AGRICULTURAL PRODUCTION: IMPACT AND CHALLENGES

by Dr. Norman E. Borlaug

Keeping Pace with Projected Increases in the Demand for Food

I am now in my fifty-first year of continuous involvement in food production programs in developing countries. During this period, I have seen much progress made in increasing the yields and production of various crops, especially cereals, in many food deficit countries. My first foreign agricultural assignment was in Mexico, where I participated in developing the wheat revolution of the 1940s and 1950s. In the 1960s and early 1970s, much of my efforts were devoted to increasing wheat production in the densely populated countries of South and East Asia, which at the time were the most critical food deficit and famine plagued areas of the world.

Spectacular increases in the yields and production of cereals and other crops in India, China, Pakistan, Indonesia, and Thailand from 1968 to 1985 made this vast region essentially self-sufficient in basic foods. Much of the research information and plant materials that catalyzed this dramatic change in production, producing huge economic returns, was generated by CGIAR centers and a predecessor Mexican Government-Rockefeller Foundation agricultural research and production program. Yet despite a more than tripling in the world food supply over the past three decades, the green revolution in cereal production has not solved the problem of poverty and chronic undernutrition afflicting hundreds of millions of people around the world, who are unable to purchase the food they need, despite its abundance in international markets.

In many of the most productive areas, especially irrigated areas located in warm climates, there are also problems of soil degradation, salinity, and declining water quality, which, if left unchecked, can lead to the permanent loss of prime agricultural land. These are not new problems that resulted from the use of high-yielding, green revolution technology. In most cases, they date back 50 to 100 years or more. The root cause of much of this environmental degradation has been mistaken economic policy—for example, irrigation systems with no provision for drainage—not modern, science-based technology. Low crop yields and little profit have prevented farmers from investing in resource conservation, while excessive subsidies in a few countries have caused misuse and overuse of agricultural pesticides, with resulting environmental damage.

Poets, as well as city folks, love to romanticize agriculture, portraying it as an idyllic state of harmony between humankind and nature. How far this is from the truth! Since Neolithic women domesticated crop species some 10,000 to 12,000 years ago, agriculture has been a battle between the forces of natural biodiversity and the need to produce more food for more people under increasingly intensive production systems. Through advances in science during the twentieth century, world food supplies have increased more rapidly than population and, in general, have become more reliable.

In 1990 global food production of all types was approximately 4.6 billion metric tons of gross tonnage—about 2.4 billion tons of edible dry matter. Of this, 98 percent was produced on land; less than 2 percent came from oceans and inland waters. Plant products constituted 92 percent of the human diet, with about 30 crop species providing most of the world's calories and protein. These included 8 species of cereals, which collectively accounted for 69 percent of the world food supply. Animal products, which come indirectly from plants, constituted 8 percent of the world's diet.

The world food production–distribution dilemma can be illustrated as follows. Had total world food production in 1990 been distributed evenly, it would have provided an adequate diet for 6.2 billion people—nearly 1 billion more than the actual size of the global population. However, had the people in developing countries attempted to obtain 30 percent of their calories from animal products, as those in the United States, Canada, and countries of the European Union, only 2.5 billion people could have been sustained—less than half of the present world population.

These statistics indicate two key problems to feeding the world's people. The first is the complex task of producing sufficient quantities of desired food, and to accomplish this Herculean feat in environmentally and economically sustainable ways. The second, equal or even more daunting, task is to distribute food equitably. The impediments to equitable food distribution are poverty and a lack of purchasing power resulting from unemployment or underemployment, which, in turn, is made more severe by rapid population growth.

At best governments of most low-income food deficit developing countries have foreign exchange to import the minimum amount of food needed to avoid famine and social unrest in urban areas. Yet the problems of hunger and famine are usually greatest in rural areas, where 60 to 80 percent of the population lives. Even if governments had the financial resources to import food for distribution in rural areas, they would be confronted with enormous problems of physically transporting and distributing such commodities among dispersed rural populations in areas often devoid of roads.

Clearly if the problem of world hunger is to be solved, it must begin with expanding food production in low-income, food deficit countries where the majority of the world's hungry people live. Moreover, without the development of agriculture and the achievement of an adequate and reliable food supply, the development of commerce and industry will be forever retarded.

