean air strategy for Europe. The European Commission's *Thematic Strategy on Air Pollution*, which sets out air-quality objectives for 2020, will underpin all further EU action on air pollution control. The new policy proposal was based on work by the Transboundary Air Pollution (TAP) Program of IIASA, under contract to the Commission, using IIASA's Regional Air Pollution INformation and Simulation (RAINS) model.



RAINS estimates of loss in statistical life expectancy attributable to exposure to fine particles from human sources for the year 2000 (months).

The decision of the European Commission was based on a 2001–2005 integrated assessment process, the Clean Air for Europe (CAFE) Programme, during which stakeholders developed a peer-reviewed scientific knowledge base about emissions, control options, atmospheric chemistry, and the impacts of air pollution on human health and the environment. Quality-controlled, real-world data were also collected from all member states and economic sectors. TAP used RAINS, as the central analytical tool for the CAFE process, to develop the baseline projections for future emissions and air-quality impacts, explore the scope and costs of further emission control measures, and identify a range of cost-effective policy scenarios.

For the CAFE Programme, IIASA developed a multi-pollutant/multi-effect perspective to address the health impacts of fine particulate matter (PM) in a cost-effective way. This approach recognizes the multiple effects of sulfur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOCs), ammonia (NH_3), and PM on human health, acidification, eutrophication, and ground-level ozone, and identifies strategies to maximize emission control synergies.

To ensure acceptance of the model results, RAINS underwent extensive scientific peer review, with input data being validated in 30 bilateral meetings involving more than 100 experts from member states and industrial associations. In January 2005, 90 stakeholder representatives attended a seminar at IIASA on the RAINS modeling approach.

The CAFE baseline projections, developed using RAINS, foresee a continued decoupling of economic development from air pollution emissions in the enlarged EU. While gross domestic product is assumed to increase by approximately 50% to 2020, emissions of SO_2, NO_x, VOCs, and PM from energy combustion and industrial activities should decline by 50–80% compared with 2000 levels (with no significant changes expected for agricultural ammonia emissions). RAINS calculates an average gain in statistical life expectancy of three months from the envisaged decline in PM concentrations.

"RAINS calculates an average gain in statistical life expectancy of three months from the envisaged decline in particulate matter concentrations."

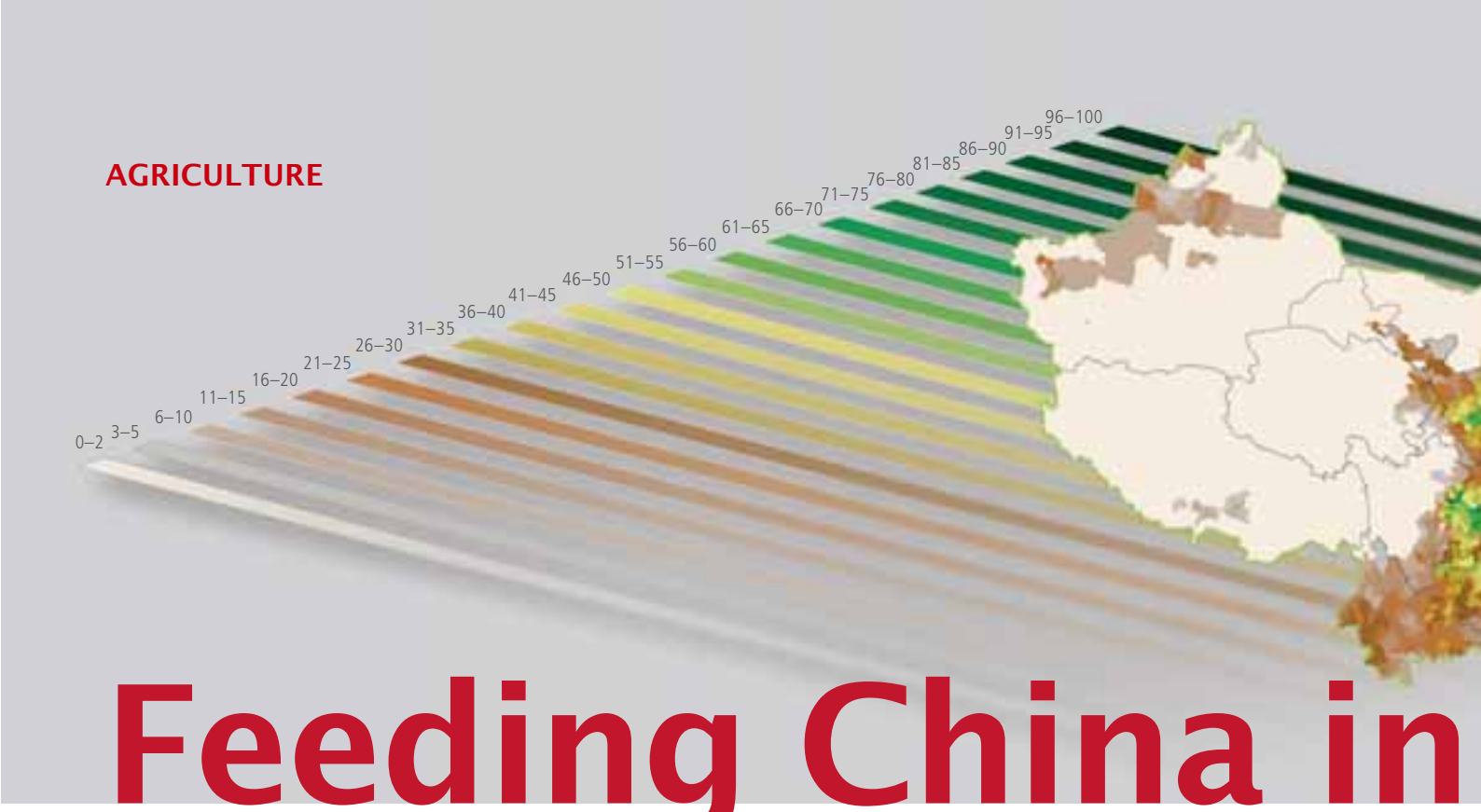
Despite these improvements, however, the life expectancy of European citizens will still be on average six months shorter because of remaining air pollution levels. CAFE has identified further measures to reduce emissions and estimated their costs.

The European Commission has proposed interim targets for reducing air-pollution-related health impacts, acidification, eutrophication, and ground-level ozone, which RAINS estimates will cost an extra 7.1 billion euros per year in 2020. Benefits from these actions should, however, exceed these costs by a factor of 3–10.

In the coming months, the European Commission's *Thematic Strategy* will be discussed by the European Parliament and the Council. In 2006–2007, the Commission will present revised national emission ceilings specifying binding caps for each member state, based on further RAINS calculations. ■

Further information RAINS CAFE Programme Web site at www.iiasa.ac.at/rains/cafe.html

Dr Markus Amann is the leader of IIASA's Transboundary Air Pollution Program.



Feeding China in

Although China has a large agricultural resource base and a solid record of productivity increases in past decades, fundamental changes in its national food policies are needed to ensure future food security, accommodate changing urban food preferences, mitigate widening rural–urban and regional income disparities, and prevent massive environmental pollution.

In 2001, the year China acceded to the World Trade Organization (WTO), IIASA's Land Use Change (LUC) Program began a research project, funded by the European Commission, entitled Policy Decision Support for Sustainable Adaptation of China's Agriculture to Globalization (CHINAGRO).[1] Based on the analysis of a range of development and policy scenarios over a 30-year time horizon, CHINAGRO aimed to establish an informed policy dialogue between Chinese and European Union (EU) institutions to improve food security, farmers' income, and sustainable agricultural development in China.

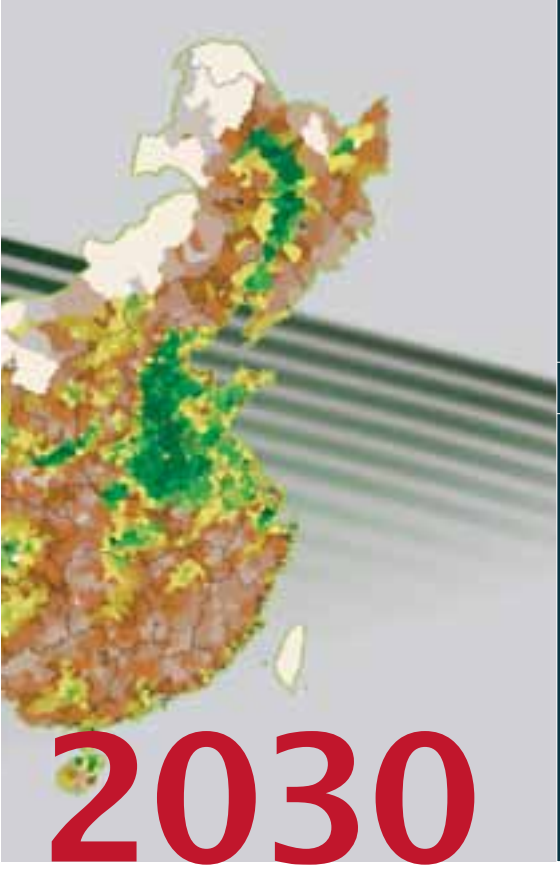
In this article, Günther Fischer, leader of the LUC Program, looks at the challenges China faces as a result of the removal of international trade barriers, shrinking farmland, rapid urbanization, increasing urban–rural and provincial income disparities, and changes in the food-demand structure—and how these challenges can be met.

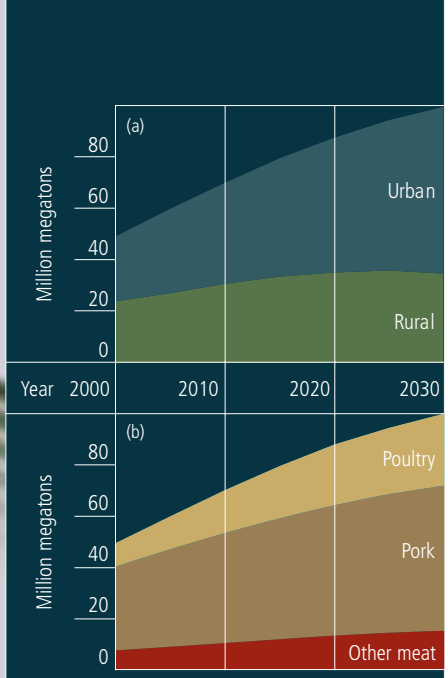
In the past 50 years, China has successfully increased the supply of food and fiber to meet the needs of its rapidly growing population. Since the early 1980s, China has also shifted from being a net food importer to a net food exporter, which has significantly contributed to world food security.

China's accession to the WTO in 2001 enabled the country to start opening up to international food markets. From a trade perspective, however, and in the light of Chinese consumers' fast-rising demand for animal proteins, the key policy concern was whether the country should aim at self-sufficiency in cereals and meat, including animal feeds, whether it should import feed, or whether it should import meat.

Another concern was the urban–rural income gap, which has been gradually widening since the 1980s, as has the farm income disparity across provinces. Moreover, the options for improving productivity per farmer are restricted by the limited availability of new arable land, loss of land due to soil degradation and urbanization, and the agronomic limits of conventional technology being reached.

A third concern was that any measures taken must be environmentally sustainable. China's strides in agricultural production and food security have taken a huge environmental toll, and current pressures on farm incomes in less-developed regions of China are partly the result of degradation of the resource base.





Central scenario (a) Projections of urban and rural meat demand; (b) projections of meat demand by type.

(Map, *left*) Intensity of cultivated and orchard land (percentage of total land in county), 2000.

Food demand and agricultural development

It was extraordinary population growth in China from 1950 to 1980 and the daunting prospects of feeding an ever-increasing number of people that triggered the drastic population planning measures introduced by the Chinese government. Although total fertility rates have declined from 4.2 in the 1970s to well below replacement level today, population growth is predicted to continue during the next two decades, rising from 1.275 billion in 2000 to about 1.45 billion in 2030.

Urbanization, a mighty driver of economic development, is also likely to accelerate to 55–65% by 2030, compared with 36% in 2000. Although the economic growth rate, which has reached 10% in the past two decades, will probably gradually decline to some 5% annually in 2030, increasing per capita incomes, together with urbanization, will have profound impacts on the structure and levels of demand.

In the CHINAGRO simulations, total direct human consumption of cereals and other staple grains changes only modestly from 2000 to 2030. Food consumption in China is already high, and there is little propensity to spend extra income on food grains. The significant differences between rural and urban consumption patterns—lower per capita consumption of cereals in urban compared with rural diets—will mean an average 10% decline in per capita consumption of cereals, in spite of increasing incomes. Conversely, urbanization is likely to accelerate meat consumption, which responds strongly to income growth. We project that consumption of livestock and fish products is likely to double between 2000 and 2030.

Thus, the basic question is no longer that posed by Lester Brown, founder of the Worldwatch Institute, namely, whether farmers can feed China's vast population; it is how farmers can feed the animals required to meet the accelerating demand for livestock products. The answer lies in the economic geography of China.

