



# Solutions to Close the Gap

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Sustainably meeting the world's growing needs

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The previous chapters have made two things quite clear. First, given trends in population growth, economic growth and changing diets, the world will have to at least double its food production by 2050. Because of environmental and practical limitations, this expanded harvest will have to come from roughly the same amount of land in production today, probably with less water.

Second, there will be grave consequences, from ecological, humanitarian and national security perspectives, if we do not meet that goal. As a consequence of the recent global economic crisis, malnutrition-related deaths have again increased—to an estimated 25,000 people each day—and one billion people, about 15 percent of the world's population, do not get enough to eat on a regular basis. Hunger and poverty go hand in hand. Defense Secretary Robert Gates noted a few years ago, before he came to the Pentagon, that “Poverty breeds hatred, discontent and desperation. Poverty and despair are the breeding grounds of instability and terrorism.” Famine and chronic food shortages can lead to mass migrations that can destabilize countries and entire regions. Governments that cannot feed their people invite their own downfall.

The need is evident. But achieving food security is complex and challenging. It will involve the insights and contributions of many different disciplines, significant and sustained investments, changes in behavior and in centuries-old agricultural practices, the waging and winning of difficult policy fights, and overcoming powerful political interests, in rich and poor countries alike. Another challenge will be apathy. Until rich-country voters and politicians are motivated to allocate more assistance, and poor-country leaders really begin to lead and invest in smallholder agriculture, too little will be accomplished.

Our years of experience in agricultural research, in farmers' fields, among policymakers and with public and privately-funded foreign assistance programs have taught us that while developing new crop varieties to increase potential yield is absolutely necessary, it is far from sufficient. We also know that even though much more agricultural investment and assistance is needed, simply throwing money at the problem won't solve it either.

In attempting to bring the Green Revolution to Africa, for instance, agricultural experts developed impressive packages of technology during the 1980s that, on farmers' demonstration plots, produced yields two-to-three times higher than average. Yet a Green Revolution failed to take off, because Africa, unlike Asia and parts of Latin America, lacked roads, railroads, power grids, irrigation systems, market institutions to deliver seed and fertilizer and to handle the increased harvests, and farmer incentives from governments to encourage modernization. It failed because Africa agriculture, largely rainfed, is more risky than the irrigated agriculture of Asia and Latin America, and risk mitigation strategies, such as irrigation and crop insurance, were not part of the agenda. Malaria, AIDS, malnutrition and widespread illiteracy, especially among women, weakened the capacity of farmers to innovate and increase their productivity. It also failed due to the lack of political will on the part of African politicians to modernize agriculture. Rather, they saw it as part of a colonial past, and wanted to leapfrog into the future as industrialized nations.

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<sup>1</sup> Work on this chapter commenced before the death of Dr. Borlaug in September, 2009. It was completed with the help of Christopher Dowswell, aide de camp to Dr. Borlaug for 30 years and a frequent co-author of papers with him.

Environmental degradation also has greatly affected African agriculture over the past three decades. Increasing population pressure and long-term nutrient depletion have overwhelmed traditional systems of shifting cultivation to restore or recycle plant nutrients. Today, continuous cropping is increasingly the norm, without viable systems to restore soil fertility. This has resulted in a progressive—and now often dramatic—degradation of the soil resource base. It has also led to serious watershed deterioration (soils, water, forests) and environmental damage. Declining soil fertility has also been a contributing factor to conflicts between agriculturalists and pastoralists, and probably was an underlying cause of the civil wars in Burundi and Rwanda in the 1990s (Sanchez et al, 1997). Unless soil fertility is restored and protected on African farmlands, other investments in agriculture will have little effect.

American efforts to develop and implement a new Africa-specific smallholder farmer strategy were hampered because foreign assistance for agriculture was drying up. U.S. spending on foreign assistance for agriculture dropped by 70 percent since the 1980s. At the same time, U.S. foreign aid programs focused on structural adjustment strategies that concentrated on private sector development and largely abandoned capacity-building of public sector institutions. Both are needed, especially in emerging nations such as those of Africa, and both must be strengthened in tandem. By the time the 2007-2008 food crisis struck, aid to agriculture amounted to only 4 percent of global official development assistance. Only recently has the situation begun to change.

