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The Strategic Importance of the World Food Supply

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The place is Rome, Italy, between 13 and 17 November 1996. Thousands of policymakers, bureaucrats, and environmentalists from 196 countries have descended on this historic city for a World Food Summit; they are polarized between the pessimists (latter-day Malthusians) and the optimists, whether technologists or those dedicated to modifying the behavior of food producers and consumers. Each group believes itself to represent realism.

Many of the attendees are alarmed about clear signs that the world is running out of food, characterized by images of people starving in Somalia in 1992. They're quick to tell you that the famine in Somalia is merely representative of the ongoing food crises in Africa and parts of South Asia. They remind you that as recently as 1983 and 1984 a million Ethiopians died in another terrible famine.

Attendees from the other camp see things differently.[1] Their world generally faces a food glut; they pay their farmers handsomely not to grow food, in order to avoid surplus. Their farmers also have been frustrated as prices of agricultural commodities have declined in the past 15 years; they make the case that other lines of work are far more promising than agriculture. Throughout the conference the two groups would remain worlds apart.

So, too, are the regions described in this article and the kinds of problems that affect them. Food problems in Africa, primarily sub-Saharan Africa, are most often characterized by insufficiencies due to war, civil strife, flawed government policies, and poverty. The latter is defined as the inability to purchase the minimum amount of foodstuffs to sustain life, even in periods of relative plenty. Hence world response to these conditions has taken the form of relief efforts to solve immediate problems, sometimes with little official regard for long-term effects of the interventions on domestic agricultural markets.

Food problems in China, as best we can discern, are different from those in Africa in both form and scope. Whereas sub-Saharan food crises have been with us in increasing numbers for several years, with no imminent prospects for slowing the trend, China's challenges lie mostly in the future. Its enormous and growing population has the potential to destabilize agricultural production throughout the world. Its growing affluence has begun to increase demand for meat products, sustainable only by increasing its production and imports of grains. And whereas the plight of individual African states will have limited effect on the well-being of other regions, China's size and location make it inevitable that its claim to the wherewithal to feed its people in 2020 could indeed affect contiguous states as well as distant regions capable of producing grain surpluses.

Clausewitz reminds us that "the first, the supreme, the most far-reaching act of judgment that a statesman and commander have to make is to establish . . . the kind of war on which they are embarking; neither mistaking it for, nor trying to turn it into, something that is alien to its nature." That admonition applies equally to the strategist seeking to understand what motivates or deters other states in a time of relative peace. For a while during the oil crisis of the 1970s, food was sometimes called the green weapon, apparently on the assumption that the embargo of one commodity could be countered by the embargo of another. At the time, no one took the concept very seriously. Now, however, with the world's population half again what it was at that time, food--who has it, who doesn't--and the arable land from which it is produced become legitimate strategic considerations.

This article explores aspects of world agriculture and suggests ways to examine and think about arable land and the world food supply, considerations that strategists are sometimes too quick to dismiss. Some support one or another of

the two opposing views, because of folk wisdom or prejudice. Some believe that the "world is full of food"; others believe that little can be done to avert starvation in Africa. Still others argue that the world food supply is not vital to US national interests. Common to all views often is a lack of opportunities to examine the matter in depth.

To encourage the study of food and arable land as strategic assets, this article addresses the supply of food worldwide, and to a lesser degree, the demand for it.[2] It looks at factors that determine the supply of food and at circumstances that can alter--for better or worse--the ability of producers to keep pace with demand. Most important, it examines the implications of success or failure to maintain a supply of basic foodstuffs that stays just ahead of the demand. Strategists need a clear, even if rudimentary, understanding of the forces that determine whether tens of millions of people will live lives of feast or famine. Such an understanding will help them shape national policy on matters with potentially unprecedented peacetime consequences.

The Demand for Food

A number of considerations shape the worldwide demand for food. Key among them are population growth, social upheavals that disrupt domestic food production and contribute to humanitarian disasters, and the amount of grain consumed indirectly by relatively affluent societies as they satisfy their newfound desire for meat.

Demographics. The world's population has now reached almost six billion. At current growth rates it could double by the year 2035 unless states take decisive actions to address the problem.[3] Relentless population growth--whatever else happens to the demand for food--means that we will have many more mouths to feed each year than the year before. One policy option is to reduce the rate of growth of the world population.

The investment that promises the biggest short-term payoff in controlling population growth is making sure that safe and effective family-planning methods are universally available. Additionally, the inequalities between the sexes that exist in many developing countries also should be addressed; it has been demonstrated that educated and emancipated women know how to space their pregnancies.[4] Poor countries also desperately need stronger economic development, which in turn reduces the social demand for large families.[5] While none of this is easy to implement culturally or politically, the simple truth is that rapid population growth is one of the few solvable problems in an otherwise complicated world.

Humanitarian Disasters. A number of African nations, notably Ethiopia, Sudan, Angola, Liberia, Zaire, Mozambique, and Malawi, are permanently threatened by famine. Food shortages in South Asia raise similar fears; many fret as well about the 800 million people (also mostly in Africa and South Asia) who are chronically hungry and undernourished. The frequency and scale of humanitarian crises that require the international community to overcome food shortfalls with food aid have increased substantially in recent years. The number of recipients of UN humanitarian assistance jumped from one million in 1970 to 17 million in 1993. Food aid for UN emergency relief operations has grown correspondingly, from one million metric tons in 1979-80 to 4.5 million metric tons in 1993-94.[6]

At first glance, events in Africa and South Asia seem to confirm the theories advanced in 1798 by Thomas Robert Malthus, the English economist who gave his name to predictions of mass starvation.[7] The Malthus thesis is that populations will always outstrip the food supply because food supplies grow arithmetically while populations grow geometrically. China's Hung Liangchi recently paraphrased Malthus: "The population, within a hundred years or so, can increase from fivefold to twentyfold, while the means of subsistence . . . can increase from three to five times."[8] Pessimists claim that the food shortfall in Africa and South Asia is merely the tip of the proverbial iceberg. They claim that food shortages in those regions are indicative of something far more ominous: the world food supply--the total amount of food available to all of the people in the world--is being squeezed. If they are right, humanity itself can ultimately be at risk.

Livestock. As people improve their living standards, especially through increased income, they usually eat more food. Also they generally begin to eat more meat, which requires an enormous amount of grain to feed their livestock. Beef cattle are especially inefficient in this respect, producing only one pound of meat for every eight to ten pounds of grain they consume. Compared to a pound of beef, however, that same eight pounds of grain can supply about ten times as many calories and more than four times as much protein when consumed directly by humans.

