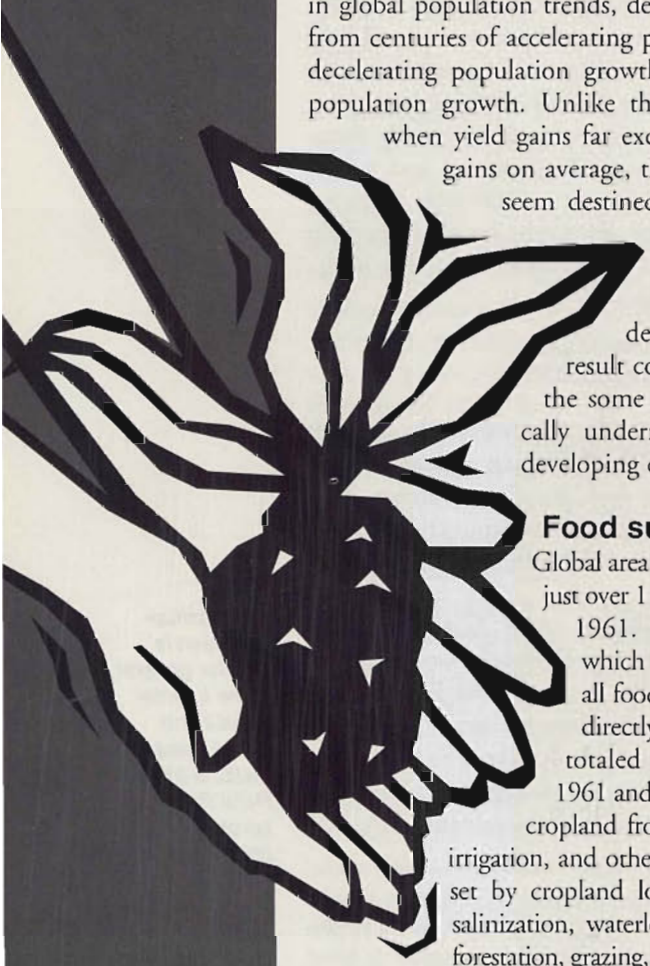
Anticipating a Tighter Global Food Supply-Demand Balance in the Twenty-first Century

by Luther Tweeten

It is especially fitting at this bicentennial of the publication of Thomas Malthus's *Essay on the Principle of Population* in 1798 that we review global trends in food demand and supply. Two striking features draw our attention. The first is the near linearity of yield trends since the 1960s, implying constant absolute but declining percentage rates of yield gain. The second is an inflection point in global population trends, demarking a transition from centuries of accelerating population growth to decelerating population growth and eventual zero population growth. Unlike the 1950s and 1960s when yield gains far exceeded food demand gains on average, the next four decades seem destined to feature a much tighter race between global food supply growth and food demand growth. The result could be hardships for the some 800 million chronically undernourished people in developing countries.



Food supply

Global area cropped has increased just over 1 percent annually since 1961. The area in grains, which supplies over half of all food either directly or indirectly (through livestock), totaled nearly the same in 1961 and in 1996 (FAO). New cropland from drainage, clearing, irrigation, and other sources is being offset by cropland lost to desertification, salinization, waterlogging, development, forestation, grazing, and other uses. World cropland area is unlikely to expand markedly without higher farm output prices. Any significant cropland expansion will have to occur mainly on land that is less productive and more environmentally fragile than current cropland.

Food production increases will come mainly from yield gains. Historic yield trends in figures 1 to 5 for major crops provide the basis for projecting future yields.

Key observations are as follows.