Funding dropped for a variety of reasons. For one, low food prices lulled the international community into complacency. For another, the young democracies that emerged after the Cold War sought to shore up the political base for reform by focusing development efforts in urban areas, where the votes are, and neglected their rural constituencies. The 2007-2008 food price crisis helped bring agriculture's critical role in development into sharper focus, we hope, but money is no panacea. Another reason, less often discussed, for the decline in assistance and investment in agriculture is that many of the programs simply didn't work. As a World Bank official in Southeast Asia told a Senate staffer looking into the food price spike in 2008, "Agriculture development proved to be a challenging agenda, with a lot of dead-ends. We have to ask if there are good ways that we can support it." A frustrating inability to accomplish the mission led to the decline in support for developing world agriculture, he suggested: "Donors and lenders were being burned. They were accused of wasting money. There was a reputational risk in taking on these types of projects." When World Bank President James Wolfensohn opened Rural Week 1997, he noted that the Bank had fewer than 100 professional agricultural staff out of a total of 4,000 professional staff.

The experience of the Asian Development Bank (ADB) is instructive. Although Asia is still home to two-thirds of the world's poor, agriculture is no longer one of the "core" missions of the bank. (Its five main areas of operation: infrastructure, environment (including climate change), regional cooperation and integration, finance sector development, and education.) This is partly because of past ADB successes in agricultural development, but also because recent projects have not done well. In its 2006 Annual Evaluation Review, the bank noted that agriculture projects "had the worst outcomes" in both the very poorest countries and in the better-off borrowers. The success rate was less than 50 percent for most types of agricultural projects, and in the poorest countries that get loans at subsidized rates, "the success rate exceeded 50 percent only for irrigation and rural development projects and for a small number of fertilizer plant projects." Similarly, the African Development Bank (AfDB), allocates only a small portion of its budget specifically to agriculture, reasoning that other institutions can do a better job. Officials say they can do more for agriculture through infrastructure, such as roads and dams.

So, yes we need to spend more money, but we need to spend it wisely. An important first step toward that wisdom is to improve donor coordination. Too often in the past, the World Bank and

the other multi lateral development banks, bilateral donors and regional assistance agencies pursued their own agendas. Coordination should encompass a set of development principles that respond to the needs of each host country, and that include a division of labor among donors. Equally important, host countries have to step up their commitment to agriculture.

During the high-growth years in Asia, governments in the region devoted 10 percent of their budgets to agriculture. In Africa and most other agriculture-based countries today, the figure averages only four percent, according to the World Bank. African Heads of State have repeatedly said that they want to see more vibrant forms of agriculture, ones that drive the overall economy and build more prosperous rural sectors. In 2003, these leaders formed the New Partnership for Africa's Development (NEPAD), which called for a doubling of public resources going into agriculture. A Comprehensive Africa Agriculture Development Plan (CAADP) has been formulated, which calls for upwards of US\$ 300 billion in agricultural and rural development investments over a 15-year period, with African governments increasing national contributions to the overall development budgets by 50 percent. NEPAD expects the international community to support Africa's plan for self-development and not to prescribe a plan for Africa. The donor community expects African governments to be much more mindful of the governance process, meeting a higher standard of performance than in the past.

Because achieving food security must be a multi-sector endeavor that goes beyond simply raising crop yields, donors must address the problem in a holistic manner. For the U.S., that means having a single agency in charge of implementing a broad, government-wide strategy. The Lugar-Casey Global Food Security Act designates the U.S. Agency for International Development (USAID) to take the lead, to ensure that chief responsibility for carrying out food security policy is held by an agency with the broad development experience necessary and isn't splintered among the many different departments that may have development programs. Lugar-Casey also would establish a global food security coordinator to develop and oversee a unified approach from a high-level position. These two steps will avoid creating bureaucratic complexities that would slow the battle against hunger and could harm overall U.S. development policy.

The place to start with new spending is on research and development. To double food output by 2050, we will need seeds to cope with changing climate and ever-evolving diseases and pests, crops that can adopt to more varied conditions, plants that pack more nutritional punch, livestock that more efficiently convert feed to meat and milk, better fertilizers, environmentally friendly herbicides and pesticides, new storage and processing technologies and other advances. This should be money well-spent: a major study by the International Food Policy Research Institute (IFPRI) found that the average rate of return on research investment was 78 percent.

The developed countries, including the United States, should re-invigorate the research programs at their own universities and institutes, which have some of the best scientists and technology, and often well-established ways, through the Collaborative Research Support Program (CRSP), to get their discoveries from the lab to the fields.