In the past, almost all beef cattle grazed on grass and other forage up to the time they were slaughtered. But since the mid-1900s, many feed lots--they fatten cattle on grain--have operated in the United States and Canada. Most beef cattle are fattened there, consuming enormous quantities of grain in the process.[9] In effect, livestock consume more calories and protein than they produce; even chicken requires roughly two kilos of grain to produce a kilo of edible products.

To help redress this inefficient conversion of grain to calories, the United States could take the lead in helping to reduce the demand for feed grain for livestock in two ways. First, the demand for grain could decline significantly if the cattle industry raised some of its animals chiefly on forage. Second, the demand for feed grain would decline if we simply decided to eat less meat. Most people in the United States, for example, could probably reduce their meat consumption as much as 30 percent without ill effects; Americans consume more than four times as much grain, partly through meat products, as do people in developing countries. The demand for grain is also increasing because affluent people in newly prosperous places like China can afford to eat more, especially more meat.[10] So restraint in meat consumption could gradually increase the amount of calories and protein available for human consumption as grain products.

Social Demand. It is useful to make a distinction between economic demand for food and what can be called social demand for it. When economists use the word *demand*, they generally refer to market demand in the context of purchasing power and price. But since poor people who cannot afford food are not part of the marketplace for grain, talking about the economic demands for food in the world ignores a large segment of humanity. It also helps to explain why there can be food scarcity in Africa and South Asia in the midst of a surplus of food in places like the United States and the European Union (EU) countries.

The social demand for food reflects population increase and the tendency for increasing affluence to be accompanied by increased consumption of food, particularly meat. In this sense, the concept offers a more complete description of aggregate demand for food than does market demand. Social demand identifies the quantity of food the world needs to feed all of its people, irrespective of commercial demand for grain in the marketplace. Quantifying the social demand can help us to reconcile the usually conflicting views of the pessimists and the optimists. And if we can think of the world food supply in such a holistic context, we discover that the social demand for food is increasing. Living standards plunge when population outstrips economic growth, creating conditions for social unrest and civil war. And when marginal or depleted natural resources--land and water--can no longer support growing populations, conflicts can arise as desperate people become refugees and seek their livelihood in neighboring countries.[11]

The finding that social demand for food is growing has strategic consequences. Countries with an abundance of food cannot ignore the problem of global mismatches between populations and foodstuffs, whether the mismatches are intermittent or permanent. The condition demands responses; it creates the kind of imperative that RAND Corporation's Marten Van Heuven frequently refers to: "Either you visit the problem, or the problem will visit you." The debate will continue over whether the relationship between anticipated population growth and arable land is cause for concern or merely a phase. The prudent individual or state, however, should be looking for hedges in the event the emerging scenario is Malthusian. All conflict, someone has observed, can be traced to resources.

The Supply of Food

Whether the world can grow enough grain to meet increasing social demand for food depends on several factors; the amount of food a country produces is determined in large measure by its agricultural resources--arable land, water, energy, and fertilizer. Of these, land and water are obviously the most important. Crop land must be fertile and fairly level; water can be from rainfall, irrigation, and in some limited instances, desalinization processes. In addition, many farmers depend heavily on energy resources, particularly petroleum fuels, to operate tractors, irrigation pumps, harvesters, and other farm equipment. Most also use some form of natural or man-made fertilizer to enrich the soil.

One of the first lessons every economist learns is that these agricultural resources, no matter how plentiful in some places, are scarce relative to what the global society would otherwise want. The permanent fact of scarcity (the condition of being in limited supply) requires choices and creates costs. In the context of the world food supply, this means that no country has an unlimited supply of land, water, energy, and fertilizer. The more we explore technical

ways with the potential to boost food production, the more we run into these natural and manmade limits. The limits need not lead to crisis; if they are ignored in assessing strategic options, however, threats may well develop that would put American soldiers at risk.

The Good News. We all know that potential threats sometimes never materialize. In fact, Malthusian forecasts about population growth outstripping the food supply have been proven factually wrong, at least until recently. For one thing, Malthus ignored, or at least did not foresee, the tremendous increase in arable land in newly discovered and exploited areas of the world. In addition, Malthus did not anticipate the rising productivity per acre that resulted from the Industrial Revolution.

Similarly, if we move to the latter half of the 20th century, we also find that doomsday conditions have not occurred on a global basis. In fact, global agriculture, in an aggregate sense, enjoyed substantial success from 1961 to 1994; during that period the world experienced a steady growth in the production of most food crops. In the past 30 years, global food output has risen faster than population.[12] In an aggregate sense at least, the world food supply has been growing over the long term.

We all need to thank Norman Borlaug, whose research led to what is commonly called the Green Revolution, for the steady rise in production. His ingenuity and innovation combined modern, higher yielding seed varieties of rice, wheat, and maize with intensive and innovative use of inputs such as fertilizers, irrigation, and pesticides. Most of the recent growth in food production in developing countries is a result of the higher yields stimulated by Borlaug's research.

For many years, the Green Revolution allayed fears that the world could not increase food production at rates that matched population growth. The results speak for themselves. Agricultural experts were amazed at the impressive growth rates in the global yields of wheat, rice, and maize.[13] And countries such as China, which adopted Green Revolution methods of farming in their entirety, showed astounding yield increases. Even countries that adopted only parts of Borlaug's methods have shown substantial increases in yields.

The Green Revolution protected the environment by enabling farmers to grow much more food without a dramatic increase in the area of cropland. Dennis Avery, a former agricultural analyst at the US State Department calculates that ten million square miles, the equivalent to the whole of North and Central America, would have been cleared for farming had the new procedures and technologies not appeared some 35 years ago.[14]

The Bad News. The success of global agriculture in the aggregate has not been shared equally by all countries. Africa and parts of South Asia continue to experience chronic malnutrition and periodic famines. This situation is particularly ironic because most African countries were self-sufficient in food at the time they became independent nations. Africa still has the potential to be a productive continent; its farmers are inventive and adaptive, and the continent has a third fewer people per acre than the developing world as a whole. Unfortunately, it is not living up to its potential; Africa presently is the continent most seriously affected by food shortages. Fifteen countries in the region are facing food emergencies. Of the 27 countries with household food security problems, 22 are in Sub-Saharan Africa.[15] Estimates of the number of Africans at risk range from five to 20 million. Consequently, many Africans and South Asians are now heavily dependent on imported food for their survival.