World population will grow by nearly 1 billion people during the 1990s, and by another 1 billion people during the first decade of the twenty-first century. A medium projection estimates that world population will reach 6.2 billion people by the year 2000 and approximately 8.3 billion people by 2025, before, hopefully, stabilizing at about 10 billion toward the end of the twenty-first century. I, however, am becoming more and more skeptical of such "optimistic" projections.

For the foreseeable future, mankind will continue to rely on plants, and especially on cereals, to supply virtually all of its increased food demand. Even if current per capita food consumption stays constant, population growth will require that world food production increase by 4.6 billion gross tons, or 57 percent, between 1990 and 2025. However, if diets improve among the hungry poor—estimated to be 1 billion people, living primarily in Asia and Africa—world food production demand could increase by 100 percent to 9 billion gross tons over this 35-year period. Moreover, this production increase must be achieved in environmentally sustainable ways.

To achieve this goal will require the continuation of aggressive research across many scientific disciplines by both CGIAR centers and NARS to develop progressively more efficient and higher-yielding packages of improved crop production practices. Similarly, the efficiency of technology transfer from research centers to farmers' fields by national agricultural extension systems must be greatly improved.

Keeping CGIAR Science Relevant

The CGIAR centers have undoubtedly played an important role in increasing world food production, but what about their future? The late Dr. F. F. Hill, former Vice President of the Ford Foundation and one of the forces behind the creation of both the first four international agricultural research centers and subsequently the CGIAR, told me in 1968 when we were traveling together in Pakistan viewing the tremendous impact of green revolution wheat production technology, "Enjoy it! Such dramatic changes in yield and commercial production are rare, once in a lifetime events." He said he was pleased to see the key role the centers were playing to bring both the wheat and rice revolutions to fruition, but he went on to warn, "I doubt the centers will have more than 25 years of highly productive life before succumbing to the twin ills of bureaucracy and complacency." If this happened, Dr. Hill thought, it would probably be easier to build a new set of institutions, rather than to try to reform the existing ones. I often ask myself, when reflecting on the current problems of the CGIAR, is Dr. Hill's prediction coming true? I hope not, but I must confess I am fearful. We must not let it happen!

Although scientists at CGIAR centers and NARS certainly have advanced the frontier of knowledge over the past three decades, I believe their more significant contribution has been the integration of knowledge across scientific disciplines and its application in the form of improved crop production technologies to overcome pressing crop production problems. This should continue to be their mission. Moreover, impact on farmers' fields and the alleviation of rural poverty—rather than the number of learned publications generated—should be the primary measure by which the value of CGIAR and NARS work is judged.

Unfortunately, agricultural science, like many other areas of human endeavor, is subject to changing fashions and fads, generated both from within the scientific community and imposed upon it by external forces, especially those that are politically induced which effect the actions of donors. In my own career, I have seen various scientific bandwagons come and go. In the 1930s and 1940s, plant

improvement through the development of polyploid varieties (i.e., the doubling of chromosomes) was promoted as the panacea. By the 1950s and 1960s, mutation genetics was the rage. In the 1970s and 1980s, anther culture, somatic tissue culture, and farming systems research were the craze. In the late 1980s and 1990s, biotechnology and genetic engineering, computer modeling of cropping systems, maximizing biodiversity, low-input, sustainable agriculture, and particularly farmer research have been in vogue.

Each of these lines of research has had, or will have, some beneficial aspects. All have something else in common: their proponents, certainly partly driven by the desire to secure research funds, have too often exaggerated the potential for benefits in new specialized spheres of research, especially in the near-term. Increasingly, I fear, the CGIAR centers are falling prey to highly specific scientific bandwagons that will not do much to solve food production problems in developing countries.

Some of the recent downsizing in the CGIAR, while painful, has probably been for the better, since many centers had grown too big and bureaucratic. In this process, however, staff morale has declined considerably. One disturbing aspect of the reduction in the core budgets of the centers, while special project funding was not affected, has been the distortion brought to overall program plans. As a consequence, friction has increased between different members of center research teams. More broadly, the perception that good career opportunities no longer exist within the CGIAR System needs to be dispelled. Twenty-five years ago, centers were able to attract the best and brightest young scientists, who wanted to direct their talents to helping solve developing country agricultural problems. Is this still true today?

