Feeding the world: How much more rice do we need?

Vaclav Smil

The key question that underlies efforts to increase rice yields, to improve the crop's nutritional quality, and to cut its postharvest losses is how much more of the grain will we need to assure global adequacy of its supply? I will look just a generation (25 years) ahead, but, even then, a precise answer is impossible as well as unnecessary: what we need is a good approximation of where we are headed. Key determinants of future rice consumption are the rates of population growth, the process of population aging, the increased mechanization of labor, the need to improve inadequate diets, and the extent and pace of dietary transitions. The complex interplay of these factors will determine potential demand, the total that should give us a better appreciation of how high we should aim our efforts at future yield increases and agronomic improvement.

Population growth

The global population growth rate has been slowing ever since it peaked at just over 2.0% in 1967 (Fig. 1). As a result, consecutive long-range population forecasts issued by the United Nations have been repeatedly revised downward and the low variant in the forecast for 2025 is just 7.3 billion people, not even 20% above the 6.1 billion in 2000 (UN 2002). The medium variant is 7.8 billion and the high 8.3 billion, but the recent accelerated decline in fertility indicates that the most likely outcome will be closer to the low total and that virtually all of the net increase will take place in Africa, Asia, and Latin America.

The medium forecast of population growth in the world's ten most populous countries where rice is the staple grain and that consume about 85% of the world crop—Bangladesh, Brazil, China, Egypt, India, Indonesia, Myanmar, the Philippines, Thailand, and Vietnam—is for about a 26% increase from 2000 to 2025, an addition of just over 800 million people. Everything else being equal, demand for rice would rise by about 25% in 25 years compared with the 68% increase from 1975 to 2000. But everything else will not be equal. Rapidly aging populations will actually require less food per capita because of the natural decline in metabolic needs (unless we assume universal obesity), further mechanization of labor will eliminate most of the hard physical tasks that are still common in many countries, and rising incomes will improve average diets and change their composition.

Population aging and activity

The process of population aging will be pronounced not only in Europe and Japan but also in China (thanks to its one-child policy) and in many countries in Asia (Fig. 1). In the world's ten most populous rice-eating countries, the share of the popu-

