Food for All in the 21st Century

BY GORDON CONWAY

To die of hunger is the bitterest of fates
Homer, The *Odyssey*

In his epic poem the *Odyssey*,[1] Homer recounts how Odysseus and his companions have resisted the lure of the Sirens, sailed safely between Scylla and Charabdis, and have come to the island of Thrinacie where the "Sun-god's cattle and plump sheep graze." Odysseus has been warned they are not to be harmed, but his companions succumb to the temptation. "To die of hunger," declares Eurylochus "is the bitterest of fates."[2] They kill the cattle and feast. No sooner have they set sail than Zeus sends a hurricane as a punishment. All perish except for Odysseus.

Today, there are more than three-quarters of a billion people who, like Odysseus's companions, live in a world where food is plentiful yet it is denied to them. If we were to add up all the world's production of food and then divide it equally among the world's population, each man, woman, and child would receive a daily average of over 2,700 calories of energy.[3] This is just about enough to prevent hunger and probably sufficient for everyone to lead active healthy lives.

Yet the harsh reality is great inequality. While in Western Europe and North America average supplies exceed 3,500 calories a day, they are less than two thirds this amount in Sub-Saharan Africa and South Asia (Figure 1). Thirty-five developing countries, including nearly half the countries of Africa, have average supplies of less than 2,200 calories per day. According to

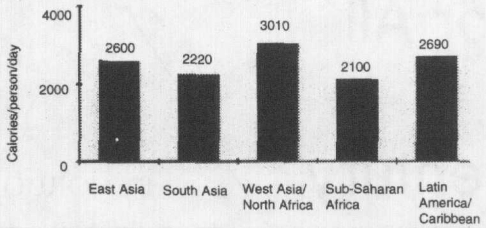

Figure 1. Average per capita calorie supplies in the world.[5]

recent estimates, over 800 million people, equivalent to 15% of the world's population, get less than 2000 calories per day and live a life of permanent or intermittent hunger and are chronically undernourished.[4]

Unlike Odysseus's companions, many of the hungry are women and children. More than 180 million children under five years of age are underweight, that is, they are well below the standard weight for their age. This represents a third of children under five years of age in the developing countries. Young children crucially need food because they are growing fast and, once weaned, are liable to succumb to infections. Seventeen million children under five die each year and malnourishment contributes to at least a third of these deaths. Nearly 400 million women of childbearing age (15–49 years old) are afflicted by anemia caused by iron deficiency. As a result, they tend to produce stillborn or underweight children and are more likely to die in childbirth.

Paradoxically, hunger is common despite 20 years of rapidly declining world food prices.[6] In many developing countries, there is enough food to meet demand, yet large numbers of people still go hungry. Although food prices are low, they remain high relative to the earning capacity of the poor. Market demand is satisfied, but there are many who are unable to purchase the food they need and, hence, to them the market is oblivious.

As Amartya Sen points out, hunger occurs because, in one way or another, people are not entitled to the wherewithal to obtain food.[7] They may be unable to: grow enough food on the land they own or rent or are otherwise entitled to cultivate; buy enough food because their income is too low, or they are unable to borrow, beg, or steal enough money; or acquire enough food as a gift or loan from relatives or neighbors or through entitlement to government rations or aid donations.

Not surprisingly, hunger is closely related to poverty. Poor people have few or no assets, are unemployed or earn less than a living wage and thus cannot produce or buy the food they need. According to World Bank estimates, over one billion people, fully a third of the developing world's population, are in poverty, which is defined as living at less than a $1.00 a day.

To the casual observer, poverty seems to be worse in the cities but, in reality, the urban poor fare better. Although the cost of living may be low in rural areas, there are fewer opportunities to make a living. At the extreme, the urban poor can at least beg or steal. To quote one statistic, the incidence of malnutrition is five times higher in the Sierra of Peru than in the capital, Lima. About 130 million of the poorest 20% of developing country populations live in urban settlements, most of them in slums and squatter settlements. Yet 650 million of the poorest live in rural areas. In Sub-Saharan Africa and Asia, most of the poor are rural poor.[8] Some live in rural areas with high agricultural potential and high population densities—the Gangetic plain of India and the island of Java. But the majority, about 370 million, live where the agricultural potential is low and natural resources are poor such as the Andean highlands and the Sahel.