The CGIAR centers should retain the best and brightest of their staff for as long as they can. The notion of forced staff turnover, following a rigid formula, is one of the craziest and nonsensical ideas I have ever heard. Outstanding senior staff members are much more than scientists. They also have strong communication skills and a good understanding of development in general.

Center research managers and decisionmakers need to spend more time on the ground, monitoring what is happening, or not happening. Furthermore, center researchers must strengthen their interactions with NARS, national agricultural extension systems, and farmers, both large and small. Too many have become detached from the realities in farmers' fields, preferring to measure their achievements by the information and products generated, and learned papers published, rather than by assuring the adoption of their technologies in the countryside to increase food production. This should be changed.

Agricultural Extension

Extension has been mentioned, but this process of technology transfer to the small farmer deserves a few more words. While the generation of new technology is essential, it is technology transfer which is currently the weakest link in the research-extension-farmer chain. Imaginative solutions, drawing upon the

experiences of the many development strategies tried over the past 100 years, are required. Their application will not be easy or inexpensive.

Linking CGIAR Research and Production

The transfer of research results from CGIAR centers to farmers in developing countries is heavily dependent upon the capacities of publicly funded national research and extension systems. Privately funded agribusiness is only playing a very small role in technology generation and transfer in African countries at present. Consequently, publicly funded efforts must still be the central components in any strategy to reach the small-scale farmer.

Any strategy to maximize investments in technology generation and transfer must, therefore, find ways to fund adequately and with stability the CGIAR centers, NARS, and national agricultural extension systems. Funding one without the others will not result in significant impact. Rather there is a need to jointly finance all three and to maximize the potential from scientific networking between researchers and extension workers at centers and outstanding NARS and national agricultural extension systems. In particular, it is essential that outstanding national researchers have adequate funds to engage fully in cooperative research with the international scientific community.

One of the important functions of CGIAR centers is to serve as hubs of various research networks. In addition to research collaboration on specific problems, center networking functions include germplasm development, regional agronomic research, and information exchange. This should include a continuing program of practical in-service training for early and mid-career researchers from national programs, as well as opportunities for senior level visiting scientists.

The key point here is that, for a network to function properly, there has to be a lot of interaction between the members of the network. Even with all of the advances in information technology, there is still no substitute for face-to-face contact. This means that NARS scientists need to visit centers regularly, and center scientists need to spend significant time visiting national program scientists and touring agricultural production areas.

Confusion in Policy Circles

Professor Robert Paarlberg of Wellesley College has written an IFPRI Policy Brief,[1] which describes succinctly the consequences of the debilitating debate between agriculturalists and environmentalists about what constitutes sustainable agriculture in developing countries. This debate has confused, if not paralyzed, policymakers in the international donor community who, afraid of antagonizing powerful environmental lobbying groups, all too often have turned away from supporting science-based agricultural modernization projects so urgently needed in Sub-Saharan Africa and parts of Latin America and Asia.

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[1] Paarlberg, Robert L. 1994. "Sustainable Farming: A Political Geography." *2020 Brief* 4(August). International Food Policy Research Institute, Washington, D.C.

This policy deadlock must be broken. In doing so, we cannot lose sight of the enormous job of feeding 8 to 10 billion people. We cannot turn back the clock. The vastly different circumstances faced by farmers, large and small, in different parts of the developing world, requiring different policy postures, must also be recognized. For example, in Europe and in the US Corn Belt, the application of 300 to 500 kilograms of fertilizer nutrients—often partly from animal manure—per hectare of arable land can occasionally result in some local environmental problems. Surely, increasing fertilizer use in Sub-Saharan Africa from 10 kilograms of nutrients per hectare—mostly applied to export crops, such as coffee, tea, cocoa, cotton, pineapple, and bananas—to 30 to 40 kilograms per hectare of arable land is not an environmental problem, but a central component in Africa's environmental solution.

In Asia, where fertilizer use has risen markedly in the last two decades driving the rapid growth in grain production, the nutrient demands of further increases in food production cannot be met without recourse to chemical fertilizer. Research on improving fertilizer use efficiency and recycling organic matter, including human waste, can help, but these means can never meet more than a fraction of the nutrient demands. China, for example, historically the most skillful, efficient, and extensive user of organic fertilizers, including animal manure, human excrement, composted crop residues, and silt from rivers and canals, has also become in the last decade the world's largest producer and consumer of chemical nitrogen fertilizer. China is also the second largest consumer and third largest producer of chemical phosphatic fertilizers. As a result, China today is the world's largest producer of cereals—an achievement it could never have attained without the use of chemical fertilizers.