China has several major urban agglomerations, situated along the coast and, except in the delta region, separated from the hinterland by hill tracts. As inland transport—especially across rugged terrain—is far more expensive than ocean shipping, importing meat or feed grains from overseas may be cheaper than using internal transportation. Hence, small-sized, remote, inland pork, poultry, and dairy farmers in China may also be at a disadvantage. In Western Europe and the United States, such commodities are generally produced either close to the consumer or near harbors that offer good sites for food processing plants (e.g., oilseed processing) and bulk imports. Hence, the answer to the important question of whether China should import meat or feed grains not only is subtle and highly differentiated geographically speaking, but also has major social ramifications.

Farmland resources

In recent years, rapid economic growth and urbanization have threatened China's limited farmland resources. According to data from the Chinese Ministry of Land and Resources (MLR), China's farmland decreased by about 0.3 million hectares per year from 1987 to 2000, and the trend is expected to continue to 2030. Some 38% of this lost farmland was transformed into forest and grasslands for conservation purposes, 25% into orchards and fishponds, and 22% into construction land; the remaining 15% became unusable because of severe damage by natural events.

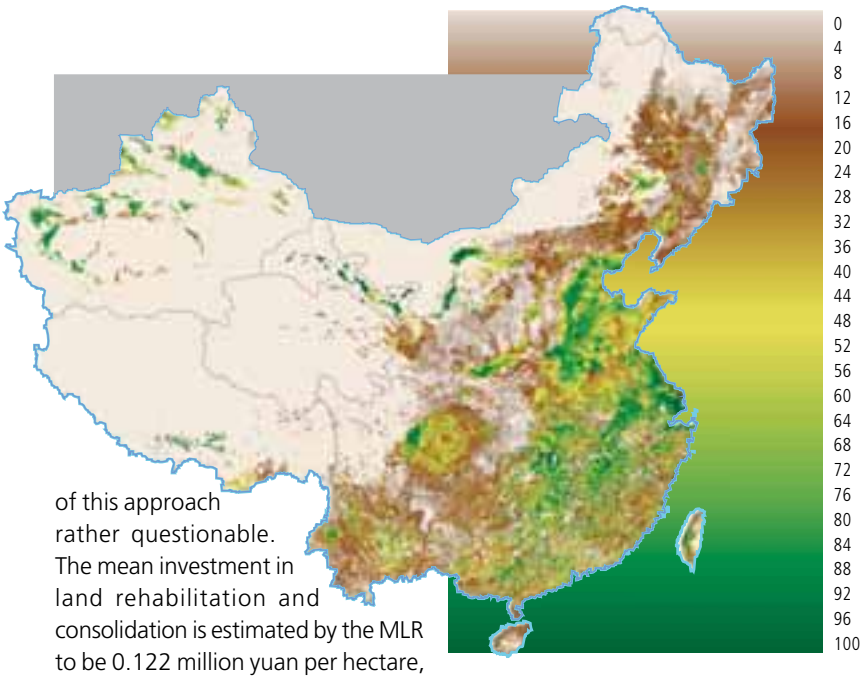
Expansion of construction land to 2030, especially in highly populated urban fringes, will contribute to farmland loss of 6.7–9.1 million hectares (i.e., 5–7% of total farmland in 2000), with great regional variation: 17–25% in the south, 12–17% in the east, 6–8% in the north, and 5% or less in other regions.

According to the Land Management Law of the People's Republic of China and related regulations, there should be full compensation (by land reclamation, farmland consolidation, or rehabilitation) for farmland converted into construction land. However, the expense makes the feasibility

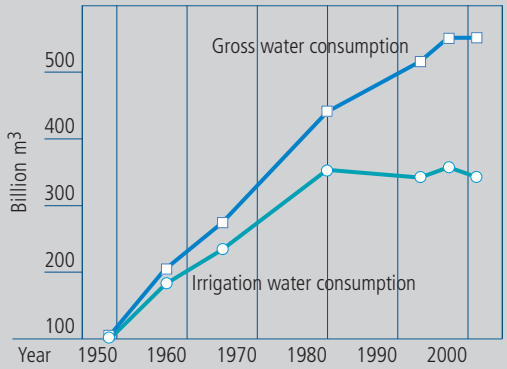
Key issues and major policy concerns

The Central Committee of China's Communist Party, Ministry of Agriculture, and Ministry of Land and Resources have indicated five areas where improvements vital to China's sustainable agricultural development must be made:

- As China has nearly reached the limit of almost all its agricultural resources (land, irrigation water, and most fertilizers) in terms of conventional technologies, improved resource-use efficiency and new technology development are required to boost agricultural production.
- The main obstacles to improved resource-use efficiency and modern technology use in agriculture—low income of farmers, high agricultural production costs, large disparity in urban–rural and regional living standards, and surplus rural labor—must be addressed.
- Systematic structural adjustments are needed in the agricultural sector, given the oversupply of low-quality food products and shortages of high-quality products.
- Following its accession to the WTO, China needs to be more competitive in world markets for grain, cotton, and other cash crops.
- China's self-sufficiency in grain is under continuous threat from increases in food and feed demand, shrinking farmland stock, difficult-to-enforce land protection legislation, environmental deterioration, and the weakness of research institutions. ■



Proportion of cultivated land that is irrigated (percentage), 2000.



Growth of water consumption in China.
Source: Ministry of Land and Resources of China (2001)

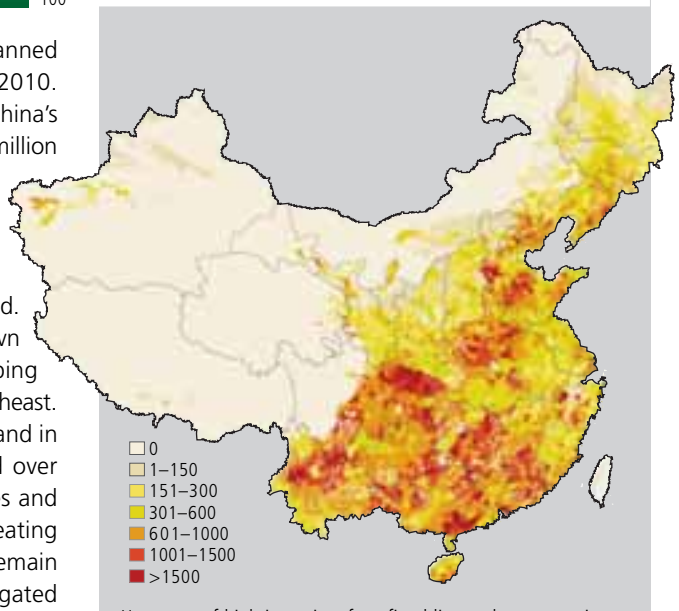
of this approach rather questionable. The mean investment in land rehabilitation and consolidation is estimated by the MLR to be 0.122 million yuan per hectare, with an annual investment of 33 billion yuan required to achieve the planned aim of obtaining 0.25 million hectares of farmland per year in 2001–2010.

Taking various forms of conversion into account, we estimate that China's farmland will decrease from 128.2 million hectares in 2000 to 118–120 million hectares in 2020, and to 114–118 million hectares by 2030 (i.e., a possible net reduction of 8–12% over 30 years).

Irrigation

Irrigation water is essential for high output from increasingly limited farmland. Nearly 45% of China's farmland is irrigated, and around 54% of all sown area in China is on irrigated land because of its superior multi-cropping conditions. The highest irrigation use is in the east and the lowest, in the northeast.

An estimated 72% of total grain output was produced on irrigated land in 2000, with irrigated land also accounting for 60% of farm labor and over 70% of chemical fertilizers and farm machinery. Scarce water resources and increasing demand for urban and industrial water in the north are creating pressing problems. As the water supply available for agriculture will remain constant or may even decline in the future, the key to maintaining irrigated areas lies in more rational and efficient water use.



Hot spots of high intensity of confined livestock consumption (livestock biomass in kilograms/hectare cultivated land), 2000.

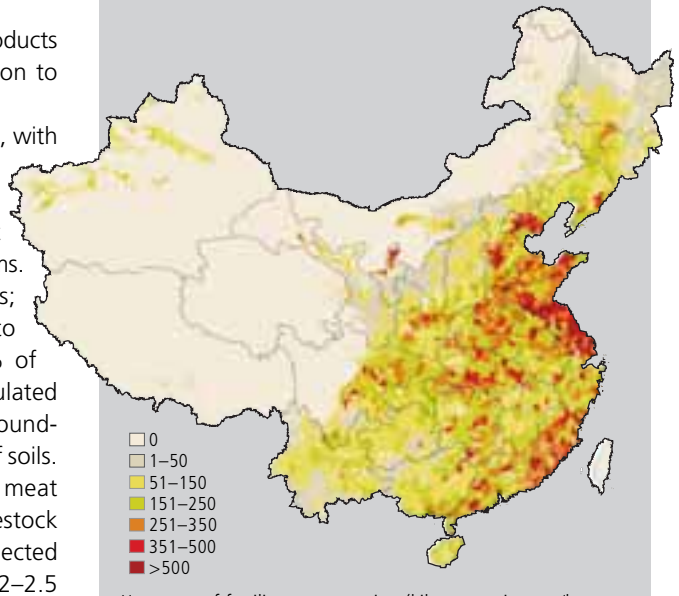
Intensive livestock farming

Over the past 20 years, China's demand for and production of livestock products has not only increased remarkably but has also changed in composition to satisfy demand for higher-quality, lower-fat products.

China has one of the highest densities of pigs and poultry in the world, with 335 million pigs and 2.7 billion fowl kept in 130 million and 144 million smallholdings, respectively, according to the 1997 National Agricultural Census of China. In 2000 traditional backyard systems accounted for about 60% of pork production, and 40% of this came from intensive systems.

Livestock production will need to grow further to meet rising demands; but growth will bring about a shift from traditional smallholdings to specialized farms and intensive large-scale bio-industry. About 80% of industrial and specialized livestock farms are located in densely populated areas and around major cities, which is causing severe pollution of ground- and surface water—and therefore drinking water—and contamination of soils.

The results obtained in CHINAGRO clearly show that increasing meat demand can be met only through a rapid introduction of intensive livestock systems. Between 2000 and 2030, pig stocks in intensive systems are expected to increase 3–3.5 times, broiling fowl 4.5–5 times, and laying fowl 2–2.5 times. With demographic changes and urbanization, backyard systems will strongly decline as a percentage of the total and decrease in absolute terms.



Hot spots of fertilizer consumption (kilograms nitrogen/hectare cultivated land), 2000.

The number of pastoral livestock will grow much less than that of confined livestock, by around 10%. Total livestock (measured in total live weight biomass) is projected to increase by about 30% during the period 2000–2030: this projection includes the counterbalancing effects of the expected 40–50% reduction in large animals used for work and transportation in traditional smallholder systems.

Environmental and health risks

The locations and methods of expanding livestock production chosen will determine both the vulnerability of socioeconomic and environmental systems to disease risk and the environmental impacts of nutrient burden from concentrated pig and poultry systems.

Problems of environmental pollution and soil loads from intensive livestock production are magnified by the concurrent increase in chemical fertilizer use. China is the world's largest consumer of fertilizers, accounting for about one-quarter of total world consumption. Our study estimates that China's future fertilizer requirements will increase from 35 million tons in 2000 to 42 and 46 million tons in 2015 and 2030, respectively.

The current estimated total amount of manure produced by confined livestock annually is around 1.4 billion tons (approximately 10.3 tons per hectare of cultivated land in 2000) and is anticipated to increase to 1.9 billion tons (15.3 tons per hectare) in 2030. The total amount of manure-related nutrients from confined animals thus increases from 19 million tons in 2000 to about 29 million tons in 2030.

Projected increases in confined livestock coincide with a decrease in the amount of cultivated land available for nutrient recycling, which inevitably leads to a considerable increase in nutrient supply in manure per hectare of cultivated land. For the central scenario, in the period 2000–2030 total amounts of nitrogen (N), phosphate, and potassium increase between 40% and 50%, and by 53–67% in terms of average nutrients per hectare of cultivated land.

Detailed nutrient supply and uptake calculations show that N uptake by crop and fruit production in 2000 amounted on average to 110 kilograms (kg) N per hectare of cultivated and orchard land. The provincial averages vary from 50 kg N per hectare (e.g., in the southwest) up to 200 kg N per hectare (e.g., in the province of Jiangsu). We estimate that crop production in 2000 took up 16 million tons of N, compared with a supply of about 24.5 million tons from chemical fertilizer use and 8 million tons from manure. Hence, the N released to the environment amounts to about 20 kg N per hectare of total land. For Jiangsu, Zhejiang, Henan, and Hubei, this value is well over 100 kg N per hectare, implying very substantial pressure on soils, watercourses, and the atmosphere.

The assessment of current and future environmental nutrient loads highlights the importance of policy measures such as (i) establishing systems to monitor the environmental impacts of excess nutrients, (ii) introducing effective economic and legal policies to encourage farmers to reduce livestock pollution, (iii) improving technology and management of nutrient application to cropland, and (iv) allocating livestock production to large livestock feed production areas with substantial untapped capacity for nutrient recycling in cropland and low livestock densities.