The immediate cause of the 1992 famine in Somalia was drought. But the deeper causes of Africa's declining ability to feed itself are more complex, an unfortunate interplay of natural and human conditions. Certainly lack of rainfall and persistent civil strife contribute to recurring food gaps. But most experts agree that the basic problem is that African governments neglect investment in agriculture. Instead of empowering the countryside, those governments tend to have an anti-rural bias and an obsession with rapid industrialization. They also spend, on average, four times as much on armaments as they do on agriculture. Ethiopia, for example, continually asks the rest of the world for food, yet as much as 43 percent of its national budget has been spent on its military establishment.[16]

In addition, Africa's rapid population growth and counterproductive public policies also contribute to food gaps. Despite the fact that total food production has more than doubled in Africa and parts of South Asia since 1961, the rise in food production has not been enough to keep up with population growth there, which tends to confirm part of Malthus's theory.[17] But Africa's problems are largely the result of self-inflicted wounds rather than the world approaching some natural limit to food production, a distinction that Malthus did not make.

That is a difference without distinction, however, for the African who is hungry and malnourished. For whatever reason, many developing countries in Africa and South Asia simply don't have enough food at hand to feed their people. Sometimes this is attributable to a lack of foreign exchange to import enough food at market prices to overcome the food shortfall. At other times, food is available to meet economic demand, but the social demand for food is not met because large numbers of the poor lack the money to purchase food on a commercial basis.

The considerations that follow--call them causes or effects--influence one's perceptions of the availability of food in the world. Some, such as specific water resources or humanitarian interventions, tend to affect the food supply of a single state or region. Others, such as the amount of arable land in cultivation, improvements in fertilizer, or the introduction of hybrid species, can affect the supply of food in a region or the entire world. The list is not exhaustive, but it contains sufficient information to provide a sense of the complexity of the food supply system. Taken together, these considerations can encourage measured responses to both optimistic and pessimistic strategic estimates of the influence of food supplies on national security issues.

Interventions

Interventions into the food supply can be classified as humanitarian and governmental. The paradox is that both, while necessary, tend to destabilize the food supply system in a country.

Humanitarian. Foreign aid packages that seek to prevent famine or offset chronic food shortages have become increasingly familiar in recent years. Global redistribution of food in 1993 by various agencies and organizations was impressive in real terms; a record 17 million metric tons of food was delivered to the chronically needy that year. Unfortunately, this figure still fell far short of the total food aid needs of that group.[18] The International Food Policy Research Institute (IFPRI) estimates a remaining shortfall of seven to ten million metric tons in the per capita global caloric intake to meet recommended minimum levels among the chronically hungry.[19]

Unfortunately, such interventions are often a mixed blessing for the recipients of the food. While these massive giveaways undeniably provide temporary relief, foreign food aid actually hurts the recipients in the long run. When the United States provides food at no cost to developing countries, the relative price of food versus other commodities is altered. Signals to potential investors in agriculture in these countries are discouraging rather than encouraging. This, in turn, undermines long-run self sufficiency in food production. In short, food aid treats symptoms, not causes of food gaps.

Government. A similar market distortion occurs when governments in developing countries set food prices at low levels. The policy is politically attractive, since it provides cheap food for growing urban populations. But farmers in the developing countries soon discover that the commodity prices paid by the government are often so low that they do not cover production costs. A low-price policy diminishes the incentives to actual and potential farmers to increase the food supply. The farmers, in turn, react by reducing the amount of food they produce. The resulting downward spiral often ends as a food shortage, triggering a vicious cycle that produces a need for more external food aid.

Poor countries need to permit returns on agriculture sufficient to raise rural incomes, even for the landless; they also should seek ways to spur economic development throughout their economies. In this sense, the food shortage is at least partially about poverty. And the poverty of farmers should be addressed by policy changes to restrict government interference in the agricultural marketplace altogether. None of these prescriptions will be applied without strife, however. When Jordan recently tried to free its wheat markets, city dwellers rioted.[20] Governments should be challenged to shift their focus to the poor rural producer, rather than continue to pander to the urban dweller.

This does not mean governments should stay on the sidelines. They can, and should, look for measures that tend to create an attractive infrastructure, one that enables private agriculture to expand to meet market pressure for increased consumables. One way to reach this objective is to spend less money on guns and more money on butter--investing in rural infrastructure, including bus and truck transportation and improved water and irrigation systems.

But what can international food agencies do about people who have no money whatsoever? Those agencies are relatively well equipped to deal with extraordinary, nonrecurring events, such as the drought that triggered the famine

in Somalia. But they lack the resources to meet completely the chronic needs of the malnourished millions in Africa and South Asia. Comprehensive macroeconomic strategies in the affected countries, rather than short-term, stop-gap policies, are required to deal with chronic underproduction of food. Governments in poor countries must work with the IMF and the World Bank to create market-friendly economic development strategies that will systematically reduce poverty.[21]

Change--cultural, social, political, and economic--sufficient to create permanent improvements in the lot of the chronically poor will not occur quickly or easily. The long-term goal of these countries should be to provide steady purchasing power to previously poor people to allow them to buy food commercially. Seen from this perspective, chronic hunger and malnutrition have more to do with poverty than with reaching full capacity in food output.

The Grain Slowdown

But are the poverty and hunger we see in Africa and in parts of South Asia really self-contained? Is this grim situation occurring in a world full of food? Not exactly. Even in the aggregate, things are not altogether rosy for global agriculture, at least in terms of output. For although world food production continued for several decades to grow faster than population, population growth is beginning to catch up, because the rate of growth in world food production is declining. From 1961 to 1992, growth in world agricultural production decelerated, dropping from three percent annually in the 1960s to 2.3 percent per year in the 1970s and two percent during the 1980-92 period.[22]

Given these declining growth rates, can the capacity of the world agricultural system continue to feed a world population increasing by about 90 million people each year? Perhaps; consider, however, the state of ocean-produced food. Maritime experts agree that almost everywhere fish stocks have been plundered to the point of exhaustion. Some would ask, having reached a natural limit on food from the sea, whether a natural limit on grain can be far behind.[23]