- Yields of all five major crops increased at nearly a linear rate in the twenty-five years from 1961 to 1996. Curvilinear trend lines fitted by ordinary least squares to annual data from 1961 through 1996 did not improve significantly on the linear trend lines shown in figures 1 to 5. Curvilinear regressions tended to indicate more, rather than less, yield plateauing than the linear trends shown and hence were more pessimistic about future yield prospects.
- No statistical test was run for cyclicality, but cyclical patterns seem visually apparent since 1961 in figures 1 to 5. For cereals and pulses, the pattern is approximately five years of somewhat flat yields followed by the leap to a new yield plateau. Vegetable and melon and root and tuber yields show tendencies to rise rapidly for several years, then drop back to a lower yield before renewing a series of years of yield ascent.
- Given equal annual *absolute* incremental yield advances on average, it follows that *percentage* increments (shown below each figure) are falling. For example, cereal yields increased on average by 44 kilograms per hectare per year from 1961 to 1996, but the percentage trend gain fell from 3.2 percent in 1961 to 1.51 percent in 1996. It is notable that cereal yields were growing much faster than population in 1961 (1.9 percent versus 3.2 percent) but were growing at the same rate in 1996, 1.5 percent.
- Trend yields of other crops (figures 2 to 5) and livestock were growing more slowly than either population or cereal yield (figure 1) in 1996. In contrast to population and cereal yields growing 1.5 percent annually, world vegetable and melon trend yields were growing only 1.1 percent, pulse yields 0.7 percent, root and tuber yields 0.6 percent, and oilseed yields 0.4 percent annually in 1996.
- Livestock yield data are sketchy; systematic global

estimates over time are unavailable. However, the U.S. Office of Technology Assessment projected gains in U.S. livestock feeding efficiency from 1982 to year 2000 as follows:

(Annual growth, %)	
Pounds beef/pound feed	0.2
Pounds milk/pound feed	0.6
Pounds pig meat/pound feed	0.2
Pounds poultry meat/pound feed	2.0

Given that these efficiency gains on average are less than for crops and given that shifting to consumption of livestock products as incomes rise will require more resources per calorie consumed by people, livestock offer little promise for reducing pressure on food production resources. However, livestock are an excellent means to utilize land unsuited for crops and provide a buffer for consumption when crops fail.

Overall food output (see side bar, p. 11) is projected to grow 1.28 percent in year 2000, 1.00 percent in year 2025, and 0.77 percent in year 2050. If global population continued to increase at the 1996 trend level of 1.5 percent, the portents of these yield projections for future world food security would be onerous indeed!

Unlike the 1950s and 1960s when yield gains far exceeded food demand gains on average, the next four decades seem destined to feature a much tighter race between global food supply growth and food demand growth.

Food demand

Whether continuation of the yield trends in figures 1 to 5 would lead to higher real food prices at the farm level attracting more cropland and other inputs depends on trends in demand. Food demand growth is driven mainly by two variables: population growth and income. Food demand projections and implied total food demand growth, assuming 0.3 percent annual increases in food demand per capita from income growth, are shown in table 1.

Compared to world population of 5.6 billion in 1995, the International Institute for Applied Systems Analysis, or IIASA, projects zero population growth (ZPG) at 10.5 billion people by year 2084, the United Nations (UN) medium population es-