Without adequate measures—technological, financial, and legislative—to handle existing and looming environmental problems, hot spots of nutrient losses may suffer irreversible environmental consequences, especially in densely populated areas where further intensification of livestock and crop production may increase human health risks. ■

1. CHINAGRO is a multidisciplinary and collaborative effort involving IIASA'S Land Use Change Program, the Institute of Geographical Sciences and Natural Resources Research of the Chinese Academy of Sciences, the Chinese Agricultural University, and the Centre for World Food Studies of the Free University of Amsterdam.

Further information CHINAGRO at www.iiasa.ac.at/Research/LUC/chinagro.html

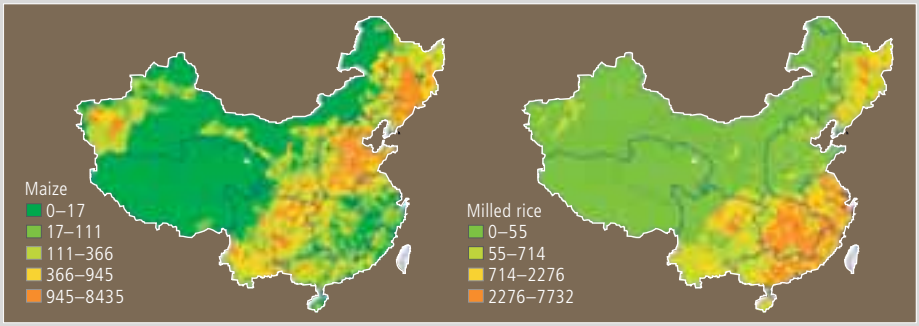
Dipl Ing Günther Fischer is the leader of IIASA's Land Use Change Program.

How we forecast the future of China's agriculture

The central tool to support policy analysis in the CHINAGRO project is a multiregional applied general equilibrium model including a detailed representation of the Chinese agricultural sector. The broader context of agricultural development and crucial external factors are summarized in a harmonized set of assumptions, presented in the form of scenarios covering plausible future trends of all important environmental, social, economic, and political processes.

CHINAGRO conducts its analysis within a modeling framework that (i) represents regional consumer, producer, and government decisions, with farmers represented at the county level; (ii) builds the supply response on a spatially explicit assessment of the resource base and its biophysical characteristics; (iii) describes agricultural processing and supply of farm inputs; and (iv) accounts for transportation costs in the economy.

The model provides a representation of different social agents in different regions, their income levels, preferences, resource constraints, and certain environmental implications of their activities. It covers interactions on regional markets between supply, demand, and prices, both in the absence of and in response to policy changes, while allowing for interregional as well as international trade.



Projections for China's production of maize and rice in 2030 (volume per total hectare).

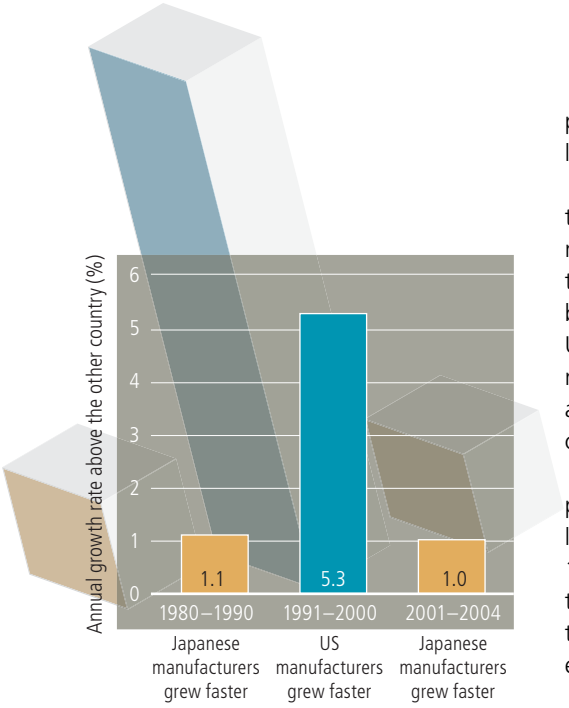
The CHINAGRO project is distinctive in that it acknowledges the enormous spatial and social diversity of the country by carrying out a county-level analysis based on over 2,400 administrative units. There is tremendous variation throughout China in terms of population densities, lifestyles, crop-growing conditions, and cropping patterns and yields. As distances are great, any policy change will affect consumers and producers very differently, depending on their location.

The CHINAGRO project is among the first to apply welfare analysis in a context with strong biophysical linkages and great spatial detail. The model divides China into 8 economic regions comprising some 2,400 county-level administrative units, distinguishing 17 commodities (16 agricultural, 1 nonagricultural) and 6 socioeconomic classes (3 rural, 3 urban). For each commodity, the model has regional markets connected to the international market. Consumer preferences, geographical distribution of supply, and costs of trade and transportation jointly determine the resulting endogenous trade flows. Nonagricultural production and urban consumption are modeled at the level of the 8 economic regions. The economy is opened up to the rest of the world, so that import and export can occur endogenously. Trade between regions and the international market is modeled bilaterally. Model simulations cover the period 1997–2030. ■

Made in Japan

Japan's economic revival

Having struggled to remain competitive in the 1990s, Japan's manufacturing industry is catching up with the United States by developing new production technologies and its approach to customers



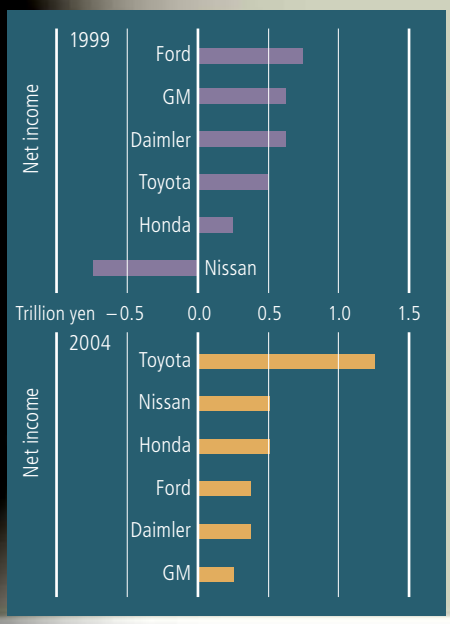
Certain Japanese manufacturers have regained the performance advantage they had over the United States during the 1980s.
Source: Watanabe & Fukuda (2005)

Some of Japan's manufacturing sector has regained its competitive advantage over the United States, argues Professor Chihiro Watanabe of IIASA and the Tokyo Institute of Technology. With manufacturing contributing over 20% to Japan's gross domestic product (GDP), this sector's recovery is playing a vital role in reviving the world's second-largest economy.

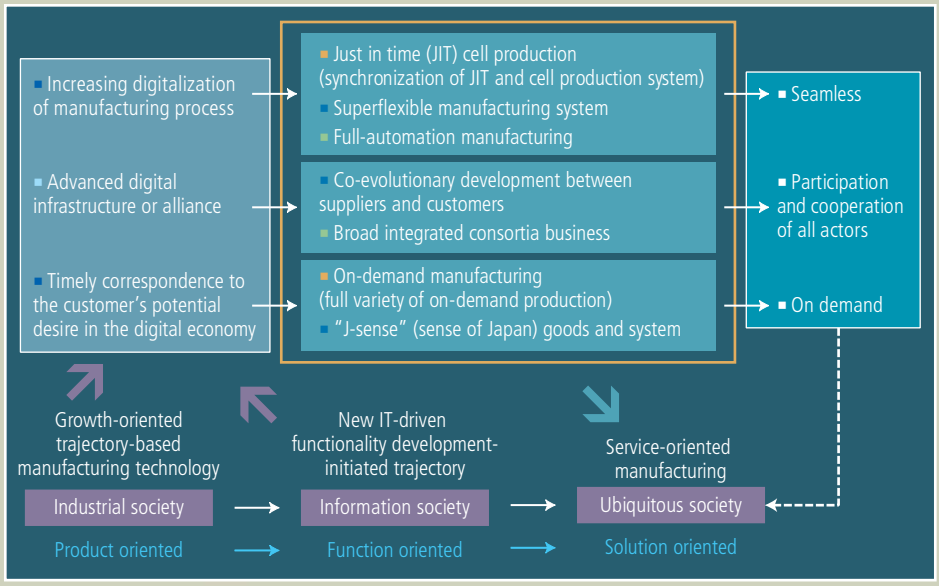
Watanabe and Kayano Fukuda of the Japan Science and Technology Agency compared the relative growth rates and relative production levels of the US and Japanese manufacturing sectors since 1980 (chart, *left*). Not surprisingly, their analysis showed that Japan's manufacturers grew faster than their US counterparts during the Japanese boom years of the 1980s. This trend was dramatically reversed during the 1990s, when US manufacturers successfully took advantage of information technology (IT) to become more competitive as Japan's economy stagnated. However, the researchers' regression analysis reveals that Japanese manufacturers have since regained a performance advantage over the United States similar to that of the 1980s.

Looking for further evidence of this reversal of fortunes, the researchers compared the performance of three leading US car manufacturers with that of three Japanese automotive leaders. The firms' respective sales and market values remained almost the same between 1999 and 2004, but the net incomes of the Japanese car giants noticeably overtook those of the American ones during that period (chart, *top left*). Watanabe argues that this increase demonstrates that these Japanese manufacturers are producing cars more efficiently, which is a sign that Japan is becoming more competitive.

Finally, the researchers highlight that the United States is concerned about losing its competitive advantage. The US Council on Competitiveness and the AeA (formerly the American Electronics Association) both fear strong competition, not only from China and India, which have learned directly from the United States by its investment and outsourcing, but also from Japan, which has built on its strong manufacturing technology base from the 1980s and learned from the United States' success in the 1990s.



Three leading Japanese automobile manufacturers overtook their US counterparts between 1999 and 2004 in terms of net income.
Source: Japanese newspaper *Nihon Keizai Shimbun* (15 April 2005)



Swell of Japan's new innovation: Developments that are making Japanese manufacturers more competitive.
Source: Watanabe & Fukuda (2005)

How have Japanese manufacturers been catching up with their US competitors?

By becoming more efficient, some Japanese manufacturers have been catching up with their US competitors. For example, since 1998, Canon, a Japanese manufacturer of digital cameras, copiers, and printers, has transformed its approach to production by replacing its conveyor belt assembly lines with small teams of workers who assemble a product from start to finish. Through their knowledge and ingenuity, these teams, known as cells, not only are highly productive but also allow Canon to manufacture only as many units as are needed.

This "just in time" (JIT) cell production is only one development that marks a swell of new innovation that is driving the sector forward (chart, *top right*). Canon's new production technique builds on the traditional areas of innovation that saw Japanese manufacturers use technology to increase productivity and save energy in the 1980s. Today, various Japanese manufacturers are using a range of new production methods, such as digitalization, JIT cell production, superflexible manufacturing, and full-automation manufacturing.

They are also learning from the United States' success in the 1990s, when it used IT to boost the productivity of its manufacturing sector and to accelerate the development of new products that more closely met the needs of its customers. During this decade, despite far higher investment in research and development (R&D) relative to GDP by Japan, the United States consistently outperformed Japan in terms of total factor productivity, or the amount of output generated by labor, capital, and other factors used in its production. Watanabe and Fukuda argue that this was because the culture of US institutions encouraged closer cooperation among manufacturers, their suppliers, and their customers to jointly use IT to build products that more closely met the customers' needs.

This approach has been successfully adopted by certain Japanese firms. For instance, NTT DoCoMo, the Japanese mobile phone company, foresaw customer demand for mobile phones that could be used for activities besides talking. The company introduced its "i-mode" service in 1999, when the mobile phone market was becoming saturated in Japan. Since then, it has successively developed new functions for its customers, such as e-mail, online shopping and banking, ticket reservations, and restaurant advice, and in doing so has attracted over 44 million subscribers.

Developing new functions is typical among the most successful Japanese manufacturers. This progress often comes from applying the companies' existing technologies to new fields. This spillover of technology within companies is helping the fortunes of Sharp, the Japanese electronics manufacturer.

Sharp has made liquid crystal since the 1970s for products from the desk calculator to the personal computer. Since the 1990s, it has also manufactured flash memory and image sensors for digital cameras. Today, Sharp is merging these technologies in new products such as game machines, car navigation systems, and personal digital assistants (PDAs). Such combinations also maximize the corporation's return on its R&D investments.

Innovation that improves manufacturing technology and results in new product functions or provides better service is helping a number of Japanese manufacturers to catch up with their US counterparts. A revival in this sector, which has been the basis of the Japanese economy since the 1960s, signals a positive outlook for the entire economy. ■

Further information Watanabe C & Fukuda K (2005). National innovation ecosystems: The similarity and disparity of Japan–US technology policy systems toward a service-oriented economy. IIASA Interim Report IR-05-057. Available at www.iiasa.ac.at/Publications/Documents/IR-05-057.pdf.