Higher Yields

To a certain extent, Green Revolution methods can continue to make farmland more productive. That's because there is still considerable untapped potential for its methods and technologies around the world. For instance, the technologies of the Green Revolution failed to penetrate much of sub-Saharan Africa. Peter Hazell of IFPRI points out that India successfully feeds twice as many people as Africa on 13 percent of the land area of that continent. Another source suggests that at least part of the reason for Africa's inability to feed its people is that fertilizer use in Africa is only one fifteenth that of Chinese levels.[24]

Similarly, innovative and intensive use of irrigation has helped to produce stunning results. The Food and Agricultural Organization (FAO) is cautiously optimistic that yield increases will continue. This is because of the existing wide disparities in yields among the best performing countries (using intensive Green Revolution irrigation methods) and those countries using less innovative irrigation practices. For example, rice yields on irrigated land vary from one to ten metric tons per hectare; today's average yield of 3.7 metric tons per hectare is well below the 6.7 metric tons per hectare achieved by the best performing countries.[25] And average yields of wheat and maize on some irrigated land are only about half the yields achieved, again, by the best performing countries.[26] Thus, FAO argues that there is considerable room for improvement by farmers currently achieving less-than-peak yields.[27]

In Asia average crop yields are a mere 40 percent of the yields achieved by scientists using the best technology now available. In Andhra Pradesh, India, for example, scientists have boosted yields almost sixfold by planting a double crop of sorghum and chickpea instead of the single cropping method used by local farmers. Thus, if farmers in the tropics have enough water, fertilizer, and other essential resources, they can grow two or three crops a year on the same land, instead of one crop, with much higher yields to show for their informed and intensive use of the same amount of acreage.[28]

Expanding Arable Land

Over the past three decades the expansion of cropland area has been significant in two regions: sub-Saharan Africa and Latin America. In fact, sub-Saharan Africa stands as the only region in the world where expansion of arable land contributed nearly as much as yield increases to the growth of cereal production during the 1961-1990 period. In Latin

America during the same period, expansion of arable land accounted for nearly one third of recorded production gains.[29]

At first glance, there would appear to be potential for developing new cropland. Despite a strong trend toward urbanization in developing countries, there remain relatively large areas of sub-Saharan Africa and Latin America that are potentially suitable for farming. In each of these areas, FAO estimates that expansion of arable land will contribute about 30 percent to the increase in crop production.[30] One World Bank estimate suggests that the world's farm acreage could increase by ten percent over the next 40 years.[31]

On closer examination, however, things look less promising, because most of the good arable land is either fallow or already in use. The land remaining in Latin America and sub-Saharan Africa is not prime land; much of it has tropical soil and a climate not conducive to farming.[32] So yields from such land would tend to be low. This fact is well known, and it is difficult to get farmers to settle and develop these areas voluntarily. Financial incentives alone are not sufficient to induce settlement, because these lands are mostly in remote areas, far from markets and transportation. Expensive infrastructure would be needed before the lands could support commercial farming. In short, it would be difficult, costly, and time-consuming to develop new land for farming in the very areas where others have identified opportunities to do so.

Irrigation

A number of conditions set clear limits on how many of the four primary agricultural resources can be harnessed to produce higher yields around the world. Since rainfall is distributed unevenly over the earth's surface, some farmers are dependent on irrigation water, if it is available, because local rainfall is too light or uncertain to raise crops to maturity. But the supply of irrigation water is limited; farmers in some countries use nearly all the available supply, creating tension with the rest of society and frequently with neighboring countries as well.[33]

Environmental factors also set limits on higher yields, causing international agriculture strategists to be concerned about features of the agricultural system that Malthus never dreamed of. Global warming, for example, purportedly threatens to desolate at least some productive arable land. Optimists counter with the idea that a measure of global warming could serve to transform some of the barren tundra into new arable land, thus offsetting losses elsewhere.

An environmental backlash appears to be developing against some of the Green Revolution policies encouraged during the 1960s and 1970s: notable among them are technological solutions to the food supply problem, such as irrigation, and the use of farm chemicals and new high-yielding seed varieties. Consequently, the rate at which cropland is brought under irrigation is declining. FAO now predicts that irrigated land in developing countries (excluding China) will expand at a rate of only 0.8 percent annually, which is much slower than the 2.2 percent annual increase in during the 1970s and the 1.9 percent annual increase in the 1980s.[34]

This decline is mainly due to the increasing cost of irrigation, both development and maintenance, and the growing competition for water uses cited above. Irrigation's environmental and health effects also inhibit further expansion. For instance, millions of hectares of irrigated land, especially in Asia, have become waterlogged or have been rendered infertile because the water has left deposits of salt. Salinization problems from improper irrigation techniques reduce crop yields and constrain future production.[35]

Fertilizer

The fertilizer situation is not very promising either. Nitrogen fertilizers used for agriculture are currently made from natural gas. But the supplies of petroleum and natural gas are strictly limited. And while increased use of fertilizer can help farmers produce more food, it can also cause environmental problems. Nitrogen fertilizers sometimes create a buildup of nitrogen compounds in the soil. Chemical fertilizers that run into rivers and lakes cause ugly, slimy blooms of algae.

Water pollution has caused the European Commission of the EU to target their farmers: "If you pour fertilizer into the Thames, the Seine, or the Rhine, you are likely to affect fisheries in the North Sea," explains one EU official.[36] The EU is expected to act early in 1997 to require all water users to pay the full "economic cost" of water in a drive to

eliminate serious water pollution and waste. EU environmental officials have completed a framework directive that could severely affect farmers, who pay very little for their water in most EU states. The draft directive defines the full economic cost of water as including a charge for environmental costs as well as operational and management costs, capital costs, and reserves for future investments. The proposal is almost certain to spark a fierce counterattack from farmers affected by the changes.[37]

Higher Costs

Although energy and fertilizer can make farmland more productive, increasing costs of energy and fertilizer also drive producer costs higher. Food prices rise in due course, eventually out of the reach of millions of people throughout the world who cannot afford to buy all the food they need even at lower prices.[38] Ways and means should be sought to expand food production at a cost that most farmers and consumers in developing countries can afford.

And even if a farmer can afford to use more expensive fertilizer and irrigation methods, he soon discovers trade-offs between the costs of these inputs and higher yields he can expect from them. In other words, greater use of these resources makes land more productive, but only up to a point. For instance, most farmers in the United States use seven to ten times as much fertilizer on each unit of land as do farmers in developing countries.[39] But US grain yields are only about twice as large as those in developing countries. US agribusinesses might be able to afford this kind of expense, but marginal farmers in many developing countries simply cannot afford the additional resources that the Green Revolution requires.