The developed countries and the international financial institutions should also boost sharply their support for the 15 international research centers around the world linked under the Consultative Group on International Agricultural Research (CGIAR), especially for creating innovative public private partnerships to solve agricultural productivity challenges. Like other international agriculture spending, funding for these institutes fell during the past two decades, creating a deficit in scientific training and the research "pipeline" that will take years to erase.

Take, for instance, the International Rice Research Institute (IRRI) in the Philippines and the International Maize and Wheat Improvement Center (CIMMYT) in Mexico, the two oldest of the international research centers, which helped lead the Green Revolution in Asia. In a sense, IRRI

and CIMMYT became victims of their own success. “One of the consequences of the Green Revolution is that many people believed the food problem had been solved,” one IRRI official told a Senate staffer. In 2007, two European donors said they planned to stop funding IRRI, and at one point early in 2008 it appeared there would be a major cutback by the U.S., which until then had been “a rock” of financial support. “Agriculture just went off the agenda,” an IRRI official said. Funding for developing and international testing of new rice, wheat and maize varieties—which account for 70% of food supply in developing countries-- declined. Training of young researchers, once an CIMMYT and IRRI forte, also fell, so that, for instance, most national scientists today are in their 50s. (Many of the threatened fund cuts at IRRI and its sister institutes never materialized, and there has been a reversal of policy by most donors.)

During the heady days of the Green Revolution, 1970-1990, annual rice and wheat yields grew an average of more than two percent annually. In recent years, that figure has been cut to less than one percent—below the population growth rate. Stronger yield growth is essential for supplies to keep pace with demand. Climate change is almost certain to make food production more difficult. Greater incidence of drought and flooding and more extreme temperatures await the world’s farmers.

This new investment must be sustained over the long-term because breakthroughs take time. For instance, IRRI scientists have developed a new type of rice that can withstand being submerged in water for a long period of time—a valuable trait in light of the potential rise in coastal flooding due to climate change. But it took 18 years to develop with traditional breeding methods. So-called “golden rice,” which is bioengineered to produce beta carotene for Vitamin A and promises to be a major weapon against malnutrition, was first developed in the late 1990s using genetic engineering techniques. But its actual deployment has been repeatedly delayed (it always seems about 3-4 years from commercial release) owing to intellectual property issues and the requisite safety and other tests and modifications.

Renewed investment in crop protection, i.e., research into fighting pests and diseases, is also important. A clear example is the new race of stem rust of wheat that has emerged in East Africa, which is capable of devastating most of the world’s commercial bread wheat varieties. There hasn’t been a major stem rust epidemic globally for more than 50 years, since the virulent race called 15B devastated much of the North America wheat crop during 1950-54. Out of that crisis came new forms of international cooperation in plant breeding, which accelerated development around the world of high-yielding, disease-resistant, broadly adapted wheat varieties. However, in the ensuing years, complacency, increasing barriers to international exchange of plant breeding materials, declining budgets, staff retirements and discontinuity in training programs, weakened international systems of cooperation. This has been evident in the slow international response to a very serious new stem rust race, called Uganda 99, or Ug99, first spotted in Uganda and Kenya in the late 1990s.

Ug99 has now escaped from sub-Saharan Africa and begun its migration to North Africa and the Middle East. It won’t be long before it reaches South Asia and later China, North America and the rest of the wheat-growing world. An international consortium of wheat scientists is scrambling to control this disease before it causes catastrophic losses to the livelihoods of several hundred million wheat farmers and widespread global wheat shortages that will affect prices and the welfare of several billion consumers.

The research agenda should go beyond plants and pests to encompass the entire agricultural value chain. One area badly in need of new impetus is fertilizer—no new ones of consequence have been developed since the 1950s. Fertilizers add one billion tons to our annual food supply, and without synthetic fertilizers, as much as 40 percent of the world’s people couldn’t eat. We need investment credits to bring more nitrogen production capacity online and develop new

phosphate and potassium deposits, new efforts to develop more efficient fertilizers and application methods (currently, only 35-50 percent of the nitrogen applied to the soil ends up in the plant), and development and promotion of precision techniques to raise efficiency rates. Like all other agricultural technologies, fertilizer use should be accompanied by agronomic knowledge transfer, precision farming systems, crop rotations, minimum tillage and other best practices.