The first question we ought to ask ourselves is: why should we be concerned? Probably everyone who reads this volume is getting an adequate diet. Does it matter to us that others are not so fortunate? Does it matter to the industrialized countries that many people in the developing countries are malnourished? Part of the answer to these questions is political. The end of the Cold War has not brought about an increase in global stability. Although conflict between East and West has declined, there is a fast growing divide between the world of the peoples, countries, and regions who "belong" in global power terms and those who are excluded. Over two billion people in the world regularly watch television. For the rich, the images on their screens provide a constant reminder of the horrors of natural disasters, civil war, and famine. For the poor, the screens portray the everyday luxuries of the affluent and well fed. Globally, the consequence is a potentially explosive mix of fears, threats, and unsatisfied hopes.

Yet this growing conflict receives relatively little attention in the industrialized countries. The volume of aid going to developing countries is stagnating in real terms.[9] We need to recognize that unless the developing countries are helped to realize sufficient food, employment, and shelter for their growing populations or to gain the means to purchase the food internationally, the political stability of the world will be further undermined. In today's world, poverty and hunger, however remote, affect us all.

At the same time, the growing interconnectedness of the world—the process commonly referred to as globalization—holds the promise of alleviating, if not eliminating, poverty and hunger. Globalization while threatening, on the one hand, to concentrate power and increase division, on the other contains the economic and technological potential to transform the lives of rich and poor alike. Much depends on where our priorities lie and, in particular, whether there is sufficient access by the poor to the economic opportunities created by the products of the new technologies.

Prospects for the Year 2020

We have little time. If nothing new is done, the numbers of poor and hungry will grow. Partly this is because most populations in the developing world are still rapidly growing. By the year 2020, twenty-one years from now, there will be about an extra 2.5 billion people in the developing world who will require food. This is additional to the three-quarters of a billion people who are chronically undernourished today.

While the growth rate of the world's population has declined from a high of about 2.0 percent a year during the late 1960s to

1.4% in the early 1990s, the size of the current annual increment is unprecedented.[10] Nearly 900 million people will be added to the world's population in the 1990s, the largest increase for any decade in history. Until well into the next century, a further 80 million people will be added each year, close to a quarter of a million people per day. If the proportion of the population of the developing countries deprived of an adequate diet remains the same, the number undernourished by the year 2020 could be greater than 1.4 billion.

What is the prognosis for feeding the world's population in the 21st century? It is not possible to foresee, with any accuracy, the situation in the latter half of the next century. Predicting the next twenty-one years is more feasible, and this will be the most critical period; after the year 2020, the annual increments in world population will begin to decrease significantly. If we can achieve a well-fed world by then, it should be possible to meet future demands, providing the resource base has been adequately protected.

Producing forecasts of world food production is complicated. At the time of writing, most attention is being paid to three models. These differ in their scope and level of detail, but what the models all have in common is their attempt to mimic the workings of a world market in which demand for food is met by supply.[11] In each of the models, the forecast is reasonably optimistic. The world population growth rate is matched by a similar growth in food production. World food prices continue to decline. However, the developing countries as a whole will not be able to meet their market demand. In the model produced by the International Food Policy Research Institute (IFPRI), the total shortfall is some 190 million tons and the model predicts this can be met by imports from the developed countries (Figure 2).

In 1990, the developing countries imported about 9% of the total grain they consumed—or 91 million tons. The predicted imports for the year 2020 are double this figure and comprise 11% of consumption. Of the 190 million tons, over 140 million tons will go to satisfy demand in East Asia, West Asia, North Africa, and Latin America. This will be primarily wheat for human con-

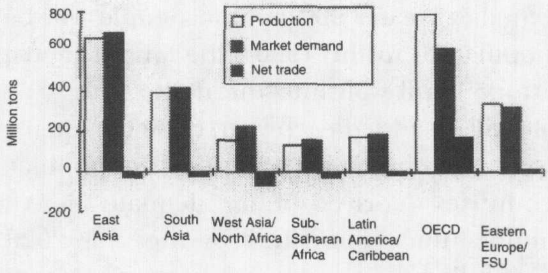

Figure 2. Grain production and market demand (for human and livestock feed) from the IFPRI model for the year 2020.[12]

sumption and maize and other coarse grains for pig and poultry feed. However, in Sub-Saharan Africa and South Asia the proportion of grain going to livestock will remain very small and the imports will be required for human food.