Ecological Degradation

Expansion of arable land can have other harmful consequences. At least 45 percent of potential cropland in sub-Saharan Africa and Latin America, for instance, is under forest or is in protected areas.[40] In many cases, conversion to arable land would destroy the forests and cause the loss of biodiversity, which in turn could hinder medical research.

The increasing need for food already has caused the deforestation of significant amounts of marginal land. In the short run, the new land sometimes increases yields of specific crops. Over time, however, some of this new cropland is not sustainable, and the total amount of arable land can actually shrink. In many regions, trees that have created a barrier to the encroachment of the desert have been burned for fuel, thus causing the fragile topsoil essential to farming to be blown away by desert winds.

Subsequently, the scarcity of wood which accompanies deforestation can require farmers to use animal dung for fuel, diverting some of it from its traditional use as fertilizer. Fallow periods frequently have been shortened, resulting in overplanting and overgrazing; soil abused in this manner eventually wears out. Finally, deforestation and land overuse have reduced the capacity of the land to absorb moisture, thus diminishing its productivity and its ability to resist drought. Experience in mitigating ecological degradation has not been encouraging.

Diminishing Returns

Because so much of the Green Revolution success story has been due to increases in yield, a key question for the future, given the obstacles cited above, is whether such increases in food production will continue, and if they do, at what rates. Unfortunately, there are already strong indications that the Green Revolution is beginning to run out of steam.

Although total yields have increased, yields of the three cereals in developing countries--rice, wheat, and maize--have recently been rising at a slower rate than in the 1960s and 1970s.[41] It may be that the existing technologies of the Green Revolution will allow food supply to continue to grow only for so long. Thus, traditional technological improvements, while essential to any comprehensive food production strategy, can go only part of the way to feeding the world.[42]

Other Options to Increase Supply

Given that cropland expansion can probably only do a small part to boost grain production, and that squeezing more

yield out of existing cropland cannot do all of the rest by itself, we need to explore other ways to boost grain production to feed eight billion people in the next century. One way we can increase grain output is by applying better farming techniques. For instance, optimizing the timing and density of planting and seeding has raised corn yields by as much as 2.5 metric tons per hectare and soybean yields by one additional metric ton per hectare.[43] Some other ways to improve at the margin include:

- Governments in Africa could encourage low-technology, small-scale agriculture. Idriss Jazairy, a former high-level UN agriculture specialist, argues that the key to Africa's food future is the very small farmer so long ignored by African governments and outside donors:

> The failure of past development strategies is that they have been based on a trickle down, social-safety net approach that emphasizes the consumption needs of the poor and identifies the poor as a burden on the growth process. Instead, we need to focus on their producing possibilities. We need to see that development is something that happens because of the poor, not in spite of the poor.[44]

- Women in Africa may also be a key to Africa's food future. In the past, too many regional governments have treated women as second-class citizens. Despite the fact that 85 percent of rural women in Africa produce 80 percent of Africa's food, less than ten percent of them own land or resources because of laws that discriminate against them. If African governments did more to empower women farmers with such things as land tenure, it is likely that they would make the long-term investments (e.g., planting more hedges and trees that are needed to arrest soil erosion). [45]
- Yields can be improved substantially by reducing post-harvest losses. The developing world generally lacks required facilities for crop storage; thus, even when crops are good, it is difficult to accumulate a surplus for the lean years. A large percentage of domestic farm output in some parts of Africa is lost to rats, insects, and spoilage; in Kenya, for example, about 24 percent of the harvested grains are damaged by molds, fungi, insects, rodents, and other pests. Estimates of total global marketing and distribution losses vary between eight percent and 25 percent of the harvest.[46] Significant gains can be obtained through better processing and improved storage and distribution facilities.
- Research scientists are now working to develop varieties of grain that not only produce higher yields but also have other improved characteristics. Such a grain might supply a more complete combination of amino acids, make more efficient use of water and fertilizer, and provide better resistance to insects and disease. The problem is that it is extremely difficult to develop a plant variety that has so many different characteristics. The necessary research therefore takes much time and money.
- Significant increases in supply may be possible through new developments using conventional plant breeding techniques. And at least with rice, a dramatic leap forward is already in sight. Researchers at the International Rice Research Institute (IRRI) in the Philippines have recently bred a new strain which invests about 50 percent of its energy in growing its ear, which contains the edible bits, compared with 30 percent in older varieties. It lifts yields 20-25 percent above the highest yielding varieties now available in Asia.[47]
- These opportunities pale in comparison to the seeming potential in biotechnical research. As the following discussion shows, however, progress in this area is not without its problems.

Biotechnology has been helpful in developing increased pest resistance in some crops and drought resistance in others. In some cases, it is speeding up the process of plant breeding and lowering the cost of achieving such research goals as greater insect and disease resistance.[48] These successes have led some agricultural experts to argue that biotechnology has the potential to create another Green Revolution. But it would be wrong to suggest that a cornucopia awaits; so far at least, biotechnology has not led to a single dramatic gain in yield of any grains.[49] The most likely reason is that research and development in the best known form of biotechnology, genetic engineering, is concentrated in medicine, not farming.[50] Even where agricultural biotechnical research is taking place, most of it is being done by private firms in the West, who tinker with the qualities of fruits and vegetables for rich markets, rather than trying to boost the quantity of basic grains for the poor.[51]

Unfortunately, the prospects for farm research in biotechnology no longer appear promising. After steady growth in the 1960s, aid fatigue has set in; IRRI is now laying off a third of its 1500 employees following budget cuts. If governments from rich countries continue to slash their own budgets for farm research, grain prices will have to rise to improve incentives for bioengineers to switch from medical work to agricultural research.[52] In addition, many

environmentalists have joined forces with budget cutters and are now campaigning furiously against agricultural biotechnology. For instance, consumer groups and retailers in several EU countries have protested against the introduction of a genetically modified soybean developed in the United States. Soya is used in 60 per cent of processed foods, and there is concern that consumers will have no choice about whether to eat the modified version. The soybean has been approved by the EU as safe; the protests derive from the fact that the US product is neither labeled nor segregated from other stocks.

In this regard, three naked women enlivened the November 1996 World Food Summit in Rome, brandishing signs at the US Secretary of Agriculture demanding that the summit "Ban the Gene Bean," a reference to the controversial practice of genetically modifying soybeans.[53] While it might be easy enough to classify the protesters and their organizations as extremists with fanciful dreams of influencing policy, the following example indicates they are closer to the mainstream than their attire would suggest.