At the same time we are rebuilding the major global research institutions, we must start to build research capacity in the developing countries, where higher education budgets are anemic and university laboratories are often in disrepair, if they exist at all. The Lugar-Casey bill calls for the creation of the Higher Education Collaboration for Technology, Agriculture, Research, and Extension (HECTARE) program, which would promote land-grant type universities in developing countries by partnering with U.S. institutions. Such assistance in the 1960s and 1970s helped build effective agricultural education and research institutions in many Green Revolution countries.

Stronger national research institutions would address local problems, stem the brain drain of students flocking to other countries, and make a major contribution to strengthening extension services. They should develop broad based curriculums that cover the entire value chain of food production. Good examples of this approach are the Escuela de Agricultura de la Region Tropical Humeda (EARTH University) in Costa Rica and Zamorano (Escuela Pan-Americano de Agricultura) in Honduras, which prepare graduates for the private sector, particularly for careers as agricultural and rural entrepreneurs. These schools emphasize the importance of practical experience in planning and operating a productive enterprise, and offer courses in business administration, accounting, finance, management and communications skills. With rural development establishing an important role in the fight against hunger, agriculture graduates will have to combine technical and scientific knowledge with applied skills, environmental and social awareness, and entrepreneurial leadership.

Technology alone can't achieve food security for the hungry without broad-based participation by food-insecure people in their own development. After all, half the hungry people today are smallholder farmers and landless rural poor. Technology must be combined with investments in basic education, health care facilities, water resource development, roads and transport systems, power grids and agricultural extension. This last item is especially key to moving discoveries from the laboratory to the small farmer's field, yet is often overlooked in aid programs. A Senate Foreign Relations Committee staff study found that in most food insecure countries, extension services were weak or non-functional. There seems to be little disagreement on the need to improve extension capacity, but, frustratingly, little action to do so.

By instructing farmers in proven best practices, extension can make significant progress in output without waiting for major scientific breakthroughs simply by improving crop management. Great variations exist today in crop yields around the globe. Corn is a good example. The top quartile countries, including the United States, account for nearly half of world production and have average national yields in the 7-11 metric tons per hectare range. However, in the lower two quartiles of countries (where yields are in the 1.5-3 mt/ha range) yields can be increased by 50 to 100%, by introducing improved corn seeds, including hybrids, increasing fertilizer, and improving pest and disease control.

Just as hunger and poverty are two sides of the same coin, so too are agricultural development and poverty alleviation. Studies have shown that in the poorest countries, GDP growth in the agriculture sector is at least twice as effective at reducing poverty as growth in other sectors. As the 2008 World Development Report on Agriculture from the World Bank noted, "Agriculture alone will not be enough to massively reduce poverty but poverty reduction will not happen without agriculture." For a true subsistence farmer, rural development, including off-farm

employment opportunities, must be a priority. While China was doubling agriculture output from 1980-2000, rural industrial employment grew from 1 percent of the industrial labor force to 20 percent. Steps taken to help agriculture will reduce poverty, and vice versa.

In 2000, the nations of the world pledged, as part of a series of development goals, to cut hunger in half and double low-income wages by 2015. In most countries these goals are not likely to be met. We must, therefore, redouble our efforts. The Food and Agriculture Organization (FAO) has argued convincingly for a “twin-track” anti-hunger strategy to achieve food security for poor people. One track calls for accelerated development of commercial agriculture and rural economies. The other track calls for safety net programs to feed those who are too weak or too poor to feed themselves. There are important synergies to exploit between the two tracks. Food-based safety-net programs can enhance food security and simultaneously expand domestic markets, provided that greater priority is given to purchasing domestically produced grain. Programs such as primary school lunch programs and food-for-work rural development programs (infrastructure, watershed reclamation, reforestation, etc) should be promoted, both to cater for chronically food-insecure segments of the population (e.g., AIDS widows and orphans, the aged, and malnourished children) and to help stimulate markets for domestic agricultural production.