Although overall the models are optimistic, there are pessimistic scenarios for significant regions of the developing world. For a long time to come, food production in Sub-Saharan Africa will be hard pressed to keep up with population increase. According to the IFPRI model, by the year 2020 the excess of market demand for grain over production will be nearly 26 million tons; this compares with current net imports of 9 million tons. And South Asia will require more than 22 million tons, compared with 1 million tons today.

Inevitably, models of this kind raise more questions than they answer. The most important omission from the calculations is the food needs of the poor and hungry. As in the real world, they are simply priced out of the market and their needs are "hidden". The gap between demand and supply that the model closes is the market gap. If we convert the market availability predicted by the IFPRI model to calories per person per day, the improvement over current calories is slight.[13] Then, as now, there is a substantial hidden food gap, particularly in Sub-Saharan Africa, where the average calorie availability remains below 2200 calories per person per day, and in South Asia.

This hidden food gap is the cereal requirement to meet the energy need of the population, less the sum of domestic production and imports. On the basis of a minimum need per person of 3,000 cereal calories per day—which covers food, livestock feed, seed, storage losses, and waste during processing—this translates into a food gap, in terms of cereals, of 214 million tons for Sub-Saharan Africa and 183 million tons for South Asia in the year 2020. If all this food were to be supplied by the developed countries, it would require nearly 550 million tons, three times that predicted by the market model (Table 1).

In human terms, the hidden gap can be translated into a persistence of large numbers of malnourished children. By the year 2020, the total numbers will have declined slightly from the current 180 million to 155 million, but in Sub-Saharan Africa they will have increased by nearly 50%. And, probably, there will still be close to three quarter of a billion people chronically undernourished.[14]

Yield Trends

These models also predict continuing increases in crop yields and production in line with recent trends. There are a number of grounds for questioning this assumption. While production per capita continues to grow in South Asia and, in recent years, in West Asia and North Africa, there is a slowing of growth in East Asia, Latin America, and a continuing rapid decline in Sub-Saharan Africa.

Recent data on crop yields and production suggest a degree of stagnation that is worrying. There is widespread evidence of declines in the rates of yield growth (Figure 3). There are also data indicating greater variability in production in some regions and evidence, albeit largely anecdotal, of increasing production problems in those places where yield growth has been most marked. For example, in the Punjab, although wheat yields are

TABLE 1. THE HIDDEN AND TOTAL FOOD NEEDS BY THE YEAR 2020, ASSUMING A CEREAL NEED EQUIVALENT TO 3000 CALORIES PER PERSON PER DAY[15]

	Million tons		
	Hidden food gap (need less production plus imports)	Imports	Total food gap
East Asia	—	55.8	55.8
South Asia	160.0	22.7	182.7
West Asia/ North Africa		68.5	68.5
Sub-Saharan Africa	187.5	26.1	213.6
Latin America/ Caribbean	11.6	15.0	26.6
Total developing countries	359.1	188 .1	547.2

still growing, this achievement is now being seriously threatened.[17] Of greatest concern is the growing scarcity of water. In some of the most intensively cultivated districts, the ground water table has fallen to a depth of 9–15 meters and is falling at about a half a meter a year. This and other, albeit largely anecdotal, evidence from Luzon, Java, and Sonora suggest there are serious and growing threats to the sustainability of the yields and production of the Green Revolution lands.[18]

Agriculture and the Environment

The causes of this slowing in yield growth are not clear, although one factor is likely to be the cumulative effect of envi-

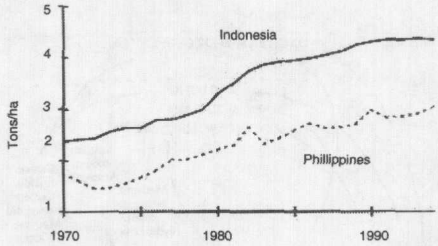

Figure 3. Rice yields in Indonesia and the Philippines.[16]

ronmental degradation, partly caused by agriculture itself. The litany of loss is familiar.[19] Soils are eroding and losing their fertility, precious water supplies are being squandered, rangeland overgrazed, forests destroyed, and fisheries overexploited. The heavy use of pesticides has caused severe problems. There is growing human morbidity and mortality while, at the same time, pest populations are becoming resistant and escaping from natural controls. In the intensively farmed lands of both the developed and developing countries, heavy fertilizer applications are producing nitrate levels in drinking water that approach or exceed permitted levels, increasing the likelihood of government restrictions on fertilizer use.