On 5 December 1996 Britain warned the United States not to try to force genetically modified maize onto the European market while concerns remained about its safety for human and animal health. In a stinging public demarche to Washington, John Gummer, the UK Environment Secretary, said in a BBC radio interview: "It is true that the Americans are trying to force this onto Europe without us making our own minds up about it. One of the important reasons for the EU is that we are strong enough to say to the Americans that we decide what we want in our food chain and not you."[54] The tough UK stance occurred during heightened consumer concern about food safety in Europe following the "mad cow" crisis in 1995 and 1996. The European Union banned exports of British beef after scientists discovered a link between "mad cow disease" and a new variant of Creutzfeldt-Jakob disease, a fatal human brain illness.[55]

Senior US trade and agriculture officials have written to the European Commission expressing dissatisfaction at EU delays in opening the market for modified maize and for rice. The US stake in the outcome is substantial; the EU, mainly Spain and Portugal, imported about $500 million of US maize in 1995. While only about 0.6 percent of this season's US maize crop consists of the modified variety, EU officials have warned that all US maize could be blocked if it cannot be segregated. The dispute threatens to create a trade row if it is not resolved soon.

China's Disappearing Act

As the largest potential source of new demand for grains, China will continue to attract considerable attention in discussions of food production. Prospects for developing more farmland in China are discouraging, a significant change from the height of the Green Revolution, when China's rising production of grain was nothing short of phenomenal. China now has an estimated 125 million hectares of cropland, but the total has been shrinking for some time and is likely to continue to decline as China industrializes.[56] Consequently, a rising appetite for grain-intensive meat in the diet of prosperous Chinese, and no substantial additions to arable land, will cause China to become a large importer of grain. How large an importer is a subject of contentious debate among international agriculture experts.

In 1995, Lester Brown, the world's leading modern Malthusian and President of the Worldwatch Institute, said that China will lose roughly half its grainland by 2030, as roads, factories, and golf courses spread across the countryside. If he is right, China's imports of grain would overwhelm world food markets and lead to skyrocketing grain prices.[57] He shocked grain dealers with a forecast that China would import 216 million tons by 2030.[58] While all the experts agree that China will be a major grain importer in the future, few are as pessimistic as he; most think the loss of land and the size of Chinese grain imports will be significantly less than what Brown predicts.

New research by a team of US and Chinese economists at the Organization for Economic Cooperation and Development (OECD) reports that Chinese grain imports will stabilize at levels much lower than predicted. The authors of the study have developed projections which run counter to Brown's earlier predictions.[59] Their OECD report says China will become a significant importer but "will not empty" world grain markets. Under the baseline scenario in their research, grain output is expected to reach 410 million metric tons by 2000, well below Chinese official projections of 455 million metric tons. OECD says China's grain imports are likely to jump to around 40 million metric tons annually by 2000 from just three million metric tons at the start of the 1990s, but will stabilize at around 43 million metric tons from 2010.

The OECD study agrees with Brown that higher imports will reflect rising demand for feed grain and meat, as well as a slowdown in supply due to reduced investment in agricultural research during the late 1980s. But the study disagrees with Brown when it argues that China itself might limit grain imports, especially if these began to affect world prices severely. Not only would that be an incentive to raise domestic production, but there might be foreign exchange constraints on large grain imports. Poor port and transport infrastructure could also impede imports, while China's leaders have long been constrained by a desire for self-sufficiency.[60]

Assuming that the OECD study on China reflects a reasonable scenario based on defensible assumptions, the amount of disappearing cropland in China means that a global expansion of farmland can play only a small part in boosting world food supplies. That being the case, a much greater part will have to come from squeezing more from existing land. In essence, that's what the Green Revolution did.

The Immediate Future

Pessimists claim that the gradual slowdown in productivity gains has led to a genuine crisis in the world food supply. They claim that recent data finally provide conclusive indicators that the world is running out of food, and at first glance they appear to be right. The food supply was squeezed during 1994 and 1995; for instance, there's no denying that food prices rose and food stocks fell during this period. Between June 1993 and May 1996, food prices rose by 47 percent after many years of decline.[61] In particular, corn-futures prices rose 57 percent from the start of 1996 to a record-setting $5.48 a bushel by July. Wheat-futures prices also jumped to an all-time high of about $7 a bushel over the same period, effectively double the price that had been stable since early 1995.[62] The higher prices did severe damage to many African nations, which are net importers of food. According to the UN Food and Agriculture Organization (FAO), higher prices in 1995 alone increased the cost to developing countries of cereal imports by about $4 billion.[63]

Between June 1993 and May 1996 the world's grain stocks fell to 13 percent of annual consumption, the lowest level ever recorded.[64] Even in the United States, "the breadbasket of the world," US granaries in early 1996 held a precariously low amount of grain--just 426 million bushels of corn at one point in September, the lowest level since the 1970s.[65]

Should one conclude that the whole world, as opposed to Africa and South Asia, is in fact running out of food? Perhaps there's another explanation. At the World Food Summit, elder statesmen were curiously relaxed in contrast to the alarm shown by many summiteers. The elders seemed satisfied that complacency about food security had been shaken, but perhaps they were thinking that they had seen the picture before. These sober and dispassionate individuals from such places as the World Bank may have remembered a similar conference in Rome a quarter century earlier. Then, as now, the mood was equally alarmist. Then, as now, the world was running out of food, or so it seemed. The pessimists at the 1974 conference predicted dire consequences, even mass famine, which proved wildly wrong.

Admittedly, the market signals in 1994 and 1995 did show some kind of shortage, but not all shortages are the same. A close examination of data from this period reveals no structural shortage that one would anticipate if the world food supply had in fact reached full production capacity. Instead, unusual circumstances of a short-term and reversible nature account for the rising prices and de-stocking of grains. Three factors--the weather, the fall of the Soviet Union, and the withdrawal of land from production--are particularly atypical of a systemic crisis in food production.