Africa is a particular case in point. More than in any other region of the world, food production south of the Sahara is in crisis. High rates of population growth and little application of modern technology have resulted in declining food production per capita, rising food deficits and worsening nutrition, especially among the rural poor. The past decades’ experience in Africa has highlighted the importance of infrastructure in boosting food production and cutting hunger. Africa’s lack of roads, electricity and irrigation has probably been the single biggest obstacle to reproducing Asia’s Green Revolution. Africa has the least developed road networks in the world. In 2005, India had 1,000 km of paved roads per million inhabitants, China 800 km—but oil-rich Nigeria had only 230 km, Uganda 94 km, and Ethiopia just 66 km. Roads are how farmers get their machinery, seeds, fertilizers and chemicals in, and how they get their crop out to market. Most agricultural production in sub-Saharan Africa is generated along footpaths, tracts and community roads, where the most common modes of transport are the legs, heads and backs of women. The largest part of a household’s time expenditure is for domestic transport. Developing an effective and efficient transport infrastructure will not only underpin farmers’ efforts to increase productivity, shift to higher-value commodities, link to markets and get non-farm employment, but also poor-countries’ efforts to improve health, education, and economic growth. As Harvard’s Calestous Juma, a leading expert on technology and farming in Africa, told a recent policy seminar in Washington, “Building roads in Africa will do more for African agriculture than all the plant breeders put together.” Road-building must assume a much larger part of the development and hunger agenda, and is an area ripe for enhanced coordination among donors and recipients.

African governments should also develop mechanisms (largely managed by the private sector) for purchasing more of surplus production to create buffer stocks, which can serve as a strategic reserve for feeding victims of extreme events, help temper the large seasonal grain price swings that occur in unmanaged grain markets, and support expanded social safety net programs. Careful and transparent management of buffer stocks is a challenge that will require the effective collective action of private traders and local and national governments, as well as inter-regional cooperation.

Irrigation and water conservation are two sides of another coin. Irrigated agriculture—which accounts for 70 percent of global water withdrawals—covers some 17 percent of cultivated land (about 275 million ha) yet accounts for 40 percent of world food production and nearly 60 percent of world cereal production. To meet future food demands, the world’s irrigated land must expand. FAO estimates that between 1997/99 and 2030, the area equipped for irrigation in developing countries will increase by 40 million additional ha (FAO, 2003). Most of this growth will occur in

Asia and the Middle East. Africa has the potential to irrigate 20 percent of its arable land, but only 4 percent is now irrigated. Yet under current projections, the irrigated area will increase by only 40 per cent in the period to 2030, from 5 to 7 million ha.

The rapid expansion in world irrigation and in urban and industrial water uses has led to growing shortages. The UN's 1997 Comprehensive Assessment of the Freshwater Resources of the World estimates that, "about one third of the world's population lives in countries that are experiencing moderate-to-high water stress, resulting from increasing demands from a growing population and human activity (World Meteorological Organization, 1997). By the year 2025, WMO predicts that as much as two-thirds of the world's population could be under "stress conditions."

The only way to avoid a future food shortage is with a major boost in water-use efficiency, a "Blue Revolution" to stretch water supplies significantly. As a complement to the new Green Revolution, the new Blue Revolution must wed water-use productivity to land-use productivity. Pricing water delivery closer to its real costs, both for farmers and city-dwellers, will provide important incentives for everyone to save water, although the consequences on equity must be considered. And the politics of raising water prices to farmers are extremely difficult.

Technology can help by improving the efficiency of water use. "More crop from every drop" is the new mantra. For one, developing more water-efficient crops with greater drought tolerance has been a successful line of research, one that has been accelerated through genetic engineering. Water-efficient maize—genetically modified and/or conventionally bred—will soon be on the market.

Other conventional techniques can be widely applied today. Wastewater can be treated and used for irrigation, which could be an especially important source of water for rapidly expanding peri-urban agriculture around many of the world's mega-cities. By using modern technologies such as drip irrigation systems, water can be delivered much more efficiently to the plants and largely in ways that avoid soil water-logging and salinity. In a wheat production method called "bed planting systems" now spreading through China and South Asia, water use is cut by 20-25 percent compared to conventional planting systems. Conservation tillage (no-till, zero-till, minimum tillage), changing to new crops requiring less water (and/or new improved varieties), together with more efficient crop sequencing and timely planting, can also achieve significant savings in water use. Maize, for example, only requires one-third the irrigation required for rice, an important reason why China is planting more maize and less rice. Finally, improved water-harvesting techniques and small-scale irrigation systems offer much promise for smallholder farmers in moisture-short areas.