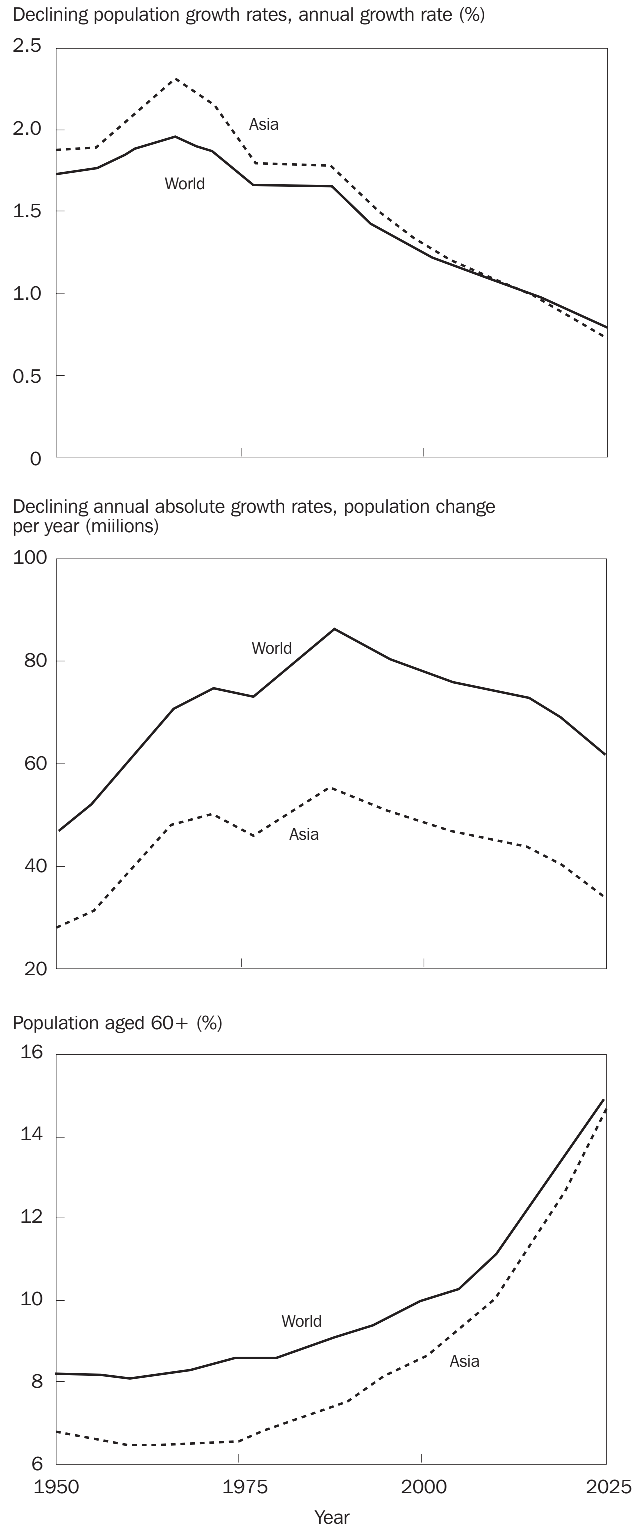

Fig. 1. Declining population growth rates and population aging: global and Asian trends, 1950-2025.

lation older than 60 years will increase by roughly 15% to about two-thirds, or nearly 600 million people, by 2025. Complexities of human metabolism preclude any accurate calculation of this aging effect (Smil 2000), but, assuming that, on average, people above age 60 consume 15–20% less food energy per day per capita than the mean for the adult population, then aging would reduce 2025 demand by no more than 2–3% compared to a population with a stationary age structure.

The continuing mechanization of agricultural and industrial tasks in modernizing countries may have a similar effect on overall food demand. Again, complexities of human metabolism make it impossible to make any accurate estimates, but, assuming an average difference of at least 10–15% between moderately and highly active population groups and a shift of 20–25% of today's labor force from more demanding tasks in agriculture and industry to mechanized manufacturing and services would lower overall food demand and hence presumably also rice consumption by 2–3% compared to the unchanged frequency of typical labor exertions. The combined effect of aging and mechanization could decrease the overall demand for rice by no more than 5% by 2025.

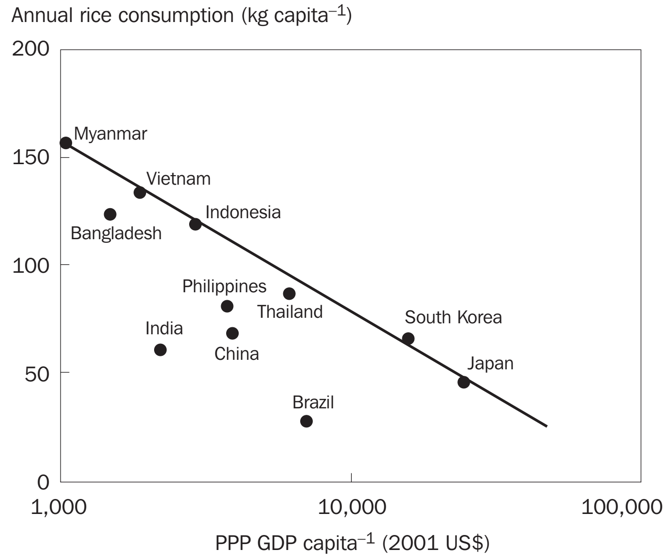

Fig. 2. Log-normal relationship between per capita GDP (PPP) and annual per capita rice consumption at the beginning of the 21st century.

Eliminating undernutrition

In spite of major gains during the last quarter of the 20th century, the FAO (Food and Agriculture Organization of the United Nations) estimated the total number of malnourished people at about 800 million during the late 1990s (FAO 2002). Nearly 60% of this total, or almost 480 million people, were in the world's ten most populous rice-eating countries. India had about 233 million undernourished people (almost 29% of the world total) and China 119 million (about 15%). Undernourished people thus added up to about 15% of the population in countries where rice is the staple cereal.

When assuming that, to eliminate these nutritional deficiencies, this disadvantaged segment of the population would have to increase its average food intake by 25%, the overall food supply in 2025 would have to rise by 3.75% above the level needed to provide larger populations merely with today's inadequate diets. An excellent confirmation of this additional amount comes from the FAO's estimates of the relative inadequacy of the food supply that was calculated for all of the world's countries for the early 1990s and that ranged for the rice-eating countries from roughly 1% in Brazil and Egypt to nearly 9% in Bangladesh (FAO 1996). The population-weighted mean of this relative inadequacy was almost exactly 4% for the ten countries and improvements during the 1990s would have reduced it by about 10%.