The high prices reflected a record low crop production due to unfavorable weather. Conditions for wheat stayed dry through May 1996, while weather for corn and soybeans remained dry in key producing regions into June 1996. Second, food production in the former Soviet Union fell dramatically because subsidies had been withdrawn from inefficient state farms. Compared with a peak production year in 1989, production in 1994 was down fully 40 percent.[66] That trend should reverse itself as economic reforms take hold in Russia and the Ukraine. And third, the fall in grain stocks reflects policy changes in the United States and Western Europe to rein in the huge overproduction of grain that had occurred in the 1980s. After their grain surpluses had reached embarrassingly high levels, the governments in Washington and Brussels (the EU) began paying grain farmers handsomely to let some of their land lie fallow. Over the past ten years, for example, US farmers took about 37 million acres of cropland out of cultivation.[67]

But not long after concerns about grain supply pushed grain prices to record-breaking levels, grain prices dropped. Corn-futures prices fell about 50 percent per bushel between July and December 1996, from $5.48 to the year's low of $2.60. Similarly, wheat-futures prices fell abruptly during the same period, from $7 a bushel in July to below $4 a bushel by December.[68]

Why the nose-dive in grain prices? The two main reasons were the better-than-expected weather and a significant surge in worldwide grain supply. Timely summer rains and warm temperatures late in the 1996 growing season boosted the 1996 US corn and soybean crops to near-record levels. Second, farmers responded to higher prices by bringing land back into production; US farmers added eight million acres of corn in 1996, and large crops came from Europe, Australia, and South America. In short, markets are adjusting to the weather and to various policy decisions, just as Adam Smith, the English free-market economist, would have expected.[69]

Grain prices in 1997 are likely to range well below the unusually high prices of the first half of 1996; commodity analysts on Wall Street estimate that wheat will average about $4 a bushel and corn about $2.60. Several factors will add to the further growth in grain supplies. Moist growing conditions in South America will lead to record crops there, and freedom-to-farm legislation--passed in the United States in 1996, and gaining momentum worldwide--will allow farmers to build up grain supplies when market conditions warrant. Finally, genetically enhanced crops could increase yields as that form of biotechnology gradually becomes more acceptable.[70]

Conclusions

Even if a world food crisis is not imminent, we should ask ourselves whether trends have indeed invalidated Malthus's thesis, or whether they have merely transformed or deferred it. One thing is certain. Given that the population in 2035 could be about twice what it is today, there will have to be a lot more grain available to meet the demand.

Most of the ways to grow more grain result from greater farm output, which can be increased either by developing new farmland or by making existing farmland more productive. The world food supply also benefits from reducing the demand for feed grain (e.g., reducing population growth) and by developing new sources of food. At the same time, there are many seemingly marginal changes in how the world manages farming that could substantially affect chronic regional shortages. Efforts to make better use of existing cropland, to reverse deforestation, to vest women with rights they now lack in some agricultural communities, to modify traditional farming practices, to reduce losses of each harvest to pests and decay--each and all could increase the amount of grain that is available each season for consumption by humans and animals.

Profound systemic change, such as was prompted by the principles of the Green Revolution, is more problematic. Biotechnology, once the hope of many agricultural specialists, may never rival the Green Revolution's legacy, but it is also probably too soon to write it off. Unanticipated breakthroughs, new theories, proof that genetically altered foodstuffs do no harm to humans when consumed directly or through animal protein--all have the potential to stimulate quantum shifts in the global supply of food. Yet we've seen enough constraints to question anyone's forecast of a food cornucopia.

In the near term, strategists need to avoid the twin pitfalls of complacency about a world full of food and doomsday alarms about a global food crisis. What is needed from world leaders is an unprecedented level of cooperation in the formulation of a long-term international food strategy. One consequence of failure could be resource-driven conflicts that might have been avoided had policymakers understood the nature and extent of the world food supply problem and taken appropriate steps to deal with it.

What is needed to avert that outcome is a comprehensive strategy that synthesizes diverse approaches to improving the growth, harvesting, storing, and distribution of the annual crop of grains, while prioritizing resources for the most promising areas of improvement. Thus, biotechnology, the sensible expansion of cropland, the responsible extension of the Green Revolution technology in neglected arable land, continued basic research into plant genetics, and smarter public policies all are important in this holistic approach. Curbing population growth and other demand reduction programs are also essential parts of any plan to stabilize the world food supply for the long term. None of these objectives will be easy to define or carry out; they all have the potential to affect profoundly the values, cultures, societies, and beliefs of the affected peoples.

When Norman Borlaug received the Nobel Prize in 1970 for his research leading to the Green Revolution, he warned that the new methods would provide only a limited respite, 30 years at most, in which governments could develop and carry out supply and demand policies for dealing with the world food supply challenge.[71] As we approach the end of Borlaug's window of opportunity, the world is still groping for that strategy. Until we develop one, there will continue to be those who yearn for simple solutions to the complex problems of world food supply and demand.

The real danger is to relegate the world food supply to the backwater of strategic studies. Strategists need to understand that the world food supply is a global challenge that bears most heavily on the peace and prosperity of the international system. World leaders have an unprecedented opportunity to move this global issue to the top of their agendas. If they fail, their successors may have to deal with the problem "when it comes to visit" as a major and enduring crisis in the early decades of the next century.

NOTES

1. For a relatively optimistic view of the world food supply, see Tim Dyson, "Be Wary of the Gloom," downloaded from *People and the Planet* home page, the Internet, 24 November 1996 (http://www.oneworld.org/patp/index.html); also see Tim Dyson's upcoming book, *Population and Food: Global Trends and Prospects*, to be published early in 1997.

2. For a comprehensive US government analysis of the international supply, demand, and trade of major agricultural commodities to 2005, see US Department of Agriculture, *Long Term Projections for International Agriculture to 2005*, Commercial Agriculture Division, Economic Research Service, Staff Paper No. AGES 9612, August 1996. In this regard, I want to thank Rip Landes and all of the impressive people at the foreign office of the US Department of Agriculture for providing me data on this complex subject.

3. See Lester R. Brown, "Ninety Million More," in his *Full House: Reassessing the Earth's Population Capacity* (New York: W. W. Norton, 1994), ch. 3; and Lester R. Brown, et al. "A Stable World Population," in his *Saving the Planet: How to Shape an Environmentally Sustainable Global Economy* (New York: W. W. Norton, 1991), ch. 7.

4. See *Closing the Gender Gap: Educating Girls* (Washington: Population Action International, 1994).

5. George D. Moffett, *Global Population Growth: 21st Century Challenges*, Headline Series No. 302 (Ithaca, N.Y.: Foreign Policy Association, Spring 1994), pp. 68-69.

