Food for all in the 21st century by gordon conway essay

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For most of the industrialized countries, there does not seem to be a food problem. They produce a surfeit of food, and health problems have more to do with being overweight than with hunger. In the rest of the world there are periodic famines, but few in the industrialized countries realize that millions of people lack enough food most days of their lives. 1 The Green Revolution was one of the great success stories of the second half of the 20th century. Food production in developing countries kept pace with population growth. Yet today about 800 million people, or some 15 percent 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. 2 Many of the hungry are women and children. More than 180 million children under five years of age are underweight, that is, they are more than two standard deviations below the standard weight for their age.

This represents one-third of the under-fives in the developing countries. Young children cruically 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 one-third of these children’s deaths. Lack of protein. vitamins, minerals, and other micronutrients in the diet is also widespread. About 100 million children suffer from vitamin A deficiency. 3 As has long been known, lack of this vitamin can cause eye damage. Half a million children become partially or totally blind each year, and many subsequently die. As recent research has shown, lack of vitamin A has an even more serious and pervasive effect, apparently reducing the ability of children's immune systems to cope with infection.

Iron deficiency is also common in developing countries, affecting one billion people. More than 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. Anemia has been identified as a contributing factor in more than 20 percent of all postpartum maternal deaths in Asia and Africa. Paradoxically, hunger is common despite 20 years of rapidly declining world food prices. Although in many developing countries there is enough food to meet demand, large numbers of people still go hungry.

Food prices are low, yet 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 irrelevant. Not surprisingly, hunger is closely related to poverty. To the casual observer, poverty seems to be worse in the cities but, in reality, the urban poor fare better. 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 percent 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. 4 Some live in rural areas with high agricultural potential and high population densitiesthe Gangetic plain of India and the island of Java. But the majority, about 370 million, live where the agricultural potential is relatively low and natural resources are poor, such as the Andean highlands and the Sahel. The first question to ask is: Why should we be concerned? Probably everyone who reads Environment is getting an adequate diet. Does it matter 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. While conflict between East and West has declined, there is a fast-growing divide between peoples, countries, and regions who " belong" in global power terms and those who are excluded. Yet this potentially explosive inequity receives relatively little attention in the industrialized countries. The volume of agricultural aid going to developing countries is stagnating in real terms. People need to recognize that unless developing countries are helped to realize sufficient food, employment, and shelter for their growing populations or helped to gain the means to purchase the food internationally, the At the same time, the growing interconnectedness of the world-the process commonly referred to as globalizationholds the promise of alleviating, if not eliminating, poverty and hunger. While globalization threatens to concentrate power and increase division, it also has the economic and technological potential to transform the lives of rich and poor alike.

Much depends on where 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 If nothing new is done, the numbers of those who are poor and hungry will grow. Most populations in the developing world are still increasing rapidly. By the year 2020, there will be about an extra 1. 5 billion mouths to feed. If the proportion of the population of the developing countries deprived of an adequate diet remains the same, the number undernourished 20 years from now could be well over one billion.

What is the prognosis for feeding the world’s population in the 21 st century? Producing forecasts of world food production is complicated. Econometric models are reasonably optimistic. 5 They show that over the next 20 years, the world population growth rate will be matched by a similar growth in food production, and food prices will continue to decline. However, developing countries as a whole will not be able to meet their market demand.

In the International Food Policy Research Institute (IFPRI) model, the total shortfall by 2020 is some 190 million tons, which will have to be imported from the developed countries. Inevitably, models of this kind raise more questions than they answer. Most important, the food needs of the poor and hungry are omitted. As in the real world, they are simply priced out of the market, and their needs are “ hidden.” By 2020, the total numbers of malnourished children will have declined slightly to 155 million, but in subSaharan Africa they will have increased by nearly 50 percent.

Probably, close to threequarters of a billion people will be chronically undernourished. These models also make optimistic predictions about crop yields and production. But there is 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 still increasing, this achievement is now being seriously threatened. 6 Of greatest concern is the increasing scarcity of water. In some of the most intensively cultivated districts, the groundwater table has fallen to a depth of 9-15 meters and continues to fall 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 of the Green Revolution lands. 7 There is also widespread evidence of declines in the rates of yield growth. 8 A combination of causes is responsible. 9 In parts of Asia, declining prices for cereals are causing farmers to invest more in higher value cash crops. But more important, there has been little or no increase in yield ceilings of rice and maize in recent years.

A third factor is the cumulative effect of environmental degradation, which is partly caused by agriculture itself. Virtually all longterm experiments with cereal crops in the developing countries exhibit marked downward trends in yields. Agriculture and the Environment The litany of environmental loss is familiar. 10 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 control. 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 the use of fertilizer. Other agricultural pollutants have the potential for damage on a much larger scale.