Increased, and inefficient, use of pesticides and nitrogen fertilizers produces severe pollution, but it is mostly local in its effect. Other agricultural pollutants have the potential for damage on a much larger scale. Although industry is often to blame, agriculture is becoming a major contributor to regional and global pollution, producing significant levels of methane, carbon dioxide, and nitrous oxide (Figure 4).[20] Natural processes generate these gases, but the intensification of agriculture in both the developed and developing countries has increased the rates of emission. Individually or in combination, these gases are contributing to: acid deposition, the depletion of stratospheric ozone, the build up of ozone in the lower atmosphere, and global warming.

Assessing the effects of global warming on agriculture is difficult because the temperature changes and their effects will vary

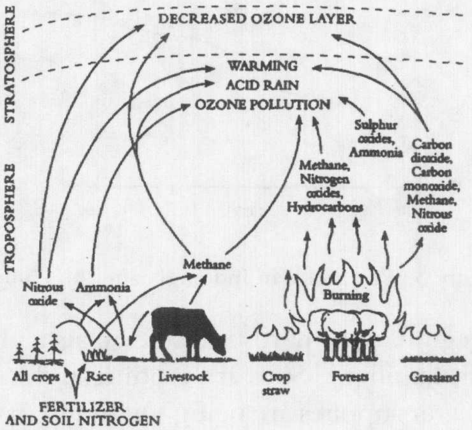

Figure 4. Global pollution caused by agriculture.[21]

from place to place and in ways that are not yet fully predictable. The greatest temperature changes will be at high latitudes, but water availability may worsen at lower latitudes. Heat and water stress may result in yield reductions, especially in the low latitudes, where most of the developing countries are situated.[22] By contrast, in the middle and high latitudes the increased CO_2 will have a physiological effect encouraging crop growth, particularly of so-called C_3 crops like wheat, barley, rice, and potatoes.[23] On average, a doubling of CO_2 produces a 30% increase in yield in these crops.[24] Combined with higher average temperatures, this may increase production of grain and other crops in the developed countries.

Sea levels are also expected to rise, initially from the thermal expansion of the oceans and, perhaps eventually, as a result of the melting of the polar ice caps. The best estimate, on current rates of global warming, is that the average sea level will have risen by up to 15 centimeters by the year 2020.[25] This is not a great amount, but it could lead to a greater risk of flooding in countries such as Bangladesh, where much of the cultivation is precariously sited in the delta of the Brahmaputra.

The most serious consequences are some time in the future, toward the end of the next century. Many doubt whether a rise of a further 0.4°C by the year 2020 is likely to have a major effect on agricultural production.[26] But there may be grounds for concern. There has already been a significant fall in precipitation in the subtropics and tropics since 1960. Another consequence of global warming may be a greater variability in the weather and a higher incidence of extreme weather conditions with unpredictable effects.[27] Floods, droughts, hurricanes, extremely high temperatures, and severe frosts may become more common. In the developing countries, rainfall may become more variable, possibly with a greater frequency of heavy rainstorms creating flooding and exacerbating soil erosion.[28] The rainy season may also shorten, reducing the pre-monsoon rains that are crucial for crop germination.

The Doubly-Green Revolution

These concerns, I believe, add up to a formidable challenge. If, over the next two to three decades, we are to provide enough food for everyone we will have to: increase food production at a greater rate than in recent years; in a sustainable manner, without significantly damaging the environment; and ensure it is accessible to all.

It is a daunting prospect, whose magnitude becomes clear when we examine two contrasting scenarios of how this goal may be achieved.

Under the first scenario, the developed countries continue to produce food well in excess of their requirements and export this excess to meet the demand of the developing countries. If, as the models assume, environmental constraints to increased food production can be overcome and if the food needs of the poor are ignored, then there is little cause for concern. On the IFPRI model forecast, this would entail some 190 million tons of cereals being sold to the developing countries by the developed world in the year 2020.

However, if the food needs of the poor are not ignored, then under this scenario, a further 300 million tons would be required in the year 2020 as subsidized or free food aid (assuming a global requirement for the undernourished of 3000 calories per person per day). This is equivalent to 30 times the current supply of direct food aid and would be extremely costly. Such massive food aid would place heavy burdens on both the donors and the recipients. For example, the environmental costs of such a scenario for the developed countries would be high. Most important, the availability of free or subsidized aid in such large quantities will depress local prices and add to existing disincentives for local food production.