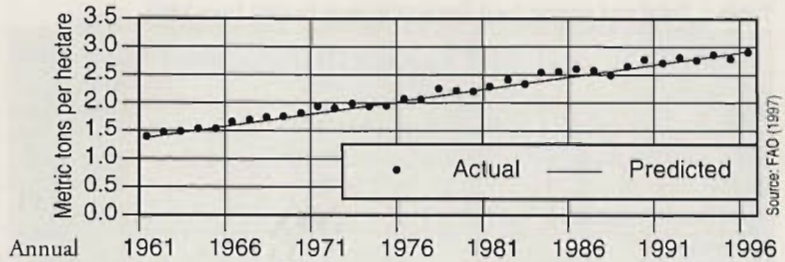


Figure 1. World cereal yields, 1961–1996

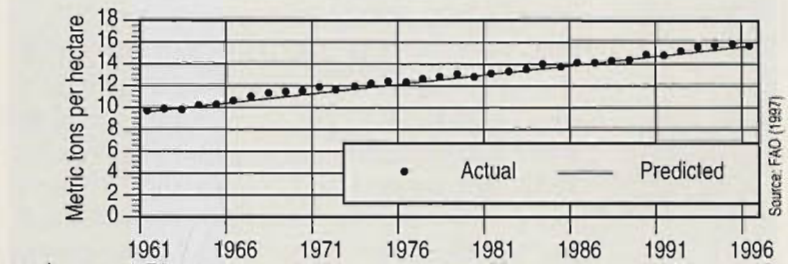


Figure 2. World vegetable and melon yields, 1961–1996

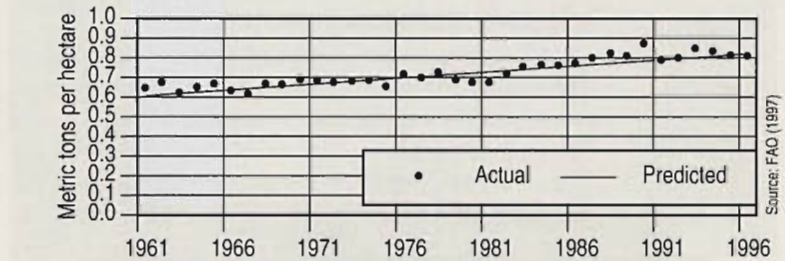


Figure 3. World pulse yields, 1961–1996

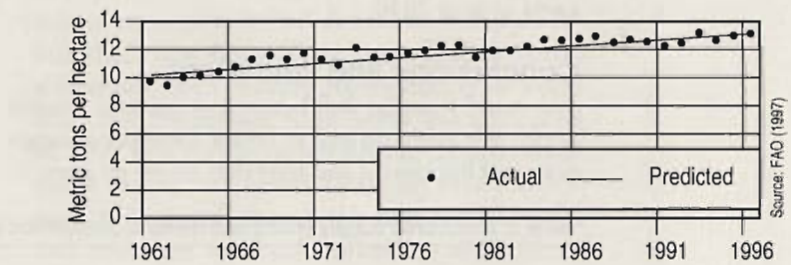


Figure 4. World root and tuber yields, 1961–1996

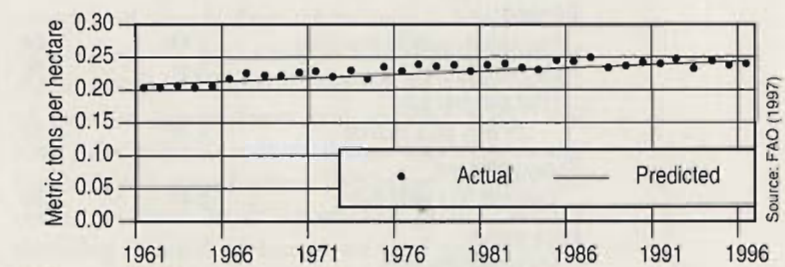


Figure 5. World oilcrop yields, 1961–1996

Table 1. Total and annual food demand growth to ZPG from 1995

Study	ZPG Population[a] (Billion)	Year of ZPG[a] (Year)	Food Demand Growth from 1995[b] (Percent)
IIASA (Wolfgang Lutz)	10.5	2084	144
UN (medium)	10.3	2094	147
World Bank (Bos et al.)	11.3	2128	201

Source: Tweeten.
Note: 1995 world population 5.6 billion.
[a]When data from the source were incomplete, the ZPG population and year were projected using a quadratic equation fitted to available data.
[b]Assumes per capita demand grows 0.3 percent/year from income.

timate projects ZPG at 10.3 billion people by 2094, and the World Bank projects ZPG at 11.3 billion by year 2128. The IIASA and UN population estimates added to the income component imply a 144 to 147 percent increase in food demand over the 1995 level by ZPG. The projected ZPG food demand at 2.5 times the 1995 level implicit in these numbers represents only a little less challenge than the tripling of food demand before ZPG implied by the World Bank estimate shown in table 1.

Supply-demand balance

Table 2 summarizes results of projections based on extending the linear yield trends of figures 1 to 5 to represent supply, and the United Nations medium population projection to represent the demographic component of demand. Per capita food demand growth from income is assumed to fall from 0.3 in year 2000 to 0.2 in year 2050 due to food price pressures. Under assumptions of table 2 including no increase in crop area, food demand is projected to increase faster than supply from yield gains to year 2040.

Conclusions and limitations

The world is not as well behaved as our neat models imply. We might do well to review some key assumptions and limitations and how they might go awry.