Professor Chihiro Watanabe is the senior advisor to the director on technology at IIASA and a professor at the Department of Industrial Engineering and Management at the Tokyo Institute of Technology. **Kayano Fukuda** is associate fellow at the Center for Research and Development Strategy, Japan Science and Technology Agency.

India's window of opportunity

The next 25 years offer India a demographic bonus: a soaring working-age population without a dramatic increase in the number of elderly

India will soon surpass China as the world's most populous country. IIASA's population projections suggest that India's population will further increase from today's 1.0 billion to around 1.4 billion by 2050. The size of this expected further population increase is more than the entire population of the United States today or that of the European Union before its recent expansion.

This significant growth is forecast even with declining fertility rates in India. In the 1960s, Indian women had almost six children on average; today this rate has fallen to three children, and further decline is expected. However, India has such a young age structure, with large numbers of women entering reproductive age, that its population will continue to climb.

Simultaneously with this rapid growth, India will also experience rapid population aging. Increasing life expectancy and falling fertility will result in an almost threefold increase in the proportion above age 65 by the middle of the century.

But there still is a window of about two decades in which the proportion of children (below age 15) will fall from today's 34% to 23% and the proportion of elderly (above age 65) will increase only moderately, from 5% to 7%. This temporary decline in the total dependency ratio, which presents a great opportunity for economic growth, has been labeled the "demographic bonus" or the "demographic window of opportunity," which all countries undergoing demographic modernization experience for a limited number of years.

It has been shown that this demographic bonus contributed significantly to the unusually high economic growth of the Asian tiger economies and is also behind the current phenomenal growth in China.

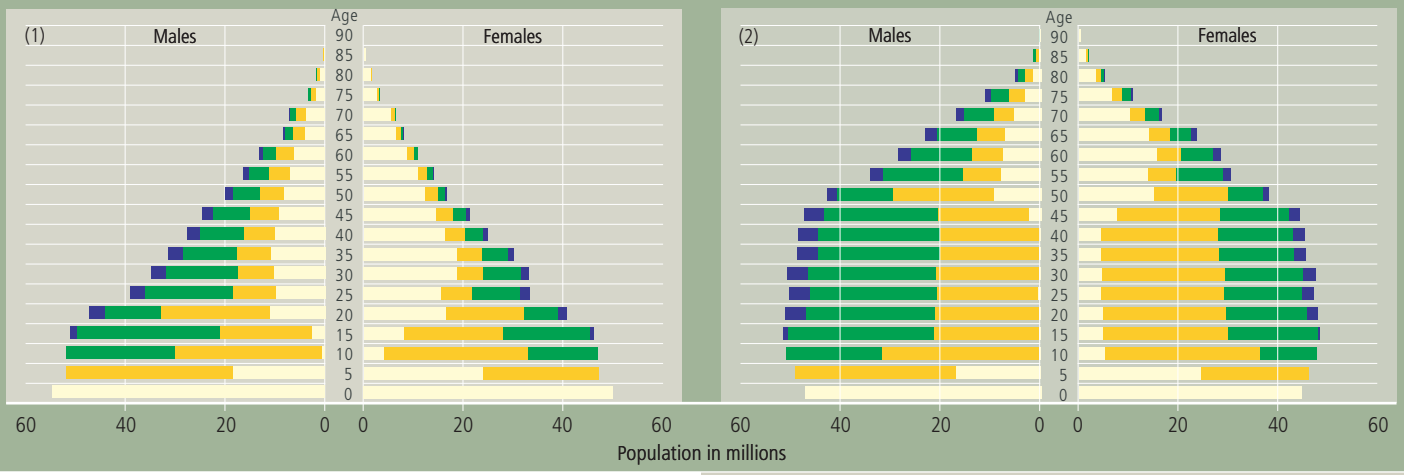
Will India profit from its demographic window as the Asian tigers and China have?

Whether India reaps all the benefits from this demographic bonus depends on the country's investments in human capital formation. Human capital is defined here as the population (by age and sex) weighted by its health status and in particular by its level of educational attainment. In terms of education of the general population, India today lags well behind China.

The first pyramid below shows that large segments of the adult population of India are still without any formal education. This is true for about half the working-age population, with many more women than men without education.

However, the pyramid also reveals that recent education efforts have resulted in higher education levels for the younger cohorts and a gradual shrinking of the gender gap. The population pyramid also illustrates that the group of highly educated Indians so visible

Age and education pyramids for India (1) Distribution of education in 2000 by age and sex; (2) education levels in 2030 if enrollment rates remain at today's levels; (3) education levels in 2030 if school enrollment rates reach those of the United States today.

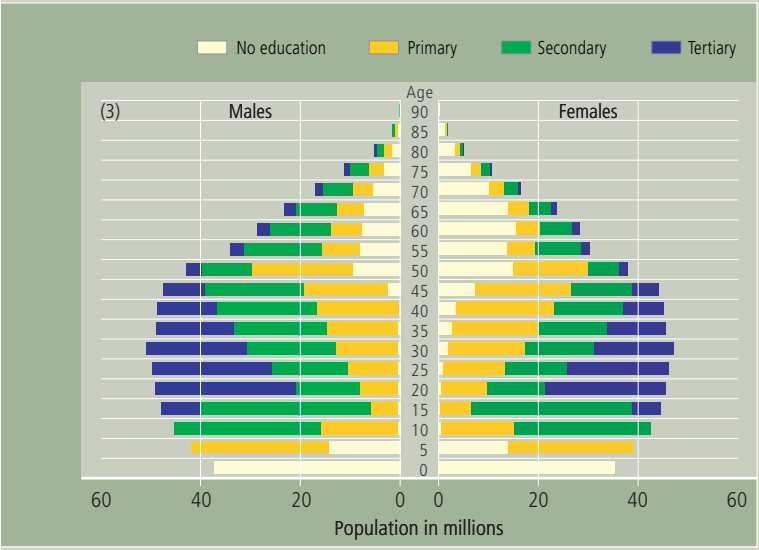


in the field of information technology is only a tiny minority of the total population. However, this group is still large in absolute numbers because of the huge size of India's population.

The years of demographic bonus until around 2025 will give India the opportunity to further invest in the education and health of all segments of its population. The future human capital of India will greatly depend on such investments. Pyramids 2 and 3 give two alternative population projections by level of education in 2030.

In the first scenario, educational enrollment rates at all levels of education are kept constant at their current levels. As a result of the replacement over time of less-educated older cohorts by better-educated younger cohorts, the average educational attainment of the adult population will still increase substantially compared with today's level. Despite these improvements, India's human capital will fall significantly behind that of China and other developing nations that continue to invest heavily in education.

Pyramid 3 illustrates the consequences of another, extremely optimistic, scenario in which school enrollment rates by 2030 reach those of the United States today. Here, the gender gap completely disappears for the youngest cohorts, and universal primary and very high levels of secondary and tertiary education are achieved for the population below age 30 by 2030.



For the older segments of the population, particularly those above age 50, these huge educational investments will not have much direct effect on their human capital. Nonetheless, these people are still expected to benefit from the general positive societal consequences of such developments. This scenario describes a future with high levels of social development as well as an internationally highly competitive work force that, with the right macroeconomic policies in place, could result in spectacular economic growth over the coming decades.

Slowing population growth

Strong investments in education, particularly for women, is likely to slow India's population growth. Women with higher levels of education have lower fertility rates than less-educated women. In India today, women without formal education have on average 3.8 children, while women with some tertiary education have fewer than 2.0.

Although fertility is likely to decline for all educational groups, the differential by level of education is also likely to continue in the future. Hence, the uncertainty about the future educational composition of the population, which depends on future education policies, also directly translates into uncertainty concerning future average fertility levels and, consequently, the future population size of the whole country.

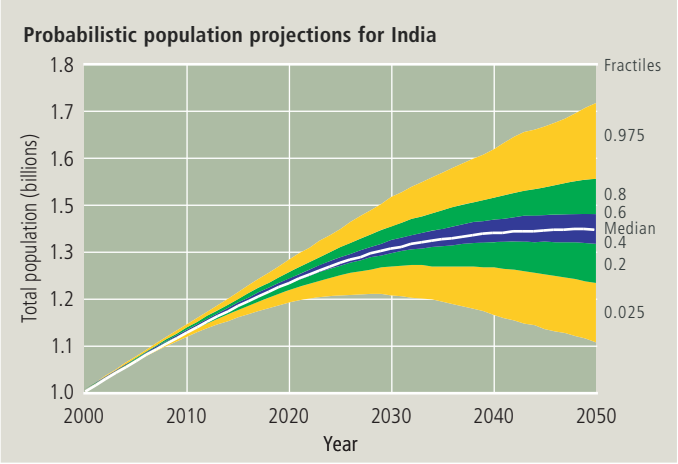
Population forecasts in an uncertain world

Wolfgang Lutz and Sergei Scherbov were the first to take this uncertainty about future education trends into account when forecasting India's population. Their work, on which this article is based, was published in a special issue of the *International Statistical Review.* The graph below forecasts the probable population for India, taking this and other uncertainties such as future mortality and migration into account.

This graph clearly shows that significant further population growth to more than 1.2 billion by 2020 is a near certainty for India. However, after 2025 the uncertainty range opens up noticeably, and by 2050 the 95% range goes from just slightly above 1.1 billion at the low end to 1.7 billion at the high end. Where India falls within this range will be partly influenced by its future investments in human capital formation. ■

Further information Lutz W & Scherbov S (2004). Probabilistic population projections for India with explicit consideration of the education–fertility link. *International Statistical Review* 72(1): 81–92. Reprints available from Marilyn Brandl at brandl@iiasa.ac.at.

Professor Wolfgang Lutz is the leader of IIASA's World Population Program. **Dr Sergei Scherbov** is a senior research scholar in IIASA's World Population Program.



DISASTER ASSISTANCE

Too Little Too Late?

At first sight, the balance sheet of the 2004 tsunami looks hopeful: 10 billion euros in damaged property and infrastructure—US$11 million in pledged or granted international humanitarian aid and donations.

Post-disaster assistance, however, continues to raise troubling questions. Could funds invested before the tsunami in an early warning system and other preventive measures have mitigated the human and economic tragedy in the Indian Ocean? Will post-disaster aid encourage people to rebuild in the same risky locations? Is assistance reaching the most needy and vulnerable in a timely and respectful manner? Will actual disbursements fall short of pledges?

Disaster aid is often too little, too late. In the first 60 days after the 2004 tsunami, even with a massive relief effort, just 60% of families in India and Sri Lanka reported receiving timely and adequate aid. More worrying, however, is that the prospect of disaster assistance discourages governments and individuals from taking advantage of the high returns on preventive action.

Developing countries are the most affected by disaster. Research for the 1980–2004 period shows fatalities per event to be higher in low- and middle-income countries compared with high-income countries and losses as a percentage of gross national income (GNI) also to be highly negatively correlated with per capita income (chart). Pre-disaster assistance, when coupled with measures to reduce human and economic losses, will not only mitigate a human and material catastrophe but also provide secure funds for reconstruction.

Three examples demonstrate the potential for donor-supported risk-transfer programs in developing countries:

Public–private insurance systems Only 1% and 3% of households and businesses in low- and middle-income countries, respectively, have catastrophe insurance coverage, compared with 30% in high-income countries. This is understandable since disaster insurance premiums are rarely affordable for low-income households and businesses. Instead of insurance, they rely on family and public support, which is not always forthcoming for catastrophes that affect whole regions or countries at the same time. Without support, disasters exacerbate poverty as victims take out high-interest loans (or default on existing loans), sell assets and livestock, or engage in low-risk, low-yield farming to lessen exposure to extreme events.

The recently launched Turkish Catastrophe Insurance Pool (TCIP) is the first of its kind to offer affordable insurance, in this case for earthquakes, in a highly exposed developing country. The World Bank provides a part of the back-up capital for this system in the form of a contingent loan with highly favorable conditions. If the TCIP reinsured purely through the commercial market, the premiums would likely be significantly higher and out of reach for many apartment owners.

Donors could follow the example of the TCIP by providing back-up capital to public–private insurance systems in middle-income developing countries. Improving on the TCIP, they could couple their support with preventive measures, like retrofitting homes, schools, and other public

Photo: REUTERS/Pawel Kopczynski

An injured Indian girl drinks water in the western Indian city of Bhuj on 29 January 2001, following a massive earthquake that killed an estimated 15,000–20,000 people. Pre-disaster assistance could have lessened the human and material impacts of the catastrophe.

buildings, and by ensuring public acceptance through early involvement of stakeholders. (See article on page 9.)

Weather derivatives for farm communities
Public–private insurance systems are not feasible for less-developed countries, which lack the financial means to form viable national risk pools. Instruments are also emerging to address the needs of these countries, even for slower-onset disasters like droughts.