These issues raise doubts about the viability of such a scenario, but a more fundamental objection is to an assumption implicit in the scenario—that a large proportion of the population in the developing world would fail to participate in global economic growth. An alternative scenario, which explicitly addresses this objection, is for the developing countries to undertake an accelerated, broad-based growth, not only in food production, but in agricultural and natural resource development, as part of a larger development process aimed at meeting most of their own food production needs, including the needs of the poor

Implicitly, this scenario recognizes that food security is not a matter solely of producing sufficient food. It is too simplistic to add up a nation's food production and divide by the size of population. Nor is it enough to point to declining food prices. A nation is food secure only if each and every one of its inhabitants is food secure, that is, has access at all times to the food required to lead a healthy and productive life. To achieve this, each individual or, in practice, each household must grow sufficient food or be able to purchase the food from income earned either through selling agricultural products or by engaging in agricultural or non-agricultural employment. For urban dwellers, the only option is to engage in non-agricultural employment, but for the vast numbers of rural poor, if they are not growing enough food to meet their needs, they must have the means to purchase the food they require. For them, food security depends as much on employment and income as it does on food production, and agricultural and natural resource development is crucial in both respects.

Food security, so defined, is also a key determinant of family size. The more confident women are about the immediate and long-term future, the more likely they are to produce fewer children. Enhanced earning opportunities for women, as provided by the production, processing, and trading activities generated by broad-based agricultural and natural resource development, can contribute to lower fertility rates. The greater the degree of security and the higher the level of their education, the more will women take advantage of new opportunities and plan ahead for themselves and their families.

In addition, appropriate agricultural and natural resource development can significantly contribute to greater environmental protection and conservation. Properly designed, sustainable approaches to food production and to forestry and fishery management can reverse land degradation, reduce pollution from agrochemicals, remove pressure on national parks and reserves, conserve biodiversity and, at the same time, increase food security.

Finally, vigorous agricultural and economic growth can stimulate world trade, providing significant benefits for all countries, developed and developing.

I believe these arguments, when taken together, point to the need for a second Green Revolution, yet a revolution that does not simply reflect the successes of the first. The technologies of the first Green Revolution were developed on experimental stations that were favored with fertile soils, well-controlled water sources, and other factors suitable for high production. There was little perception of the complexity and diversity of farmers' physical environments, let alone the diversity of the economic and social environment. The new Green Revolution must not only benefit the poor more directly, but also must be applicable under highly diverse conditions and be environmentally sustainable. By implication, it must make greater use of indigenous resources, complemented by a far more judicious use of external inputs.

In effect, we require a Doubly-Green Revolution, a revolution that is even more productive than the first Green Revolution and even more "Green" in terms of conserving natural resources and the environment.[29]

Over the next three decades it must aim to: repeat the successes of the Green Revolution, on a global scale, in many diverse localities and be equitable, sustainable, and environmentally friendly

The complexity of these challenges is daunting, in many respects of a greater order of sophistication than has gone before. There is certainly no case for abandoning technology. Indeed, at the outset, we have to recognize that there is much technology that has yet to be fully applied. In many regions, average farm yields are below those possible with only a modest increase in inputs and well below those achievable on experimental station conditions. Yet, despite what can be done with these well-tried technologies, I believe the challenge of the Doubly-Green Revolution is only likely to be met by exploiting two key, recent developments in modern science. The first is the emergence of molecular and cellular biology, a discipline, with its associated technologies, which is having far reaching consequences on our ability to understand and manipulate living organisms.

Biotechnology

Hitherto, the success of the Green Revolution has depended on working to blueprints of desirable new plant and animal types through painstaking conventional plant breeding. Biotechnology, and especially genetic engineering, offers a faster route and also the means of tackling the particularly intractable problems of drought, salinity, and toxicity that typically face the poorest farmers on the marginal lands.

A good start has been made in improving rice varieties using these technologies. In 1984, the Rockefeller Foundation launched its International Program on Rice Biotechnology with the aim of facilitating the creation of a number of Asian centers of excellence in biotechnology. To date, over $80 million has been spent on collaborative programs with laboratories in the industrialized world, involving a network of some 700 researchers, fellows, and advisors. Practical results include the development, through tissue culture, of a new rice variety in China, named La Fen Rockefeller, now widely grown in the Shanghai area and producing yields 25% above previous varieties. Genetically engineered rices are now available incorporating the Bacillus thuringiensis gene (Bt), which confers resistance to insect pests. Others confer resistance to bacterial blight, rice stripe virus, and hoja blanca virus. Molecular markers have been used successfully to incorporate multiple resistance in rice in India, China, and Colombia. Of even greater significance in the long term, rice is proving to be a model plant for cereal biotechnology. The major cereals have remarkably similar genomes and the techniques that have been acquired, and many of the genes themselves, have the capability of being utilized in wheat, maize, sorghum, and millet breeding.