Dietary transitions

Predicting the course of dietary transitions is difficult because they can be greatly influenced by unexpected changes in a nation's economic course: post-Mao China is the best example of such unpredictable shifts. As gross domestic product (GDP), and with it average income, rises beyond subsistence levels, it may be accompanied by a temporary increase in demand for staple grain, followed by a prolonged decrease in consumption as more varied diets and higher shares of lipids (both plant oils and animal fats), meat, eggs, and dairy and aquatic products displace staple grains (Caballero and Popkin 2002). No other rice-eating country experienced such a precipitous decline in average intake as did post-World War II Japan: as annual per capita consumption dropped to less than 60 kg, rice ceased to be a staple food and became more of a luxury foodstuff (Chern et al 2003). The South Korean drop was also precipitous, from nearly 125 kg per capita in 1975 to about 85 kg in 2000, or more than 30% in 25 years.

Many country-specific scenarios of future dietary trends are thus possible, but there is no doubt about the general decline in average per capita rice consumption with rising economic performance. Every tripling of purchasing power parity-adjusted per capita GDP appears to be accompanied by a 50-kg decline in average annual per capita rice consumption (Fig. 2). Consequently, even when assuming a sluggish growth of average per capita GDPs in the world's ten most populous rice-eating countries—on the order of 1.5% per year, or less than half of the rate they achieved during the 1990s—a nearly 50% increase in that average would correspond to an annual per capita reduction of about 20 kg of milled rice. By 2025, this would translate into overall demand about 20% below the level that would result from unchanged dietary patterns.

Overall demand for rice

This is not a forecast, merely an exploration of key countervailing trends that point us in the most likely direction and that should be useful in guiding our decisions regarding future agronomic efforts. By 2025, population growth in the world's ten most populous rice-eating countries whose consumption dominates the global demand for rice will increase demand by about 25%; lower intakes because of aging and the physically less active population would reduce it by about 5%, and improvements in average diets needed to eliminate the existing undernutrition would boost it by about the same amount. The single largest factor determining the eventual outcome will be the extent and rapidity of dietary change and even very conservative assumptions point to a decline on the order of 20%.

This would leave us with the need to produce only about 5% more rice than we do now, or, bracketing the estimate by a factor of two, the range would be from no net increase at all to as much as a 10% higher output. Postharvest losses in the ten most populous rice-eating countries are on the order of 15% (Smil 2000) and cutting them in half during the next generation would only reinforce the conclusion that there may be no need for any net increase in rice production, or that the needed increase could be only a marginal addition of a few percent above the current level.

Even in the unlikely case that these estimates err on the low side by as much as 100%, it is obvious that, during the first quarter of the 21st century, we will need increases in global rice production that will not be even remotely comparable to those of the past 25 years. Consequently, our research and development should concentrate primarily on the maintenance of existing yields, on improved nutritional quality, and on lowering the environmental effects of rice cultivation, particularly on reducing large (commonly in excess of 60%) losses of nitrogen from applied urea (Cassman et al 2002).

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Notes

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Development of sustainable agriculture from rice, water, and the living environment

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The Green Revolution based on the development of irrigated agriculture

Wisdom developed from soil and water has continuously been the fundamental element of all human activities since ancient civilization. The tragedies and ruins of the Mesopotamian/Sumerian civilization remind us of the significance of building sustainable agriculture and society. The drama of the collapse of Mesopotamia started with a gradual rising of the saline groundwater level. The collapse advanced rapidly when this level exceeded a threshold. It is well known that this problem was caused by faulty irrigation. Can we be confident that the current threshold is high enough when we look at the global expansion of commercialized agriculture and hazardously exploited water resources, such as in the Aral Sea basin, the Ogallala aquifer (Nebraska) and Central Valley (California) in the United States, Punjab and Haryana in India, and Northern China?

A stable water supply was a strong driving force behind the Green Revolution. Irrigated agriculture provides an essential environment for high yield, so that improved bred varieties of crops can be fully used. From 1961 to 2002, global irrigated agricultural land roughly doubled from 139 million to 277 million ha, while total land for arable and permanent crops expanded slightly from 1,357 million to 1,534 million ha (Fig. 1). Global population and cereal production have also doubled from 3.08 billion to 6.23 billion and from 877 million metric tons to 2.03 billion metric tons. Irrigated land, which accounts for about 18% of agricultural land area, produces about 40% of the food for the global population, contributing considerably to the alleviation of global poverty and starvation.

Sound and sustainable irrigated agriculture is indispensable for humankind to survive in the future. Now, about 70%, or 2,504 km^3, of the world's annual freshwater usage of 3,572 km^3 is for agriculture, and, of this, about 70% is used mainly for rice paddy agriculture in Asia.

Our generation is primarily responsible for assuring sustainable and efficient agriculture through wiser governance and management of soil and water resources.