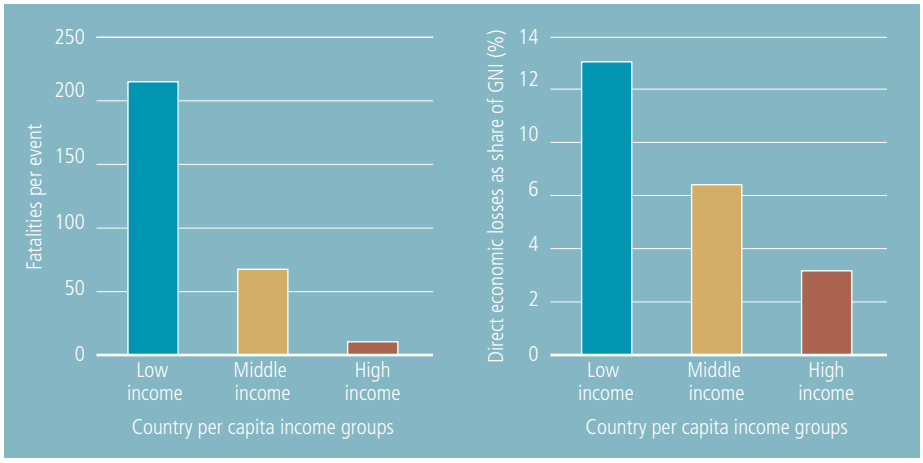
In India a number of pilot schemes provide low-cost weather derivatives to protect farmers against droughts, storms, and other extremes. Contracts are written against a physical trigger, say, severe rainfall shortages measured at a regional weather station. The contracts are sold by banks, farm cooperatives, or microfinance organizations. Since payouts are not coupled with individual loss experience, farmers have an incentive to engage in loss-reduction measures (e.g., switching to a more robust crop variant). A physical trigger also means that claims are not always fully correlated with losses, but this "basis risk" may be offset by the reduction of moral hazard and elimination of long and expensive claims settling.

In addition to providing technical support, the international donor community could make these schemes more affordable by subsidizing premiums and/or providing reinsurance for these schemes. For example, the World Food Programme is planning to subsidize weather derivative premiums in a pilot project in Ethiopia.

Risk-transfer instruments for governments
If governments lack sufficient post-disaster funds to repair critical infrastructure and assist victims, the follow-on indirect losses can be extensive. For example, five years after the devastation of Hurricane Mitch in 1998, the gross domestic product of Honduras was 6% below pre-disaster projections. Donor pledges of US$2.7 billion were considered exceptionally high but amounted to only about half the estimated reconstruction costs.

There are innovative prospects for governments of developing countries to ensure sufficient post-disaster funds for disaster relief and reconstruction. Mexican authorities, for example, are planning (with IIASA modeling assistance) to issue a catastrophe bond to reinsure their national catastrophe fund (FONDEN). A "cat bond" is an instrument whereby the investor receives an above-market return when a specific catastrophe does not occur in a specified time but sacrifices interest or part of the principal following an event. The government's disaster risk is thus transferred to international financial markets that have many times the capacity of the reinsurance market. Although Mexico, a middle-income developing country, will finance the bond from its own means, a similar, but donor-assisted, bond is an option for poorer countries.

In considering a catastrophe bond or other insurance instrument, countries like Mexico must compare the cost of risk transfer with that of relying on post-disaster funds from taxes, loans, or aid. IIASA has developed an interactive simulation model (CATSIM) that is helping government officials to assess their financing and loss-reduction strategies. This tool also has great potential for supporting donor organizations in allocating their scarce resources.



Disasters cause more fatalities and economic losses in low-income countries than in high-income nations.

The case for donor-assisted risk transfer

Why should the donor community support risk-transfer schemes for developing countries, given their high costs compared with post-disaster aid? For a start, pre-disaster support means that developing country governments will rely less on debt financing, and assured funds for repairing critical infrastructure will attract foreign investment. Pre-disaster donor support will provide poor households, farmers, and businesses with access to affordable means of spreading risks, which will secure their livelihoods and improve their creditworthiness. For many, an insurance contract is a more dignified way of coping with disasters than relying on (or begging for) the generosity of donors after a disaster strikes. Contractual arrangements might have reduced the despair of the 2004 tsunami victims, many of whom have expressed concerns about the dignity and cultural sensitivity of the relief supplies and the distribution process.

There are also compelling advantages for donors. By sharing responsibility with individuals and the state, donors leverage their limited budgets and substitute a calculable annual commitment to a risk-transfer system for the unpredictable granting of post-disaster aid. By making this assistance contingent on requirements or incentives for prevention as part of a comprehensive risk-management program, pre-disaster assistance can ultimately reduce the human and economic toll that disasters take on the poor. Switching to pre-disaster donor aid, even at extra cost, can thus be an efficient long-term strategy because of its potential to reduce the need for humanitarian assistance.

Recent initiatives to put risk-transfer programs into place are remarkable. Still, there are many challenges for implementing these programs on a large scale and ensuring that they genuinely provide affordable security to the poor. The science underlying the risk models must be viewed as reliable by insurers, investors, and donors. The avoidance of corrupt practices through good governance is another challenge, as is overcoming the reluctance of individuals and governments to invest in protection against low-probability disasters. Finally, these programs will depend on the political will of developed countries to provide the necessary support. ■

Further information Linnerooth-Bayer J, Mechler R & Pflug G (2005). Refocusing disaster aid. *Science* 309 (5737): 1044–1046. Available at www.sciencemag.org/sciext/disasters.

Dr Joanne Linnerooth-Bayer is the leader of IIASA's Risk, Modeling and Society Program. **Dr Reinhard Mechler** and **Dr Georg Pflug** are research scholars in IIASA's Risk, Modeling and Society Program.

RURAL CHINA

Changing energy demands

IIASA's Population and Climate Change (PCC) Program is currently investigating the different ways energy use may unfold in urban and rural settings in developing countries and how population shifts toward urban areas can affect overall trends. With households accounting for one-quarter of China's energy use, changes in the size, age, composition, and incomes of these households may have a dramatic impact on the nation's energy demand and greenhouse gas emissions.

Over the next few decades, global dominance in greenhouse gas emissions is expected to shift from the industrialized to the developing world, with large countries such as China, India, and Brazil becoming the principal emitters. In developing countries, past work in the energy and development field has identified a recurring pattern in rural areas. As incomes rise, an "energy transition" takes place where households relying primarily on biomass energy sources, such as fuelwood, crop residues, and dung, shift to more modern fuel sources, such as kerosene, natural gas, and electricity, as prosperity increases.

Although the *proportion* of household energy derived from biomass declines during the transition, changes in the *absolute amounts* of biomass used are unclear. If modern fuels are substituted for biomass fuels, biomass use would be expected to decline. If modern fuels are simply added to biomass, rising incomes could lead to increases in the use of all energy sources, including biomass. The form the transition takes will have important health and environmental consequences: a decline in household use of biomass fuels will ease ecological pressure and reduce health impacts, while increased use of all types of fuels could exacerbate problems.

A recent PCC study of China found that, since 1980, the share of energy from biomass in rural households has fallen. When the transition began during the 1980s, the per capita use of biomass increased (with the use of modern fuels increasing even faster). During the 1990s, the absolute amount of biomass use per person began to decline, driven almost exclusively by a reduction in fuelwood use, with crop residue use remaining constant.

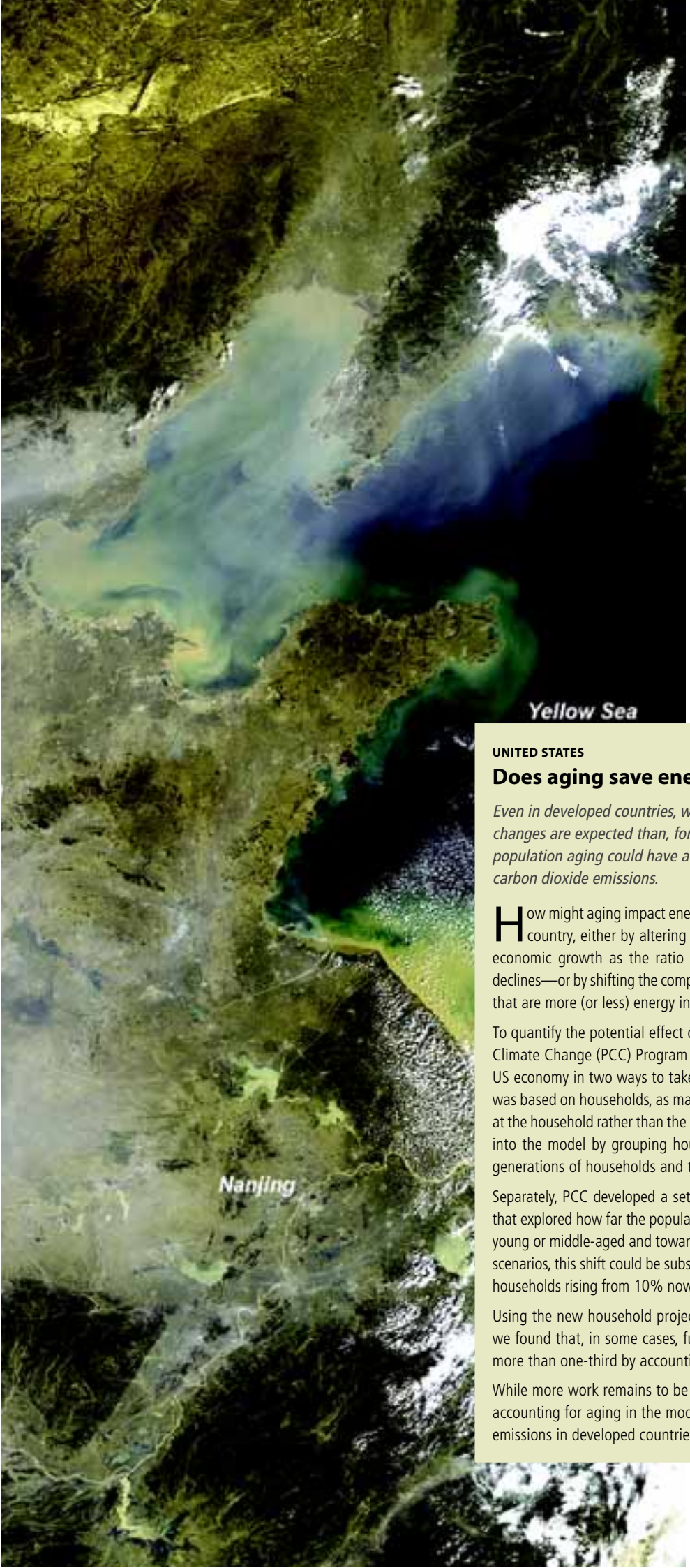
The transition is clearly associated with the general economic development process. But is rising income alone enough to explain the shift, or do other factors, such as changes in the size and composition of households, or changing access to different energy sources, also matter?

To gain a closer look at rural energy-use patterns, PCC supplemented its examination of national statistics in China with an analysis of a 1999 survey of 50,000 households. This was the first study to take a household-level approach using a nationally representative sample.

Several broad facts emerged immediately. Averaged across the country, biomass use, while falling, is still the dominant source of energy in rural areas, accounting for nearly three-quarters of total household energy use. While access to electricity is reported in 98% of households, it accounts for less than 5% of total energy use. Examination of the data separately for different regions shows sharp differences in energy patterns, probably based on resource availability. Coal-rich provinces such as Shanxi and Hebei show high coal use; rural areas in provinces with large urban populations such as Beijing and Shanghai (where electricity supply is likely to be of higher quality and lower cost) show relatively high electricity use.

Are the data consistent with typical conceptions of the energy transition? Statistical analysis of the dataset indicated that, as expected, income does appear to be an important determinant of household biomass use. However, only in the top 10% of households with, on average, three times the median rural income has biomass use begun to decline. Many other factors play a role, including

Photo: European Space Agency



An unfortunate side effect of economic success—China's economic boom is reflected in this haze of pollution, captured by ENVISAT over China in 2004.

geographic location, occupation and education level of the household head, and household size. Use of other fuels showed a similarly complex picture, with the importance of income being complemented by price effects, location, accessibility of various fuels, and household size.

PCC is currently carrying out a similar examination of urban energy-use patterns in China to see how future urbanization could affect total energy demand. Similar work has begun on India. The goal is to improve understanding of energy transitions and develop models able to include transitions in projections of future energy demand and greenhouse gas emissions. ■

Further information Jiang L & O'Neill BC (2004). The energy transition in rural China. *International Journal of Global Energy Issues* 21(1/2): 2–26. Available at www.iiasa.ac.at/Research/PCC/pubs/house

Dr Brian O'Neill is the leader of IIASA's Population and Climate Change Program. **Dr Leiwen Jiang** is an assistant professor at the Watson Institute for International Studies.

UNITED STATES

Does aging save energy?

Even in developed countries, where less dramatic demographic changes are expected than, for example, in China, the effects of population aging could have a significant impact on energy use and carbon dioxide emissions.

How might aging impact energy use and greenhouse gas emissions in a developed country, either by altering the scale of the economy—for example, by slowing economic growth as the ratio of people of working age to the total population declines—or by shifting the composition of consumption and production toward goods that are more (or less) energy intensive?