Another element of infrastructure that has been too often neglected is post-harvest technology, which can cut crop losses and boost food quality and marketability. In developing countries, 20-30 percent of the crop may be lost after it is taken from the field. Even in a middle income country like the Philippines, officials joke that the biggest rice dryer is the National Highway, where grain is laid out in the sun. Poor farmers need to do a better job first of getting their crop out of the field and into secure storage, and second, of adding value to primary products through drying, pressing, grinding, oil extraction, cooking and/or fermenting. The former usually requires 1) timely removal of the crop from the field after it reaches maturity and before it is attacked by insects; 2) mechanized grain threshing to avoid soil, stones, animal refuse, and other contaminants that normally end up mixed in with the grain when threshed using traditional practices; 3) drying in cribs or on patios to ward off the growth of molds; and 4) storage in pest-free structures and containers. The latter calls for the use of small-scale equipment and improved processing technology. Also, packaging and transport are important issues that must be addressed if smallholders are to participate effectively in the market.



The trouble is, such technologies need more capital than improved crop production technologies. Moreover, many of the activities require the hiring of off-farm workers to perform required tasks. Thus, they must be undertaken with a business orientation, generally of two types: family-owned enterprises and/or cooperative business enterprises. Experience has shown that getting them into widespread use remains an important development challenge.

Producing enough food is one thing. Producing the right kind of food and delivering it to poor consumers is another. Even in countries with moderate food insecurity, one can find alarming rates of malnutrition due largely to reliance on a limited range of staple foods. In India, for instance, per capita GDP soared fourfold between 1992 and 2006, yet the percentage of underweight children aged 3 and under dropped only from 52 percent to 46 percent. Indonesia, which has improved its overall hunger index, shows a negative trend in child malnourishment, which rose from 24 percent in 2000 to 28 percent in 2005, according to UNICEF. For the food insecure, of course, the problem is much worse: the FAO estimates that in Africa, just 40-50 percent of children under age 2 have a sufficiently nutritious diet. Experts focus on child malnutrition because it can have lifetime effects: stunting, cognitive deficiencies, and increased vulnerability to disease and mortality. If children under age 2 can be reached, these effects are reversible.

Again, the solution is two-fold. For many poor people, fortifying foods and providing nutrition supplements is a cost-effective answer. We can also use plant breeding and biotechnology to make crops more nutritious—in addition to “golden rice,” for instance, there is “quality protein maize” or QPM, which looks and tastes like regular corn but has the protein punch of skim milk and is now grown on 800,000 ha in the developing world. But people also have to change behavior: we should pursue aggressive public health education efforts to get people to diversify their diets, break old food “taboos”, pay more attention to maternal health and adopt better practices for feeding infants and toddlers.

In fact, women hold a key to greater food production as well, especially in Africa. The Chicago Council on Global Affairs says women and girls provide 80 percent of farm labor in Africa, and 40 percent in South Asia. In Africa, where the AIDS epidemic has left many women as heads of households, they receive less than 10 percent of small-farm credit and own just 1 per cent of the land, according to the World Bank. A typical African farmer may be a woman whose husband has died or moved to the city for work, tending a plot of land too small for a surplus and to which she has tenuous title. She also has to tend a number of children, including orphans of other family members. As the ones who go to the market to sell their produce and processed goods, women have an important advantage in knowing what sells and what doesn't.

Experience shows that investing in women pays off. In fact, when African women were given the same level of training, experience and farm inputs as men, their agricultural yields increased proportionally more than male farmers (up to 22%, according to an IFPRI study). Women with access to education have healthier children. According to a State Department consultation paper, “Economic output could be increased by 15-40 percent and under-nutrition reduced by 15 million children simply by providing women with assets equal to those of men.” All international development programs, not just those earmarked for agriculture, should integrate these considerations into their design and implementation.

So far, we have outlined an ambitious research, development, investment and assistance agenda that should be pursued with vigor and resources, by the developed countries, the international financial institutions, universities, the UN, agribusiness, and the numerous private foundations that have enlisted in the fight against hunger. But such efforts won't have sufficient impact without important policy changes by the developing countries that are home to most of the world's poor and hungry. As often as not, poor harvests come from bad policies, and good policies can

lead to abundance. The disastrous reign of Robert Mugabe has turned Zimbabwe from southern Africa's breadbasket to a basket case, where 60 percent of the population subsists on one meal a day. Ukraine is blessed with unusually fertile soil, its famous "black earth," that could make it an agricultural superpower. But thanks to mismanagement in the Soviet era and neglect since, it is producing far below its potential. China under Mao experienced hunger and famine. Under the market reforms of Deng, which started with farmers and the countryside, China has lifted hundreds of millions out of poverty. From 1990-2002, it cut malnutrition rates by two-thirds to where only 7 percent of children under age 5 are underweight. Same land, same climate; different policies, different outcomes.