6. Patrick Webb, "A Time of Plenty, A World of Need: The Role of Food Aid in 2020," *International Food Policy Research Institute (IFPRI) 2020 Brief No. 10* (Washington: IFPRI, 1995), p. 2.

7. See Thomas Robert Malthus, *Population: The First Essay*, foreword by Kenneth E. Boulding (Ann Arbor: Univ. of Michigan Press, 1959).

8. *The Economist*, 16 November 1996, p. 18.

9. See Lester R. Brown, "Moving Up the Food Chain," in his *Who Will Feed China? Wake Up Call for a Small Planet* (New York: W. W. Norton, 1995), ch. 3.

10. Ibid., pp. 44-53.

11. See George D. Moffett, *Critical Masses* (New York: Viking Penguin, 1994); "Science Summit on World Population: A Joint Statement by 58 of the World's Scientific Academies" and the "African Academy of Sciences on Population," *Population and Development Review*, 20 (March 1994).

12. Ibid.

13. World Resources Institute et al., *World Resources: 1996-97* (Oxford Univ. Press, 1996), pp. 226-27. Hereafter *WR*.

14. *The Economist*, p. 23.

15. Food and Agriculture Organization of the United Nations, *The State of Food and Agriculture 1994* (Rome: FAO, 1994), p. 11. Hereafter FAO.

16. See Jeffrey Alan Lefebvre, *Arms for the Horn: U.S. Security Policy in Ethiopia and Somalia, 1953-1991* (Pittsburgh: Univ. of Pittsburgh Press, 1991).

17. See Food and Agriculture Organization of the United Nations, FAOSTAT-PC, on diskette (Rome: FAO, 1995).

18. See Margaret Missiaen et al., US Department of Agriculture, *Food Aid Needs and Availabilities: Projections for 2005*, An Economic Research Report, GFA-6, October 1995.

19. Patrick Webb, "A Time of Plenty, A World of Need: The Role of Food Aid in 2020," *International Food Policy Research Institute (IFPRI) 2020 Brief No. 10* (Washington: IFPRI, 1995), p. 2.

20. *The Economist*, p. 18.

21. A market friendly economic development strategy includes a stable macroeconomy, a competitive microeconomy, investment in people, and global linkages. For a concise discussion of this concept, see The World Bank, *World Development Report 1991: The Challenge of Development* (Washington: Oxford Univ. Press, 1991), pp. 6-9.

22. Nikos Alexandratos, ed., *World Agriculture Towards 2010, An FAO Study* (Chichester, UK: John Wiley and Sons; and Rome: Food and Agriculture Organization of the United Nations, 1995), pp. 38-44.

23. See Lester R. Brown, "Overharvesting the Oceans," in his *Full House*, ch. 5.

24. *The Economist*, p. 22.

25. Alexandratos, p. 14. One hectare equals 2.471 acres.

26. Ibid., p. 174.

27. *WR*, p. 232.

28. *The Economist*, p. 22.

29. The World Bank, *World Development Report 1992* (Washington: The World Bank, 1992), p. 135.

30. Alexandratos, p.170.

31. *The Economist*, p. 22.

32. Alexandratos, p. 155.

33. See Kent Butts' article on the strategic importance of water in this issue of *Parameters.*

34. Alexandratos, p.160.

35. Pierre Crosson and Jock R. Anderson, "Resources and Global Food Prospects: Supply and Demand for Cereals to 2030," *World Bank Technical Paper No. 184* (Washington: The World Bank, 1992), pp. 47-53.

36. *The Financial Times-On Line*, 10 December 1996.

37. Ibid.

38. See Frances Cairncross, *Costing the Earth: The Challenge for Governments, the Opportunities for Business* (Boston: Harvard Business School Press, 1992).

39. For more on "the fertilizer fall-off" see Brown, *Full House*, pp. 121-31.

40. Alexandratos, p. 152.

41. Ibid., p. 39.

42. *The Economist*, p. 22.

43. Vaclav Smil, "How Many People Can the Earth Feed?" *Population and Development Review*, 20 (June 1994), 267.

44. Moffett, *Global Population Growth*, p. 36.

45. Ibid., pp. 35-36.

46. P. Berck and D. Bigman, *Food Security and Food Inventories in Developing Countries* (Wallingford, UK: Cab International, 1993), p. 19.

47. Brown, *Who Will Feed China?*, p. 78.

48. Brown, *Full House*, pp. 139-40.

49. Ibid.

50. *Economist*, p. 23.

51. Ibid.

52. Ibid.

53. Ibid.

54. *Financial Times On-Line*, 5 December 1996.

55. The origin of consumer concern cited here can be traced back to a British government announcement that there appeared to be a link between "mad cow" disease, also known as bovine spongiform encephalopathy or BSE, and ten cases of a new variant of the Creutzfeldt-Jakob disease, a rare but devastating human disease that progressively and fatally destroys brain tissue. The announcement caused widespread panic among British consumers and prompted a temporary ban on British beef in Europe.

56. Alexandratos, p. 15.

57. For an alarmist view of potential Chinese cropland loss, see Brown, "The Shrinking Cropland Base," in *Who Will Feed China?*, ch. 4.

58. *Financial Times On-Line*, 27 November 1996. For a copy of this OECD study entitled *China in the 21st Century*, contact the Publications Service, OECD, 2 rue, André-Pascal, 75775 Paris Cedex 16.

59. Ibid.

60. All studies on the world food supply are based on important assumptions. In this case, the OECD authors (Justin Lin of the University of Beijing, Huang Jikun of the Chinese Academy of Agricultural Sciences, and Scott Rozelle of

Stanford University) note that their forecast is subject to wide variations depending on population and income growth. With high income growth total grain demand would reach 647 million metric tons by 2020, compared with 594 million metric tons under the baseline scenario. Equally, with high investment in research and irrigation, China could lift output to 627 million metric tons against 552 million under the baseline scenario.

61. *The Economist*, p. 21.

62. *The Wall Street Journal*, 2 January 1997, p. R35.

63. *The Economist*, op. cit.

64. The Economist Index of Food Prices, as cited in *The Economist*, p. 21.

65. *The Wall Street Journal*, op. cit.

66. See FAOSTAT-PC, op. cit.

67. *The Economist*, p. 22.

68. *The Wall Street Journal*, op. cit.

69. *The Economist*, p. 22.

70. *The Wall Street Journal*, op. cit.

71. Moffett, *Global Population Growth*, p. 29.

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