- *Constant future cropland area.* Millions of acres are being lost from cropland each year to urban development, desertification, erosion, and the like. Developed countries seek to avoid cropland expansion as evidenced by swampbuster, sodbuster, conservation compliance, and Conservation Reserve Program efforts in the United States. Land best suited to crop production is already being utilized, and adding significantly to cropland will require higher real farm commodity prices. Global area irrigated has been dropping in recent years. Given the narrow shortfall of supply growth (from higher yields) below demand growth in table 2, even modest area expansion could avoid higher real farm prices. Whether future real food prices will rise or fall secularly may be too close to call, but the overall supply-demand balance seems destined to be tighter than that experienced since 1950 on average.
- *Linear yield trend.* Biotechnology could raise future yields above trends in figures 1 to 5. But much new biotechnology such as Bt corn and Roundup-Ready soybeans is mainly input saving rather than yield enhancing. Conventional hybrid seed, irrigation, and commercial fertilizers will continue to increase yields, but at diminishing rates. Finding new technologies to provide future yield gains comparable to past contributions of these technologies will be challenging indeed. Technological obsolescence is real, and major investment will be required merely for yield maintenance.

  The private sector is now a major source of investment in science and technology. This is felicitous but could lull society into too little investment in public training of scientists and in basic research essential to improve technology enough to avoid marked expansion of cropland into fragile environments.
- *UN medium population projections.* Perhaps the

Table 2. World crop supply (yield) and demand (population and income per capita) trend growth rates by selected years

Supply or demand	2000	2010	Projected 2020	2030	2040	2050
Supply						
Total (weighted average)[a]	1.28	1.14	1.01	0.92	0.84	0.77
Demand						
Population gain UN (medium)	1.44	1.24	1.08	0.88	0.65	0.48
Income effect gain[b]	0.31	0.29	0.27	0.24	0.22	0.20
Total demand gain						
UN pop. plus income	1.75	1.53	1.35	1.12	0.87	0.68
Excess demand						
Demand less yield gain	0.47	0.39	0.34	0.20	0.03	–0.09
Price impact						
Price flexibility (3.0)						
times excess demand	1.41	1.17	1.02	0.60	0.09	–0.27

[a]Linear trend from figures 1 to 5 weighted by calorie shares shown in the side bar.
[b]See Tweeten, 1998, Annex table 1.

most disputed projection component is population. The International Institute of Applied Systems Analysis, the World Bank, and the United Nations are reputable agencies employing demographers skilled in projecting population. The projections from the three agencies are quite similar.

On the other hand, several individuals project ZPG to occur earlier and at lower world population than estimated in table 1. Steven Mosher, president of the Population Research Institute, projects global ZPG at 7 billion people by year 2030; David Seckler of the International Irrigation Management Institute and Michael Rock of Winrock International project ZPG at 8 billion by year 2040; and Dennis Avery of the Hudson Institute projects ZPG at 9 billion or less by year 2040. If these latter projections are realized, food demand growth will be less than that shown in table 2 and real farm prices will likely continue to fall. While the assumptions underlying estimates of Avery, Mosher, Seckler, and Rock are not explicit, their projections may inadequately account for *population momentum* from the large numbers of women in developing countries who will be in child-bearing ages to year 2030. Of course, population projections by agencies and individuals undergo frequent revisions.

Finding new technologies to provide future yield gains comparable to past contributions of these technologies will be challenging indeed. Technological obsolescence is real, and major investment will be required merely for yield maintenance.

- *Measurement error.* Some yield and population data, especially for developing countries, are crude. Crop estimates by FAO for some countries are judgments rather than the result of statistical sampling. It is impossible to conclude whether errors are consistently on the high- or low-yield side, and whether the direction of any bias in the numbers has changed over time.
- *Evidence of a tightening food supply-demand balance.* Given that global yield growth has fallen short of food demand growth for more than a decade, why aren't real farm prices rising?

The impacts of slow yield growth relative to demand are already apparent. Excess production capacity apparent in set-aside cropland, accumulated government commodity stock reserves, subsidized exports, and food donations is sharply diminished. Real farm prices in the United States, a relatively open country representative of world economic conditions, were nearly the same level in 1997 as a decade earlier despite annual multifactor productivity gains averaging nearly 2 percent. Millions of acres in the Brazilian Cerrados and elsewhere in South America and in Africa were brought into crop production for the first time in the 1980s and 1990s—a feat unlikely to be repeated.