Unfortunately, outsiders have little or no leverage to change harmful laws and policies in developing countries, especially when they are rooted in tradition or backed by entrenched political interests. Take, for instance, land tenure. The first Green Revolution occurred on irrigated lands where farmers had relatively secure ownership rights. But Africa has unequal and insecure systems of land tenure, which are major causes of poverty and civil unrest. Moreover, they discourage the long-term investments needed to utilize high-yield varieties and other tools of the Revolution. Traditional pasture rights also conspire against investments in land conservation, leading to growing tensions between pastoralists and agriculturists, and to over-grazing and soil degradation. In many countries around the world, land reform has been focused on political objectives—breaking up large properties to give to the landless—rather than farm yield. Poor people need secure access to land through individual or community ownership, long-term rights, functioning rental markets, or some other means. Especially needed is more access for women to secure land tenure arrangements. Achieving these goals will be a formidable challenge.

Food production turns on a host of such domestic policies, from taxes and investment, to trade regulations and food import/export restrictions, and more. Local activists and outside donors have tried over the years to change the most egregious ones, with mixed success. Beyond individual regulations and policies, developing countries must confront a larger problem to address their food deficits, namely, governance.

The Nobel-winning development economist Amartya Sen has famously written, "No famine has ever taken place in the history of the world in a functioning democracy." But even democracies are not immune from corruption, which former World Bank President James Wolfensohn called a "cancer" on development. Hearings by the Senate Foreign Relations Committee established that many projects funded by the World Bank and others fail to meet their goals because of corruption. Half of the 35 worst off countries in IFPRI's Global Hunger Index also rank in the top 35 of Transparency International's "most corrupt" list. Yet for decades the World Bank refused to acknowledge publicly that corruption was a contributing factor to hunger and poverty. Thankfully, that attitude has changed, but corruption's corrosive impact has not. Any strategy to boost food production in the developing world must include a strong governance component. (Some may complain that when we say poor countries themselves are partly responsible for their food problems, we are blaming the victim. The victims are the poor and hungry; the culprits are the autocrats and political elites, who are always well-fed, no matter how disastrous their policies or corrupt their regimes)

Finally, we should acknowledge that the United States and other developed countries can do more to change their own policies that hobble world agriculture. We should start by creating a global trade system that is efficient, fair and transparent, one that provides new, rich-country markets for poor-country farmers. The Doha round would achieve much of that, but its prospects remain dim. We should recognize that there is a direct link between energy prices and global food inflation and work harder to stabilize energy markets and promote efficiency, alternative fuels and biofuels from agricultural waste. Americans and Europeans should end the farm subsidies that hurt our own economies and distort agricultural policies around the world. The U.S.

should also continue to revise and reform its food aid policy. Conflict, drought and other natural disasters mean we will always need emergency food relief. But it has been estimated that up to 60 percent of the food aid budget doesn't feed anyone; it goes to transportation, administration and other expenses. We can find more cost effective ways to deliver it, and adopt strategies that discourage chronic dependence on donated food and encourage local production over the long term.

Most importantly, Europe must end its hostility to genetically modified (GM) crops, particularly its active opposition to them in Africa. In 2008, GM seeds were planted on 310 million acres across the globe (Clive James, ISAAA, 2009). They are widely planted in the United States (including 80 percent of our corn crop), Canada, Argentina, and Brazil. Asia is about to witness a major increase in GM crop production: China has approved the commercial use of GM rice and maize, while India, already a large producer of GM cotton (as is China) is aiming to release commercial food crop varieties. It seems only a matter of time before most of the world is growing GM crops. Africa must not fall farther behind. GM crops, grown commercially since 1996, are proven safe and have already cut out millions of pounds of pesticide use. The European anti-GM campaign contributes to African hunger in the short run. Unchecked, in the long run it will virtually doom those countries' efforts to adapt their agriculture to changing climate conditions. We hope the recent European Commission decision to approve planting of starch-rich Amflora potatoes in the E.U. represents a change in attitude. At the same time, public sector institutions should increase their role in GM research and development, which until now has largely been conducted by large, multi-national corporations. This would encourage production of GM varieties suitable for small farmers, and help assuage the fears of some in the developing world that use of hybrids and GM seeds will make them hostage to rich-country private sector monopolies. While we must always accord sufficient protection to inventors' intellectual property rights, we should acknowledge that this resentment presents a real political obstacle to use of advanced technology. Government, industry and scientists should sit down together and work out ways to sort out this issue through means similar to the "humanitarian license" for Golden Rice, or public-private partnerships to address the crop needs of the poor.