While 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. 11 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 buildup of ozone in the lower atmosphere, and global warming. The effects on the natural environment and human well-being are well known, but in each case there are significant adverse effects on agriculture. In relation to global pollution, agriculture is both culprit and victim.

The Doubly Green Revolution In theory, the industrialized countries could feed the world. However, this would require several hundred million tons of food aid, many times what they now supply. It would place heavy burdens on both the donors and the recipients. The environmental costs for the developed countries would be high, and for the developing countries the availability of free or subsidized aid in such large quantities would depress local prices and add to existing disincentives for local food production.

More importantly, this scenario implies that a large proportion of the population in the developing world would fail to participate in global economic growth. The alternative scenario is for developing countries to undertake an accelerated, broad-based growth, not only in food production but also in agricultural and natural resource development. This would be part of a larger development process aimed at meeting most of their own food needs, including the needs of the poor. Implicitly, this scenario recognizes that food security is not a matter solely of producing sufficient food.

For the rural poor. food security depends as much on employment and incomes 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 greater the degree of security and the higher the level of education, the more women will take advantage of new opportunities and plan ahead for themselves and their families. Appropriate agricultural and natural resource development can also significantly contribute to greater environmental protection and conservation. Finally, vigorous agricultural and economic growth can stimulate world trade and provide significant benefits for all countries, both developed and developing. These arguments, taken together, point to the need for a second Green Revolution, a revolution that does not simply reflect the successes of the first. The technologies of the first Green Revolution were developed on experiment 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 environments.

The new Green Revolution must not only benefit the poor more directly, but must also be applicable under highly diverse conditions and be environmentally sustainable. In effect, the need is for 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. 12 During 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. Policies for a Doubly Green Revolution.

There is no single recipe for successful agricultural development, though there is a broad consensus on many of the essential ingredients. These include: economic policies that do not discriminate against agriculture, forestry, or fisheries; liberalized markets for farm inputs and outputs with major private sector involvement; efficient rural financial institutions, including adequate access by all types of farmers to credit, inputs, and marketing services; in some cases, land reform or redistribultion: adequate rural infrastructure, including irrigation. transport, and marketing; investments in rural education, clean water, health, nutrition programs, and family planning; specific attention to satisfying the needs of women and of ethnic and other minority groups and securing their legal rights; and effective development and dissemination of appropriate agricultural technologies in partnership with farmers. Although listed separately above, they are intimately interconnected.

While economic liberalization within developing countries and reform of international trading policies are necessary prerequisites for significant agricultural growth, they are not sufficient by themselves. Accelerated growth in agricultural output cannot be maintained without adequate investments in rural infrastructure and in agricultural research and extension. Indeed, without such investment, the results of liberalization policies may well fall short of expectations and set governments against market-oriented approaches.

They will not contribute significantly to poverty alleviation and the reduction in inequity, at least in the short term, unless the poor are deliberately targeted. Essential steps include the creation of employment for the land poor and landless, increased production on small and medium-sized, and large farms, provision of nearby input and output markets, and, recognizing where the rural poor are mostly located, attention to regions of lower agroclimatic and resource potential, not just the best. This means that agricultural innovation. at least in the developing countries, cannot be simply left to market forces.

Inevitably, private research focuses on the major high-value crops, on labor-saving technologies, and on the needs of capitalintensive farming. By contrast, research to feed the poor is less attractive. It frequently involves long lead times, for example, in developing new plant types of minor staples. It is risky, particularly when focused on heterogeneous environments that are subject to high climatic or other variability. Moreover, the beneficiaries have little capacity to pay for the research, The products cannot be restricted to those who can pay, and intellectual property rights can rarely be protected.

The complexity of these challenges is daunting, in many respects of a greater order of sophistication than those encountered before. Yet, because of the potential of two key, recent developments in modern biological science, it seems possible. The first is the emergence of molecular and cellular biology, a discipline, with its associated technologies, that is having far-reaching consequences on the ability to understand and manipulate living organisms. (For more on this, see L. Levidow’s article, “ Regulating Bt Maize in the United States and Europe: A Scientific-Cultural Comparison,” in the December issue of Environment and R. Paarlberg’s article, “ Genetically Modified Crops in Developing Countries: Promise or Peril?,” on page 19 of this issue.)

Biotechnology Hitherto, the success of the Green Revolution has depended on working with blueprints of “ creating” desirable new plant and animal types through painstaking conventional plant breeding. Biotechnology, and especially genetic engineering, offers a faster route. Moreover, it will be essential if yield ceilings are to be raised, excessive pesticide use reduced, the nutrient value of basic foods increased, and farmers on less favored lands provided with varieties better able to tolerate drought, salinity, and lack of soil nutrients. A good start has been made in improving rice varieties using biotechnology.