The conclusion is that, even allowing for error, world food supply-demand balance is likely to be tighter over the next three to four decades than in recent decades. Affluence coupled with the "noise" of weather shocks from year to year masks real food price gains in industrial countries. Americans, for example, spend about 2 percent of their incomes on farm food ingredients. Hence, even a doubling (absurd) of farm-level food prices would reduce their real income only 2 percent. Thus, affluent societies will hardly notice tighter food supplies except for occasional food price spikes.

Global Calorie Shares

On the supply side, overall food output trends from higher yields depend on the global calorie shares for consumption derived from the various food categories as noted below:

	Global Calorie Share (%)	
	1961	1995
Cereals (maize, wheat, rice, millet, etc.)	50.1	49.4
Vegetables (green beans, cabbage, onions, tomatoes, etc.)	2.0	2.1
Pulses (dry beans, chick peas, groundnuts, peas, etc.)	3.9	2.2
Roots and tubers (cassava, potatoes, yams, etc.)	8.0	5.1
Oilcrops (soybeans, rapeseed, cottonseed, canola, etc.)	1.7	2.0
Meats (poultry, beef, pork, lamb, etc.)	4.9	7.5
Other (dairy products, eggs, fruits, etc.)	29.4	31.7
	100.0	100.0

Source: FAO.

Consumption patterns were faily stable across broad food groups over time. The major change is a reduction in consumption of pulses, roots, and tubers and an increase in livestock and livestock products.

Given no substantive basis to predict a turnaround in yields from the straight lines of figures 1 to 5, those linear trends are merely extended to year 2050 and weighted by the above 1995 calorie proportions. This projection provides a baseline estimate of overall future food supply assuming that yields of livestock and other excluded commodities (including fish) increase at the same rate as the weighted average yields of the five major crops and that crop area does not change.

Farmers and low-income consumers at home and abroad are likely to notice the change, however. Because farmland earnings are a residual, real farm prices rising 1 percent per year on average would raise real land earnings and prices in excess of 1 percent per year. Even stable real farm commodity prices would contrast sharply with real prices which have fallen by over half since 1910–14. Farmers are cautioned against rushing to bid for land however, because cyclical price downturns within a secularly favorable price trend would bring severe financial setbacks.

The major problem will be for consumers in Africa and low-income countries who will have difficulty competing with more wealthy regions for food.

The major problem will be for consumers in Africa and low-income countries who will have difficulty competing with more wealthy regions for food. Africa has especially low investment in research relative to agricultural output at a time when it and other regions cannot be complacent about future food supplies. Neglect of efforts to raise agricultural productivity in recent decades, especially in developing countries, is a subject of enormous importance beyond the scope of this analysis (see Tweeten and McClelland). ◙

■ For more information

Avery, D. "Why the Food Summit Failed." *Global Food Quart.* 18(Fall 1996):3–7.

Bos, E., M. Vu, E. Massiah, and R. Bulatao. *World Population Projections, 1994–95 edition.* Baltimore MD: Johns Hopkins University Press for the World Bank, 1994.

FAO (Food and Agriculture Organization). FAOSTAT Statistics Database [Online]. Available HTTP: http://apps.fao.org (1997).

Lutz, W., W. Sanderson, S. Scherbov, and A. Goujon. "World Population Scenarios for the Twenty-First Century." *The Future Population of the World.* Wolfgang Lutz, ed., chap. 15. Laxenburg, Austria: International Institute for Applied Systems Analysis, 1996.

Mosher, S. "Too Many People? Not By a Long Shot." *Wall Street Journal,* 10 February 1997, A–18.

Seckler, D., and M. Rock. "UN 'Low' Projection of Population Most Accurate." *News and Views,* p. 5. Washington DC: International Food Policy Research Institute, October 1997.

Tweeten, L. "Dodging a Malthusian Bullet in the Twenty-first Century." *Agribus.* 14, no.1 (1998):15-32.

Tweeten, L., and Donald McClelland, eds. *Promoting Third-World Development and Food Security.* Westport CN: Praeger, 1997.

United Nations. *World Population Prospects: The 1996 Revision.* Annex II and III: Demographic Indicators by Major Area, Region, and Country. New York: United Nations, Department for Economic and Social Information and Policy Analysis, Population Division, 1996.