Another example of the confusion among policymakers is the extent to which fertilizers are lumped in with pesticides in public debate on policy related to agrochemicals, where all pesticides are considered equally dangerous and modern agriculture is branded as polluting. Yet has anyone thought what the development of disease and insect resistance in modern varieties has done for reducing pesticide use? This confusion prevents logical debate on the risks and alternatives that agricultural research has provided mankind.

We have failed to educate policymakers about the strong linkages in the developing world between population, primitive agricultural production methods, environmental degradation, and rural poverty. Without a doubt, the reduction in rural poverty among small-scale farmers is a necessary condition for improved resource conservation and lower population growth. As Mr. Richard Leakey correctly pointed out, "You have to have at least one square meal a day to be a good conservationist or environmentalist." Take, for example, the land-saving effect of employing high-yielding food production technologies to increase output over the last 30 years. By being able to feed many more people from each hectare of land suitable for high-hield agricultural production, many hectares of environmentally sensitive land have been saved. Do most environmentalists and policymakers realize this?

The United States is an illustrative example of this. In 1940, the production of the 17 most important food, feed, and fiber crops totaled 252 million tons from 129 million hectares. Compare these statistics to 1990, when American farmers harvested approximately 600 million tons from only 119 million hectares—10 million hectares less than 50 years earlier. If the United States had attempted to produce the 1990 harvest with the technology that prevailed in 1940, it would have required an additional 188 million hectares of land of similar quality. This theoretically could have been achieved either by plowing 73 percent of the nation's permanent pastures and rangelands or by converting 61 percent of forest and woodland areas to cropland. In actuality, since many of these lands are of much lower productivity potential than those now planted with crops, it would have been necessary to covert a much larger percentage of pastures and rangelands or forests and woodlands to cropland. Had this been done, image the additional havoc from wind and water erosion, the obliteration of forests, the extinction of wildlife species through the destruction of their natural habitats, and the enormous reduction in outdoor recreation opportunities that would have resulted.

Impressive savings in land use have also accrued in China and India through the application of modern technologies to raise crop yields. Had the cereal yields of 1961 still prevailed in 1992, China would have needed to increase its cultivated cereal area by more than three-fold, and India by about two-fold, to equal 1992 harvests. Clearly such a surplus of agricultural land is not available.

Within the last 8 to 10 years, research has developed new appropriate technologies—based on liming combined with appropriate fertilization, and the development of aluminum tolerant crop varieties of pasture grasses, soybean, maize, wheat, and several tree species—that have opened, or will open, vast areas of acid oxisols in Brazil, Colombia, and several African countries to successful cultivation. The application of new improved technology, if supported by continuing research, promises a huge increase in food production over the next 3 to 5 decades.

Twenty-five years ago, in my acceptance speech for the 1970 Nobel Peace Prize, I said that the green revolution had won a temporary success in man's war against hunger, and which, if fully implemented, could provide sufficient food for humankind through the end of the twentieth century. However, I warned that, unless the frightening power of human reproduction was curbed, the success of the green revolution would only be ephemeral.

So far agricultural research and production advances, and the efforts of the world's farmers, have kept gains in food production ahead of aggregate world population changes. However, there can be no lasting solution to the world food-hunger-poverty problem until a more reasonable balance is struck between food production and distribution and human population growth. The efforts of those on the food production front are, at best, a holding operation which can permit others on the education, medical, family planning, and political fronts to launch an effective and sustainable human attack to tame the population monster.

Agricultural scientists, responsible environmentalists, and policymakers have a moral obligation to warn the political, educational, and religious leaders of the

world, as well as the general public, about the magnitude and seriousness of the arable land, food, population, and poverty problems that lie ahead. If we fail to do so in a forthright manner, we will be negligent in our duty and will inadvertently contribute to the pending chaos of incalculable millions of deaths from starvation. The problem will not vanish by itself. To continue to ignore it will make a future solution ultimately more difficult to achieve.

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