The potentials for genetic engineering are almost endless. But there are serious hazards, some easily perceived, others yet to become apparent.[30] Perhaps the most obvious hazard is the possibility of a transferred gene being further passed through natural processes to another organism, with detrimental effects.[31] Many crops have wild relatives and natural hybrids containing genes that increase a plant's competitiveness or resistance to stress could become weeds.

The developed countries are clearly better equipped to assess such hazards. They can call on a wide range of expertise and most have now set up regulatory bodies and are insisting on closely monitored trials to try and identify the likely risks before genetically engineered crops and livestock are released to the environment. So far, few developing countries have put such regulation in place, raising fears that developed country corporations may use developing country sites as unmonitored laboratories with potentially severe consequences. My personal belief is that the hazards are often overstated, but if the evident benefits are to be realized for the developing countries it is the responsibility of all involved to ensure the hazard assessments are as rigorous as in the developed countries.

More important than the potential hazards, at least to my mind, is the question of who benefits from genetic engineering, and indeed from conventional breeding processes. Genetic engineering is a highly competitive business and, inevitably, the focus of biotechnology companies has been on developed country markets where potential sales are large, patents are well protected, and the risks are lower. However, biotechnology companies are now turning their attention to the developing countries, and are embarking on an aggressive policy of identifying and patenting potentially useful genes. Part of the answer to this challenge lies in public—private partnerships where agreements ensure that new varieties are freely available in the developing countries.[32] But I believe that developing country governments and the international agricultural research institutes should also give priority to characterizing and patenting their own genetic materials, to ensure they remain in the public domain.

The Application of Ecology

The second development is the emergence of modern ecology, an equally powerful discipline, that is rapidly increasing our understanding of the structure and dynamics of agricultural and natural resource ecosystems and providing clues to their productive and sustainable management. Specifically, modern population, community and ecosystem ecology has direct relevance for pest, disease, and weed control and for improvements to cropping systems and rangeland management.

The widely successful application of Integrated Pest Management (IPM) to control rice pests in Southeast Asia is proof of what can be achieved. IPM looks at each crop and pest situation as a whole and then devises a program that integrates the various control methods in the light of all the factors present. As practiced today, it combines modern technology, including the application of synthetic, yet selective, pesticides and the engineering of pest resistance, with natural methods of control, including agronomic practices and the use of natural predators and parasites. The outcome is sustainable, efficient pest control that is often cheaper than the conventional use of pesticides.

A recent, highly successful example is IPM developed for the brown planthopper and other rice pests in Indonesia. Under the program, farmers are trained to recognize and regularly monitor the pests and their natural enemies. They then use simple, yet effective, rules to determine the minimum necessary use of pesticides. The outcome is a reduction in the average number of sprayings from over four to less than one per season, whereas yields have grown from 6 to nearly 7.5 tons per hectare. Since 1986, rice production has increased 15% while pesticide use has declined 60%, saving a $120 million a year in subsidies. The total economic benefit to 1990 was estimated to be over $1 billion.[33] The farmers' health has improved and a, not insignificant, benefit has been the return of fish to the ricefields.

The next challenge is to extend the principles of integration established in IPM to other subsystems of agriculture, for example to nutrient conservation, and to the management of soil, water, and other natural resources.

Participation

However, a successful Doubly-Green Revolution will not come from the application of biology alone. If the first Green Revolution started with the biological challenge inherent in producing new high yielding food crops and then looked to determine how the benefits could reach the poor, this new revolution has to reverse the chain of logic, starting with the socio-economic demands of poor households and then seeking to identify the appropriate research priorities.

Biologists will have to listen as well as instruct.[34] There will be no easy solutions and few, if any, miracles in the new revolution. Greater food production will come from targeting local agroecosystems, making the most of indigenous resources, knowledge and analysis. More than ever before, we will have to forge genuine partnerships between biologists and farmers. It will not be enough simply to test new varieties on farmers' fields at the end of the breeding process.[35] Experiments in many parts of the developing world are showing very effective ways of involving farmers right at the beginning, in the design of new varieties and in the breeding process itself.