Is there a single silver bullet that will solve the world's food needs? Clearly not. As we said at the beginning, the solution will be multi-faceted, involving many different disciplines, governmental functions and individual actors, some of them far removed from agriculture itself. But from this copious list of solutions we have presented, we can identify some key recommendations to help guide policymakers, donors, academia and others:

1. Congress should pass the Lugar-Casey Global Food Security Act, and the U.S. government should implement its key provisions, namely, make food security a national priority, create a coordinator to set government policy, substantially increase funding for agriculture assistance, and enlist U.S. universities to strengthen food and farm research in developing countries.
2. The World Bank and other international development organizations should rebuild their agriculture programs that have withered over the years, especially in the area of smallholder farming. They should improve coordination, implement programs that meet local priorities, build local capacity for planning and development, and rigorously evaluate progress and incorporate lessons learned. Their efforts should include such issues as infrastructure, land tenure and governance discussed above.
3. Agricultural research should be reinvigorated, more focused, and funded with a long-term perspective. Scientists and other experts should draw up a comprehensive global research program that identifies the most pressing needs and the most promising avenues of inquiry. They should draw up a rational division of labor among international institutes, universities and industry.

4. The unique problems of Africa need special attention. Working with African partners, a priority should be placed on restoring and maintaining soil fertility, using science and technology to develop more stress tolerant crops, and building robust agricultural extension systems. Programs should be created to help African smallholders grow a mix of basic food crops and higher-value, market-oriented products.

5. Increased water use efficiency must move higher on the agenda. The most powerful tool to achieve this, raising the price of water to the farmer, is also the most politically difficult. Science and technology can develop new seeds to get 'more crop per drop', while policymakers and development agencies must promote better tillage systems, new cropping patterns, more efficient irrigation methods and other proven techniques to cut water consumption.

This outline of prescriptions is long, and many of them may seem too technical, or too difficult to achieve politically. We should not, however, lose sight of the enormous job before us to feed 9 to 10 billion people, 90 percent of whom will begin life in a developing country, and many in poverty. Only through dynamic agricultural development will there be any hope to alleviate poverty, improve human health and productivity, and reduce political instability.

The original Green Revolution won a temporary success in man's war against hunger. Had it been fully implemented, it could have provided sufficient food for all humankind, but only if the pace of population growth were curbed and smallholder farmers throughout the world adopted productivity-enhancing technology. This only happened partially. As a result, two billion people still live in dehumanizing poverty and one billion people still face hunger every year. Hunger is especially severe in South Asia, and is one of the de-stabilizing social and political factors in Afghanistan, Pakistan and Nepal. But the incidence is greater in sub-Saharan Africa, where declining soil fertility, lack of rural infrastructure, illiteracy, poor health, and low-yielding agriculture all undermine economic development and peace.

The need to extend the reach of modern agricultural technologies to those who have yet to receive such benefits is as pertinent today as it was 40 years ago. This new "doubly green revolution" must address the issues of marginal lands as well as ensuring the environmental sustainability of the high potential (irrigated and well-watered) areas. Science and technology—including biotechnology—can play major roles in improving dependability and overall productivity of crop yields and the nutritional quality of our staple foods. But for this to happen, critical issues in technology priority setting and access must be addressed by nations and civil societies.

The United States is the world's greatest agricultural success story. Through science and technology and farmer ingenuity, American agriculture has achieved levels of productivity second to none. Our private agri-businesses have invested heavily in the development of productivity-enhancing technology, not only to the benefit of this country but also the world.

The United States also has a great a tradition, especially in earlier decades, of helping low-income, food-deficit nations to get their own agricultural systems moving. American public institutions—the land-grant universities and colleges, USAID, the USDA, and the U.S. Department of State—played key roles in the transformation of subsistence agriculture, especially in Asia and Latin America. We need to return to this tradition. It is good for the world and the American people.

Lest we forget, world peace will not be built on empty stomachs or human misery. A world in which 40 percent of the total population is marginalized in the global economy is not one where peace or environmental stewardship will prosper. Modern agriculture is not the nemesis of the environment or socio-economic development. Rather it is one of their greatest allies.

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