To quantify the potential effect of aging in the United States, IIASA's Population and Climate Change (PCC) Program modified an energy–economic growth model of the US economy in two ways to take demographic factors into account. First, the model was based on households, as many decisions about consumption and labor are made at the household rather than the individual level. Second, age structure was introduced into the model by grouping households into several different dynasties (particular generations of households and their descendants).

Separately, PCC developed a set of new household projections for the United States that explored how far the population might shift away from households headed by the young or middle-aged and toward those headed by the elderly. We found that in some scenarios, this shift could be substantial, with the percentage of people living in elderly households rising from 10% now to nearly 40% by the second half of the century.

Using the new household projections to drive the energy–economic growth model, we found that, in some cases, future carbon dioxide emissions could be reduced by more than one-third by accounting for age.

While more work remains to be done to test this result, clearly there is potential for accounting for aging in the models, as this could help shed light on energy use and emissions in developed countries. ■

RAPID URBANIZATION IN CHINA

City limits?

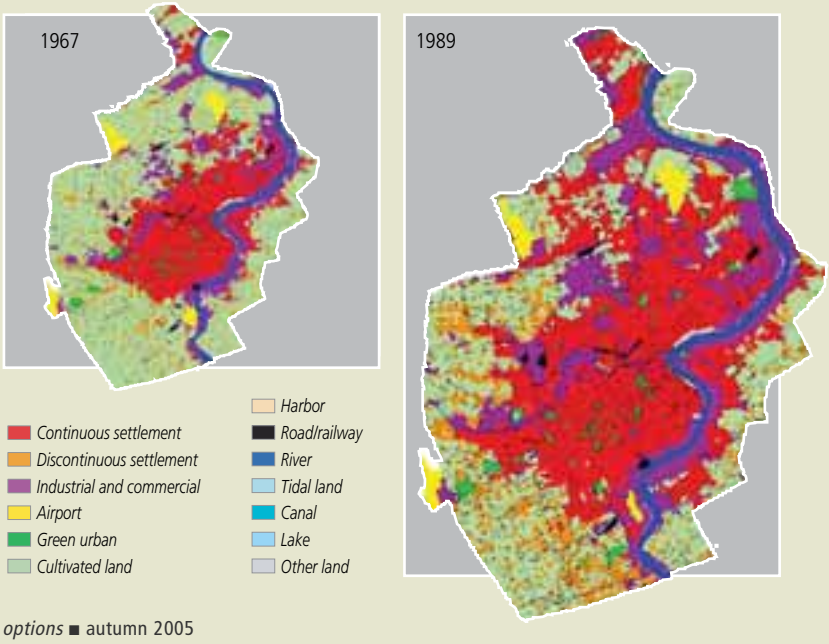
IIASA projections help policy makers

Last year, IIASA and the Institute of Population Research at Peking University in Beijing established a cooperative project on regional urbanization and human capital projections for China. This project not only will make an important contribution to IIASA research projects on land use, forestry, energy, population, and climate change, but will also assist policy makers as China prepares to meet enormous urbanization challenges over the next three decades.

Since the adoption of its "open door" policy in 1978, China has experienced rapid urbanization and dramatic economic growth, both of which have far-reaching implications for policy making in terms of industrial restructuring, social security, education, and sustainable economic and environmental strategies for towns and the countryside.

Really rapid urbanization began 20 years ago following a change in China's internal migration policy that allowed rural dwellers to seek jobs in the cities. The growing urban–rural income gap has forced millions of people from traditional agricultural societies into urban areas, increasing the land area used for urban development by 80.8%. Urbanization has also been driven by rapid economic growth averaging 9.2% per annum from 1978 to 2003; new social areas have emerged, including high-income suburban residential areas around Beijing, Shanghai, and Guangzhou, which are directly influencing urban expansion and consumption patterns.

Once a seaside fishing village, now the premier industrial city of China, Shanghai (below) is a magnet for job-seeking rural migrants. The city's population topped 20 million in 2003.



IIASA's urbanization projections for China trace the likely population movement in the next three decades, based on the trends of the past two decades. The medium scenario shows Chinese urbanization increasing from 36.1% in 2000 to 58% in 2030, mainly through net rural-to-urban migration. Though fertility is low in urban China, the urban population is set to double, with about 288 million rural inhabitants expected to move to urban regions in the next 30 years. Initial projections indicate around 24.9 million immigrants and an urban growth rate of 33.4% for Shanghai and around 8.5 million immigrants and a 80% urban growth rate for Beijing.

Though urbanization is recognized as the driving force behind much-needed economic restructuring, dynamic growth, and social development in China, such rapid urbanization will present major challenges on the demographic, environmental, and energy fronts in particular.

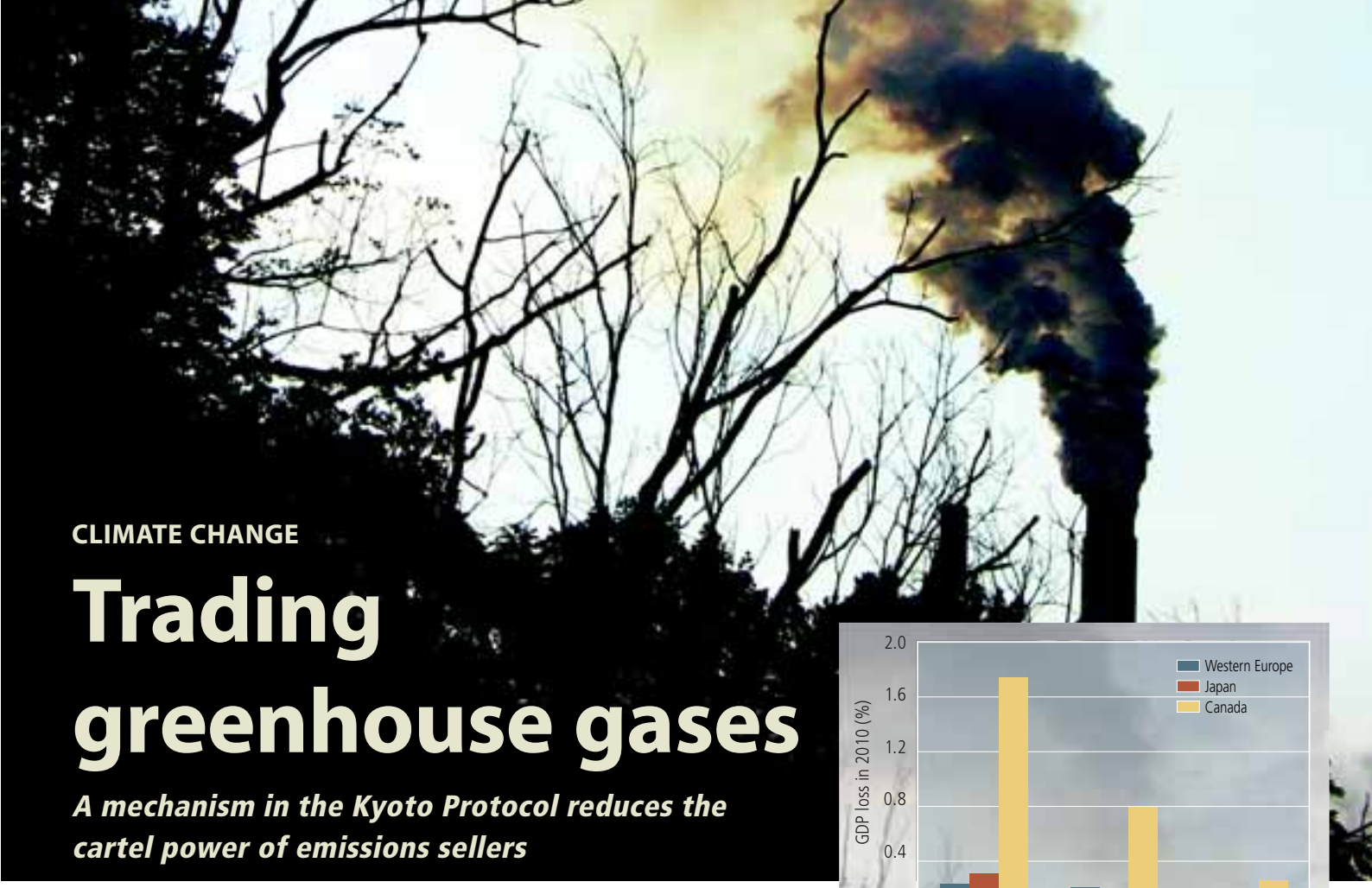
According to IIASA projections, the urban population will be younger than its rural counterpart, and the aging population will put strong pressure on the social security system. As China's social security system is largely urban based, the problem will be to address the needs of both rural migrant workers in the cities and the coming surge of rural elderly, with which current welfare systems are ill-equipped to cope.

The rapidly growing urban population will produce tremendous environmental effects, including a reduction in arable land, increasing demand for forest products, and changes in the ecology of the urban environment due to human activities. Urbanization, the expected large growth in per capita income, and the ongoing demographic transition will also cause major changes in the consumption and production of foodstuffs and forest products.

As far as energy is concerned, in 1995 average consumption per urban household was 3.65 units of commercial energy, compared with 1 unit per rural household. Decision makers will thus need to focus on developing environmentally compatible energy strategies and on increasing access to high-quality, less-polluting commercial energy if they are to meet escalating urban requirements. ■

Further information IIASA's Regional Urbanization and Human Capital Projections for China project. Contact Gui-Ying Cao at cao@iiasa.ac.at.

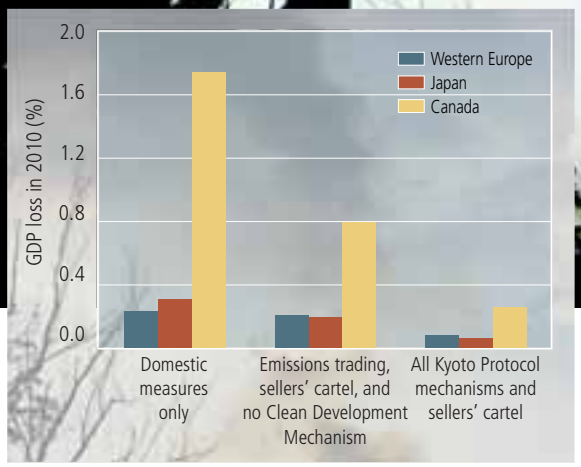
Dr Gui-Ying Cao is a research scholar in IIASA's Forestry Program.



CLIMATE CHANGE

Trading greenhouse gases

A mechanism in the Kyoto Protocol reduces the cartel power of emissions sellers



Mechanisms in the Kyoto Protocol lower the costs of reducing greenhouse gas emissions.

Recent research shows how safeguards in the Kyoto Protocol will protect countries like Japan and Canada from soaring costs, even if a cartel of emissions traders emerges.

Russia is expected to dominate the international trade for emissions allowances, the core flexibility mechanism of the Kyoto Protocol. This mechanism allows countries and companies within them to buy emissions allowances if they emit greenhouse gases over their agreed target and sell them when they emit less.

Russia can be expected to have a surplus of such allowances during the Protocol's first commitment period, 2008–2012. This surplus will arise because Russia's target was set equal to the country's greenhouse gas emissions in 1990. Since this base year, Russia's economic output has declined—as have its greenhouse gas emissions.

Today, Russia is still emitting comfortably below this level. It is rational for Russia to try to maximize its income from emissions trading by limiting permit sales on the global market in cartel-like behavior.

In a recent paper in the German *Quarterly Journal of Economic Research*, Leo Schrattenholzer and Gerhard Totschnig of IIASA explored the impact of Russian strategies for a number of different geopolitical scenarios and for a range of different patterns of permit trading within the Kyoto Protocol. For each of these scenarios, the researchers estimated compliance costs for various countries bound by the Protocol, including Japan and Canada.

One scenario examined the costs of complying with greenhouse gas constraints using purely domestic measures. In this extreme case, Japan would have a 0.31% lower gross domestic product (GDP) in 2010 because of its Kyoto commitments and Canada would have a much larger 1.75% loss (see chart).

Canada's costs are so high because its greenhouse gas emissions have grown so rapidly since the 1990 base year. By 2010, the researchers project these to have grown by 35%, compared with Japan's 21%. Japan's costs are further reduced because of its comparatively high allowances for using forests as carbon sinks to remove carbon from the atmosphere

A second scenario looked at the costs with full emissions trading and a sellers' cartel. Despite the cartel, the trading ensures that costs are significantly lower than in the first scenario, at 0.19% of GDP for Japan and 0.79% for Canada. This is because countries can now meet their targets by paying other countries to reduce emissions when doing so is cheaper than decreasing their own.

Emissions trading is not the only flexibility mechanism of the Kyoto Protocol. In addition, there is the Clean Development Mechanism (CDM), which allows Parties to the Protocol to achieve some of their reduction commitments through projects in countries that are not bound by it—generally developing countries.