In Rwanda, a five-year experiment conducted by the Centro Internacional de Agricultura Tropical (CIAT) and by ISAR (Institut des Sciences Agronomiques du Rwanda) involved farmers very early in the breeding process. Beans (Phaseolus vulgaris L.) are a key component of the Rwandan diet, providing 65% of the protein and 35% of the calories, and are grown by virtually all farmers. There is an extraordinary range of local varieties—over 550 identified—and farmers (mostly women) are adept at developing local mixtures that breeders have difficulty in bettering. In the experiment, farmers assessed 80 breeding lines over three years, using their criteria to reduce the number of lines. This was accomplished by inviting farmers to tag favored varieties on the station with colored ribbons. An even wider diversity of criteria emerged. A final set of 20–25 lines was then taken to field trails. Two approaches were tried. In one, the research scientists drew up standard protocols (varieties sown in lines, at given densities) and the farmers were invited to assess the results. The researchers gained valuable feedback, but the process of adaptive testing and diffusion was slow. In the alternative model, the local communities determined the way the trials were conducted. A core group of farmers divided up the varieties and tested them on individual plots. The group then undertook a selection and subsequently was responsible for multiplying and diffusing the most promising varieties.

Participation has long been a slogan of development. For the first time, we now have effective techniques to make it a reality. Under the heading of Participatory Rural Appraisal (PRA), there is a formidable array of methods that permit farmers to analyze their own situations and, most important, to engage in productive dialog with research scientists and extension workers. PRA arose in the late 1980s out of earlier participatory approaches by combining semi-structured interviewing and diagram making.[36] It enables rural people to take the lead, producing their own diagrams, undertaking their own analyses and developing solutions to problems and recommendations for change and innovation. Maps are readily created by simply providing villagers with chalk and colored powder and no further instruction other then the request to produce a map, of the village, or the watershed or a farm. A threshing floor or a cleared space in the village square is all that is needed to produce such a map, often of considerable complexity.

The approach has been rapidly taken up with enthusiasm, particularly by leaders of NGOs eager to find ways of creating greater levels of participation. The range of diagrams has quickly expanded: people who are illiterate and barely numerate can construct seasonal calendars using pebbles or seeds. Pie diagrams—pieces of straw and colored powder lain out on an earthen floor—are used to indicate relative sources of income. Although this is encouraging, it is the use to which the diagrams are put that is important. Maps, seasonal and pie diagrams not only reveal existing patterns but point to problems and opportunities and are seized on by rural people to make their needs felt. The diagrams have become a basis for collective planning and the approach has begun to change the relationship between "expert outsiders" and village people. In every exercise, the traditional position of rural people being passive recipients of knowledge and instruction has been replaced by the creation of productive dialogs.

PRA has now spread to most countries of the developing world, and been adopted by government agencies, by research centers and university workers as well as by NGOs. As a deliberate policy, no central guidebook has been produced, although much has been written and there is an extensive network of practitioners. The methodologies, which are described by a bewildering variety of names, have evolved according to local needs and customs, and reflecting local ingenuity.[37] PLA Notes produced by the International Institute for Environment and Development in London and distributed to several thousand individuals world-wide disseminates good practice and new ideas, so that innovations in the approach reported from an African village are being tried out in an Asian village only a few weeks later.

In some ways, it has been a revolution, a set of methodologies, an attitude and a way of working that has finally challenged the traditional top-down process that has characterized so much development work. Participants from NGOs, government agencies, and the research centers rapidly find themselves, usually unexpectedly, listening as much as talking, experiencing close to first hand the conditions of life in poor households and changing their perceptions about the kinds of interventions and the research needs that are required.

Over the past decade, the development of powerful participatory techniques has produced a revolution every bit as important as the revolution in molecular and cellular biology and ecology. If we can bring all three together, I believe we can feed the world in the 21st century, in a way that is not only equitable, but also sustainable.

Notes

[1]This paper is largely based on my recent book, Conway, G. R., The Doubly Green Revolution: Food for all in the 21st Century (Cornell, NY: Cornell University Press, 1999).

[2](12, 342) Translated in Ash, H.B. (1941) Lucius Junius Moderatus Columella on Agriculture. Vol.1. Loeb Classical Library. Harvard University Press, Cambridge and William Heinemann, London.

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