As Schrattenholzer and Totschnig's results show, the additional trading opportunities provided by the CDM reduce the costs to Japan and Canada to small fractions of 1% of GDP, as seen in the figure above. This is because adding the CDM to the scenario reduces the market power of permit sellers. ■

Further information Schrattenholzer L & Totschnig G (2005). An analysis of alternative emission trading strategies of the parties to the Kyoto Protocol. *Vierteljahrshefte zur Wirtschaftsforschung* 74(2): 217–234. Available at www.diw.de/english/produkte/publikationen/vierteljahrshefte/index.html.

Dr Leo Schrattenholzer is the leader of IIASA's Environmentally Compatible Energy Strategies Program. **Dr Gerhard Totschnig** is a research scholar in IIASA's Environmentally Compatible Energy Strategies Program.

Human capital investment

A competitive edge for smaller states

A new IIASA Interim Report on projections of educational attainment for Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam, containing a regional perspective on human capital in Southeast Asia, will be published next year.

The Asian economies have recovered strongly from the series of financial crises that erupted in the region in mid-1997, and the Asian Development Bank is predicting percentage growth rates for gross domestic product in 2006 (2007) of 5.6 (5.4) for Southeast Asia, 6.1 (6.8) for India, and 8.7 (8.8) for the People's Republic of China.[1] Today, with greater competition from China and India in industries that rely on the export of labor-intensive, low-skill products, the smaller regional economies of Southeast Asia, such as Thailand, Malaysia, and Indonesia, are seeking areas of comparative advantage to ensure their own continued growth and prosperity. Indeed, the national development plans of countries in the region show just how strongly Southeast Asian governments believe in human capital as a driver of future growth.

Through its connections with the Asian MetaCentre, IIASA's World Population Program has been working with its partners in Southeast Asia to train demographers and statisticians from Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam to assess their countries' human capital potential for the coming decades by projecting their populations by level of education. These findings will form the basis of the forthcoming IIASA Interim Report.

The starting point was a series of training workshops held at the College of Population Studies of Chulalongkorn University, Bangkok, between 2001 and 2003 entitled "Past and Future Demographic Trends by Level of Education in the Countries of South-East Asia." The workshops were led by Sergei Scherbov of IIASA and the Vienna Institute of Demography, assisted by Anne Goujon and Wolfgang Lutz of IIASA, and attended by participants from the six countries.

The aim of the workshop was bidirectional: first, to teach the demographers and statisticians IIASA's technique of multi-state population projections by level of education to enable them to apply the methodology to their own country; and second, to derive a prospective picture for the region by comparing the different countries' experience and thereby feed information back to IIASA on the future of each country in education and human capital terms.

Participants implemented both the official population scenarios of their country and the development plan for education, extending the projection period to 2030 and keeping the assumptions more or less constant until 2050. The projections show very high levels of human capital in Singapore, Malaysia, and Philippines, which will clearly have economic and social advantages in the decades to come. It was found that more progress will be needed in Vietnam and Indonesia to bring the education level of the working-age population to the overall level of the region, with Thailand in an "in-between zone" but with rapid improvements already under way.

The research concluded that the Southeast Asia region seemed to have a clear human capital advantage over its two giant neighbors, China and India, especially in the availability of a relatively large population with tertiary education to boost the labor force in the coming decades. ■

1. Asian Development Bank (2005). Asian Development Outlook (Update). ADB, Manila, Philippines, September, p. 89.

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Asian MetaCentre

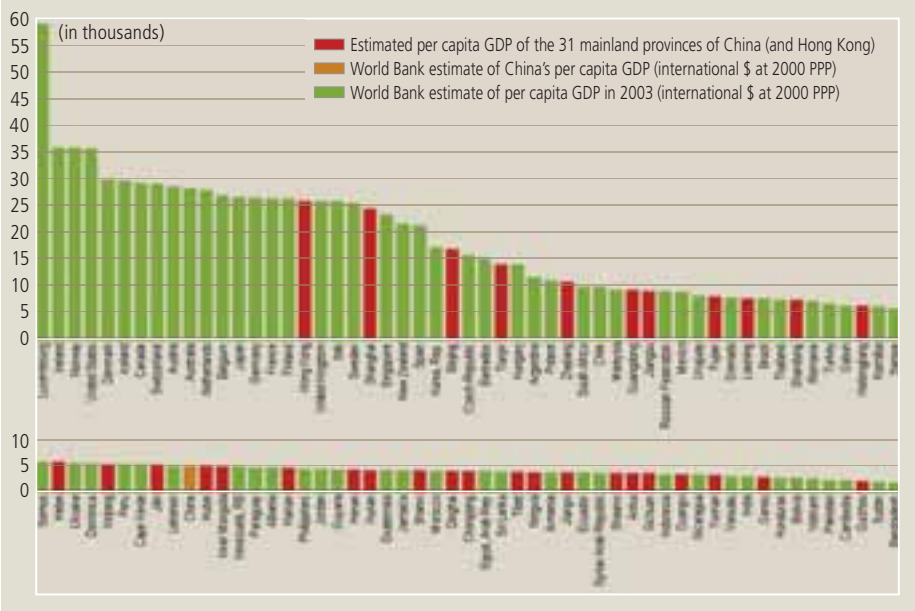
A major partner of the World Population Program of IIASA is the Asian MetaCentre for Population and Sustainable Development Analysis, with headquarters at the National University of Singapore (NUS) and cofounded in 2000 by IIASA, NUS, and the College of Population Studies of Chulalongkorn University, Thailand. Working to the three main themes of population, sustainable development, and health, the Asian MetaCentre fosters international cooperation and skills transfer among several research centers in Asia through online collaboration, workshops, training courses, and research projects.

Further information www.populationasia.org

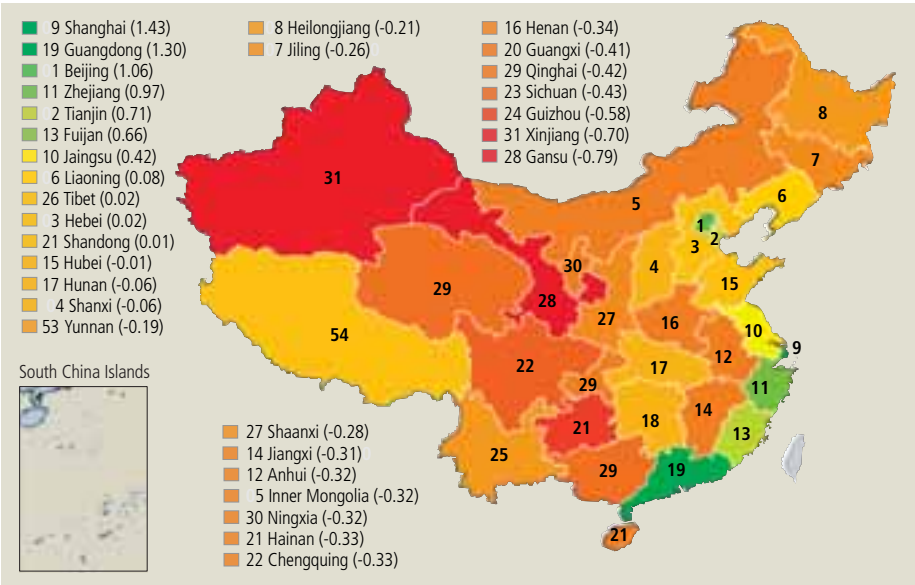
Demographers from across Asia work together to develop their skills and knowledge.

Many Chinas!

IIASA's Sustainable Rural Development (SRD) research activity has been analyzing China's astounding regional diversity



Per capita GDP in 2003 for 74 countries plus China's 31 provinces
For this figure, the World Bank per capita GDP estimate for China of $4,726 (in international dollars at 2000 purchasing power parity [PPP]) was divided among the 31 mainland provinces of China according to the 2003 regional per capita GDP published by the National Bureau of Statistics of China.
Sources: Based on data from the World Bank's World Development Indicators, 2005, and the *China Statistical Yearbook*, 2004, Table 3-11 (Gross Domestic Product by Region, 2003).



Results from the RAPS Regional Economic Development Index
Red areas represent low values in our Regional Economic Development Index; green areas represent high economic development. Index values are standardized with mean of 0 and a standard deviation of 1.
Sources: The map displays the Regional Economic Development Index from the RAPS-China tool, which was developed by the IIASA SRD research activity. Data are from various *Statistical Yearbooks*.

Everyone is impressed with China's breathtaking economic development. But not everyone realizes that the amazing economic growth is actually generated by a relatively small number of provinces and urban areas. China has 31 mainland provinces, but just five of them (Guangdong, Jiangsu, Shandong, Zhejiang, and Hebei) generated more than one-third of China's gross domestic product (GDP) in 2003, and fewer than half the provinces generated 71% of the total GDP. The remarkable regional disparities are even more apparent when we look at per capita GDP.

The top figure shows the World Bank estimates of per capita GDP for 74 countries. In addition, we have calculated per capita GDP estimates for the 31 mainland provinces of China, based on the World Bank national estimate. We found China's highest per capita GDP in Shanghai, at about $24,260 (in international dollars at 2000 purchasing power parity [PPP]) in 2003, which is comparable with the level of Sweden (with $25,271 PPP) and Singapore ($23,127 PPP). China's lowest per capita GDP was calculated for the province of Guizhou, with only $1,871 PPP per person per year in 2003. This is about the same level as in Cambodia ($1,963 PPP) or Sudan ($1,805 PPP). As these data clearly illustrate, there are huge regional discrepancies in China's economic development. While the most advanced provinces and urban areas are "playing in the same league" as some of the most advanced Western countries, less developed provinces are still at the economic level of poor African and Asian nations.

The bottom figure shows the results of our Regional Economic Development Index for China, which includes many other economic variables in addition to regional GDP. It also confirms the concentration of economic development in a few coastal areas. The IIASA Sustainable Rural Development research activity has been analyzing various dimensions of China's regional discrepancies, including environmental, political, and demographic disparities, but also discrepancies in infrastructure and availability of natural resources. SRD has also developed a Regional Analysis and Planning System (RAPS), which is a tool to analyze China's regional development. ■

Further information IIASA's Sustainable Rural Development research activity at www.iiasa.ac.at/Research/SRD

Dr Gerhard Heilig is the leader of IIASA's Sustainable Rural Development research activity.

How did we do this?

What goes up, must come down

Mathematics helps us to understand the world. By constructing and analyzing a mathematical model of a physical, biological, or social process with variables, parameters, and their relationships, we can manipulate the variables to see how the process would behave in different situations.

Mathematical models used to have only a handful of variables. Over 300 years ago, Sir Isaac Newton described gravity as a mathematical equation. This groundbreaking theory used four factors to explain why objects fall to the ground: the mass of the object and the Earth, the distance between them, and a gravitational constant:

Newton's Law of Gravity

$$F = G\frac{m_1 m_2}{r^2}$$

F = gravitational force between two objects
m_1 = mass of first object
m_2 = mass of second object
r = distance between the objects
G = universal constant of gravitation

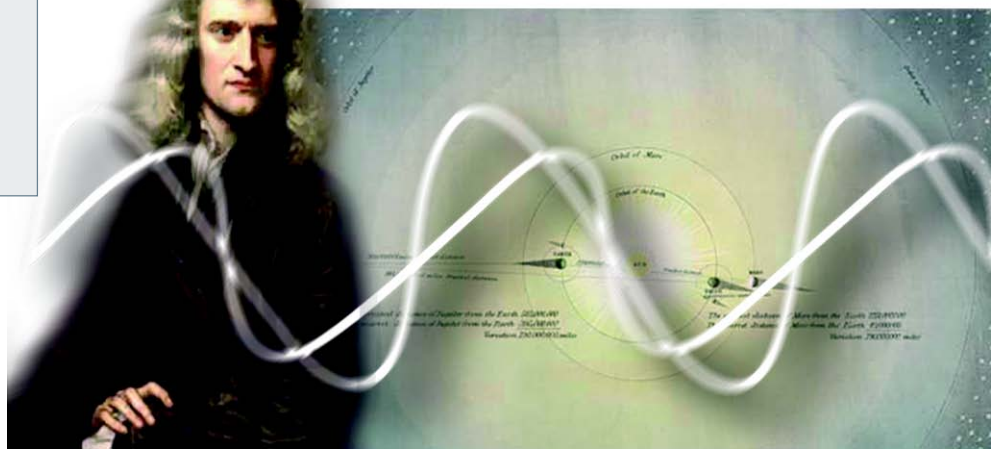
Thanks to Newton's findings and those of subsequent generations of scientists, today's scientists can model complex systems that involve even millions of interrelated aspects.

For example, what are the most cost-effective ways to control air pollution? Mastering such a complex problem requires an analysis of a huge variety of subjects, from industrial production to atmospheric chemistry to negotiations between countries.

However, the established modeling methods are often inadequate for many of IIASA's research areas. As part of the Institute's Risk, Modeling and Society (RMS) Program, researchers are developing methods and tools to fill this gap. This requires collaboration with leading researchers in diverse fields, including the Japan Advanced Institute of Science and Technology, Japan's Kyoto University, and Poland's National Institute of Telecommunications.

Today's models not only integrate many more subjects, but within each subject there exists a huge amount of accumulated knowledge. How can these models be built? What variables should be selected, and what is their interrelationship? The answers to these questions are not easy, and they depend on what the model's users want to achieve and the latest science in the relevant field.

Unlike with Newton's equation, often there is no single view on the relationship between a model's parts. For example, chemists know that nitrogen oxides and volatile organic compounds contribute to making ozone in the troposphere, but they define this relationship in several different ways.



Once the most appropriate relationship has been decided—normally through close cooperation between the modelers, the model users, and the pertinent scientific specialists—the modelers can move on to finding the most suitable mathematical representation of the relationship.

This is enormously complex. For example, the Institute's Regional Air Pollution INformation and Simulation (RAINS) model, which analyzes the most cost-effective way to control air pollution, examines over a million relations among over a million variables, all structured into six sub-models.

And with complexity come other issues for modelers. What computing resources are needed to analyze the model? What is the most efficient way to use computational grids? Is the model transparent and controllable enough to meet the strict requirements of policy users?

Finally, even when a reliable model has been established, its quality depends on the data it uses. If some of the data are missing or of suspect quality, the model will provide unsatisfactory results.

Before delivering the model, its developers must answer a crucial question: How do we know if the mathematical model describes the system well? There are diverse techniques for validating and testing the model. If the model passes the tests, then it can be assumed that the model represents the real system well.

It took over a hundred years for Newton's successors to accurately calculate his gravitational constant because they did not know the weight of the Earth. Fortunately, in today's world of sophisticated methodology, there are ways to improve the quality of limited data, but that is a topic for another article. ■

Today's mathematical models are enormously complex.

$$xBase_{ia} \le xs_{ipa} - \sum_{b \in Asrc_a} sr_{iba} * y_{iba} + \sum_{b \in Arec_a} y_{iab}, \quad i \in I,\ p \in P,\ a \in AIP_{ip}$$

This simple algebraic relation, which actually represents over 100,000 constraints, illustrates the complexity of the indexing structure used in models such as the Regional Air Pollution INformation and Simulation (RAINS) model.

Further information From January 2006, the modeling activities of RMS will expand into a new IIASA Project, Integrated Modeling Environment, led by **Dr Marek Makowski**.

WORLD-CLASS RESEARCH

IIASA scientists receive awards

IIASA Council Chair **Simon Levin** of the United States has received the 2005 Kyoto Prize in Basic Sciences for establishing the field of spatial ecology and expanding scientific understanding of the biosphere as a "complex adaptive system." The citation mentions Professor Levin's "use of mathematical models to understand the complex patterns of the biosphere," which has made "a substantial impact on environmental sciences and led to new methods of environmental protection."

Professor **Georgy Golitsyn** has been awarded the Alfred Wegener Medal by the European Geosciences Union (EGU) in recognition of his leadership in the atmospheric sciences over several decades and his distinguished contributions to geophysical fluid dynamics. Dr Golitsyn was chair of the IIASA Council from 1992 to 1997 and is a member of the Russian National Member Organization (the Committee for Systems Analysis of the Russian Academy of Sciences).

Dr **Markus Amann**, leader of the Transboundary Air Pollution Program and co-leader of the Greenhouse Gas Initiative of IIASA, is one of this year's recipients of the Congress Award of the International Union of Air Pollution Prevention and Environmental Protection Associations (IUAPP). Markus Amman's work was responsible for much of the success of the United Nations Convention on Long-range Transboundary Air Pollution and to the development of the Clean Air for Europe Programme. ■

CLIMATE CHANGE

IIASA briefs Europe's ministers

Günther Fischer, leader of IIASA's Land Use Change Program, briefed the European Union's agriculture and environment ministers on how climate change is likely to impact world agriculture during the 21st century.

The informal meeting was hosted and chaired by the UK Secretary of State for Environment, Food and Rural Affairs in September 2005 as part of the UK's Presidency of the European Union. It offered the European ministers a rare opportunity to meet on an agenda of common interest.

Fischer presented an integrated assessment of the problems facing European farmers and the global food system. His research indicates that developed countries overall will experience an increase in agricultural productivity as a result of climate change, with a large diversity of outcomes in Europe. In contrast, developing regions as a whole suffer a loss in all the future simulated scenarios. He concludes that climate change is likely to hamper development efforts to close the gap between developed and developing countries. ■

KOOPMANS LECTURE

Landscape dynamics explained

The 2005 lecture in the Tjalling Koopmans Distinguished Lecture Series was given by Professor **Ralph H. Abraham** of the Visual Math Institute, Santa Cruz, California. A mathematician and chaos theorist since 1958, Professor Abraham gave his lecture on "Landscape Dynamics: A New Agent Based Modeling Strategy for Financial Markets and Other Social Systems." ■

STOCHASTIC PROGRAMMING

IIASA pioneers honored

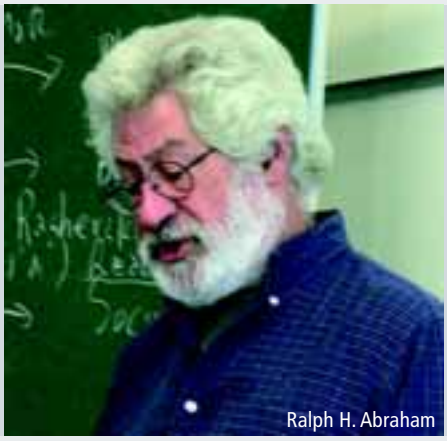
In a special session of the Tenth International Conference on Stochastic Programming, held in Tucson, Arizona, from 11 to 15 October 2004, 12 scholars, four with links to IIASA, were recognized by the Committee on Stochastic Programming (COSP) for their longstanding contributions to stochastic programming as we know it today.

Sadly, the conference was one of the last public appearances of Professor **George B. Dantzig**, a distinguished mathematician whose personality and work greatly impacted many scientists and research institutions, including IIASA. The father of linear programming, Dantzig set the direction of the methodological work at IIASA in 1973–1974, establishing the Methodology Project and, with it, the IIASA tradition of close collaboration between methodologists and those working on applied problems. Professor Dantzig died in April 2005.

Also honored was Dr **Yuri Ermoliev**, who first worked at IIASA in the System and Decision Sciences Program from 1979 to 1984, undertaking research in non-differentiable and stochastic optimization problems. In 1991 he joined the Social and Environmental Dimensions of Technology Project of IIASA to work on risk-related issues in the Risk, Uncertainty and Complexity Project. He is currently an Institute Scholar.

Two other honorees, Professor **Roger J.-B. Wets** of the University of California–Davis and Professor **Kurt Marti** of the Federal Armed Forces University, Munich, Germany, have worked or collaborated closely on a number of IIASA projects. ■


Simon Levin


Ralph H. Abraham


George B. Dantzig

iiasa news

ENGAGING THE DISENFRANCHISED

IIASA works with UNU-IAS

A joint report of the United Nations University's Institute of Advanced Studies (UNU-IAS) and IIASA, entitled *Promoting Enfranchisement: Toward Inclusion and Influence in Sustainable Development Governance*, was published last year. The report presents a research agenda for investigating the problems and questions surrounding the participation of delegates from developing nations and civil society actors—particularly those from the developing world—in international regimes for sustainable development. It discusses what it means for each of these groups to be disenfranchised, outlining the specific barriers that prevent effective engagement, and examines the specific challenges that the marginalization of these actors poses for sustainable development governance. ■

The full text can be downloaded from the IIASA Web site: www.iiasa.ac.at/docs/HOTP/Feb05/promoting_enfranchisement.pdf.

CLEAN AIR FOR EUROPE

IIASA delivers projections

The Transboundary Air Pollution Program of IIASA delivered its report, *A Final Set of Scenarios for the Clean Air for Europe (CAFE) Programme,* to the European Commission (EC) in June 2005. Contracted by the EC in 2002 to develop the baseline scenarios and integrated assessment modeling work for CAFE, the IIASA team used the Regional Air Pollution INformation and Simulation (RAINS) model, developed at IIASA, for its analysis.

The baseline projections of the CAFE Programme outline the effects of present legislation on the future development of emissions, air quality, and health and environmental impacts to the year 2020. The CAFE Programme aims to surpass the potential achievements of the current legislation to provide even greater safeguards for human health and the environment in Europe.

One advantage of this strategic action at the level of the European Union (EU) is its potential to produce a more rapid and pronounced reduction in member states' emissions of pollutants. It will also make it possible for the EU to put greater pressure on European countries outside the EU to reduce their emissions by taking a more active stance in the context of the United Nations Convention on Long-range Transboundary Air Pollution. ■

The full report is available at http://europa.eu.int/comm/environment/air/cafe/activities/pdf/cafe_scenario_report_6.pdf.

POPULATION PROJECTIONS

UNESCO adopts IIASA approach

At a meeting in Montreal in February 2005, UNESCO's Institute of Statistics took the decision to adopt IIASA's multi-state, population-based methodology for its work on forecasting literacy and educational attainment.

Multi-state methods were developed at IIASA in the 1970s and 1980s but did not spread beyond a relatively small number of methodologically sophisticated demographers. With other methods of measuring human capital stock having failed to provide the necessary information by age, sex, and level of educational attainment, the multi-state methodology is now increasingly being used by key international institutions to deal with the forecasting of population characteristics. In fact, as there is almost no limit to the behavioral and attitudinal questions to which this approach can be applied, it can add valuable new tools to the conventional toolkit of the social sciences. ■

IIASA's World Population Program at www.iiasa.ac.at/Research/POP

DISASTER REDUCTION

IIASA representatives at World Conference

IIASA's Risk, Modeling and Society (RMS) Program organized or presented no fewer than seven different conference sessions at the World Conference on Disaster Reduction held in Japan from 18 to 22 January 2005.

The aim of the conference, which symbolically took place in Kobe, the site of the great January 1997 earthquake, was to take stock of the progress in disaster risk reduction since the Yokohama Conference of 1994 and to make plans for the next 10 years.

Over 4,000 participants from more than 150 countries attended the conference, with Joanne Linnerooth-Bayer, leader of the RMS Program, and Reinhard Mechler, RMS research scholar, representing IIASA.

Conference topics included the financial management of disaster risk, the relationship between environmental management and disaster reduction, and a special session on the 2004 Indian Ocean tsunami. ■

More information is available at www.unisdr.org/wcdr/wcdr-index.htm.

Professor Sten Nilsson

IIASA's deputy director and leader of the Institute's Forestry Program

"Many times I feel like a forester with too many trees to manage and unable to see the forest," says hard-working Professor Sten Nilsson, who not only leads IIASA's Forestry Program but also works as the Institute's deputy director. "As with most people in similar positions, the most difficult part of my work is managing unplanned interruptions arising from urgent needs at the institute or program level that throw my planning overboard. The positive side of these interruptions is that my days are very different, and one day is never the same as the next."

Since leaving the army as an officer in 1967, the 61-year-old professor has studied forests worldwide, from Siberia to Bangladesh. This work has taken him around the globe many times, far from his native Sweden and his adopted home of Austria, where he has lived for almost 20 years.

Having authored and coauthored over 300 scientific publications, the Swedish academic is reticent about singling out one specific achievement during his career. "I think the most satisfying experience is the long string of correct policy identifications for many issues in the forest sector. Although these policy recommendations have not always been recognized at the time of release, they have eventually been put into practice," he points out.

Professor Nilsson recalls one example from North America in 1999. His research questioned whether the harvesting of trees in Canada and the United States was really sustainable. Together with North American experts, some from government forestry agencies who initially feared for their jobs, Nilsson criticized the governments for not correctly assessing what constituted a sustainable harvest. This brave approach worked: the governments ultimately ordered new assessments in line with the recommendations and promoted their outspoken employees.

Other innovative approaches to feeding the Forestry Program's research findings into policy, such as writing a "mock" governmental bill for Sweden (see article on page 10), are just some of the skills Professor Nilsson is teaching his multinational and multidisciplinary team of forest researchers. The Forestry Program currently has some 30 people involved from such wide-ranging countries as China, Canada, and Russia, and such widespread disciplines as economics, forest ecology, and mathematics.

"Among my main tasks are to develop the team's activity and help it produce sufficient quality outputs as well as to interact inside and outside the Institute," he says. His varied days also include securing additional funding for the Program, deputizing for IIASA Director Leen Hordijk, and developing a research agenda for his group of forest experts. Working with such a committed and hardworking team is one of the Swede's most fulfilling experiences. He has led this team in its various forms since 1986 and modestly refuses to take credit for creating it. "The team builds the team," he explains. ■

A day in the life of a program leader

6:30	Walk the dogs
9:00–10:00	Read and respond to emails
10:00–11:00	Management meeting of the Directorate
11:00–12:00	Meeting with one of the internal committees of the Institute
12:00–13:00	Lunch with colleagues
13:00–15:00	Meeting with forestry scientists to discuss their projects
15:00–17:00	Meeting with international visitors
17:30	Walk the dogs in Laxenburg's Schlosspark
18:00	Time for own work
20:00	Arrive at home
21:00	Read *The Financial Times* and *The Economist* and do some writing
23:00	Bed