Over the past 15 years, the Rockefeller Foundation funded some $100 million of plant biotechnology research and trained more than 400 scientists from Asia, Africa, and Latin America. At several locations in Asia, there is now a critical mass of talent applying the new tools of biotechnology to rice improvement. To date, most of the new varieties are the result of tissue culture and marker-aided selection techniques. For example, a rice variety resulting from tissue culture, called La Fen Rockefeller, is providing farmers in the Shanghai region with 5-15 percent increases in yield. Scientists at the West Africa Rice Development Association have also used tissue culture to cross the high-yielding Asian rices with the traditional African rices.

The result is a new plant type that looks like African rice during its early stages of growth (it grows in dry conditions and is able to shade out weeds) but becomes more like Asian rice as it reaches maturity, resulting in higher yields with fewer inputs. Marker-aided selection is being used in rice to pyramid two or more genes, on the one hand, for resistance to the same pathogen, thereby increasing resistance to pathogens and, on the other hand, to make rice plants more drought tolerant. For some time to come, this is likely to be the most productive use of biotechnology for cereals.

However, progress is being made in the production of transgenic cereals for developing countries. As in the industrialized countries, the focus has been largely on traits for disease and pest resistance, but Mexican scientists have added genes to rice and maize that confer tolerance to aluminum toxicity. Indian scientists have added two genes to rice that together appear to help the plant tolerate prolonged submergence. The realization that the genes of the major cereals are allelic versions that evolved from a common set of genes in a common ancestor means there is enormous potential for sharing genetic information across the cereals and for moving alleles from one cereal to another to modify traits.

For example, the dwarfing genes in wheat, maize, and other plants were recently shown to be alleles (any of the alternative forms of a gene that may occur at a given locus). 13 In the long run, there is the possibility of increasing yield ceilings, such as through more efficient photosynthesis or the improved regulation of stomata. 14 To date, the most exciting development has been the introduction of genes that produce beta-carotene in the rice grain. 15 Beta-carotene is present in the leaves of the rice plant, but conventional plant breeding has been unable to put it into the grain.

The transgenic rice grain has a light golden-yellow color and contains sufficient betacarotene to meet human vitamin A requirements from rice alone. This " golden" rice offers an opportunity to complement vitamin A supplementation programs, particularly in rural areas that are difficult to reach. The same scientists have also added genes to rice that increase its bioavailable iron content over threefold. Over the next decade, much greater progress in multiple gene introductions that focus on output traits or on difficult-toachieve input characteristics is likely." The potentials for genetic engineering are almost endless.

But alongside the benefits are risks, some real, some imagined. An impassioned debate in Europe is raising genuine concerns about ethics, the environment, and the potential impact on human health. 17 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 identify the likely risks before releasing genetically engineered crops and livestock into the environment. So far, few developing countries have such regulation in place.

Perhaps 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 that the hazard assessments are as rigorous as in de The Risks of Biotechnology In practice it is difficult to draw a distinct line between traditional plant breeding, techniques (through which we have been redesigning nature for thousands of years) and biotechnology. But the capacity of genetic engineering to move genes across genera and families as well as between animals and plants may give rise to unanticipated interactions well as between animals and unknown effects. It is a new technology with which we have had limited to experience. While we gain experience we need to move cautiously.

The most serious environmental risk is the likelihood organic varieties escaping from cultivated crops into wild relatives (or contaminating organic varities on nearby farms). This is a justified concern. Genes from existing commerical crops can and do pass to organic crops, and vice versa, and genes from both transfer to wild relatives Even self-pollinated crops. such as rice, will cross with wild rices. The question is whether the genes remain in the wild relatives and whether they result in adverse ecological effects, such as the production of superweeds. Only extensive, well-designed, and monitored field tests will provide answers. A potential solution to this problem is to incorporate the gene in the plastid's genome. In most crops, plastids are maternally inherited only and not transmitted via pollen.

Another potential hazard arises from plants containing genes from viral pathogens that confer resistance to these same pathogens. Expressing the viral genes in plants somehow disrupts the virus infection process. But exchange of these genes with other viral pathogens may be possible, creating entirely new virus strains with unknown properties. A third significant risk-the potential for pests to evolve resistance to the toxins produced by Bacillus thuringiensis (Bt) genes-is well known, as are some of the counterstrategies, One answer is to employ refuges of non-Bt crop plants.

Another uses two or more toxin genes each with a different molecular target. Experience indicates the need to anticipate the eventual breakdown of control. Introduction of Bt into a wide range of crops implies a much higher selection pressure than from spraying the insecticide on a single crop. Insect populations need to be carefully monitored for resistance and alternative strategies continuously developed. The most publicized health risk is that genetically modified (GM) crops carrying antibiotic genes used as selectable markers may generate antibiotic resistance in livestock or humans.

The likelihood is fairly small, but alternative selection technologies are now available and should be used. There is also concern that transgenes may increase allergies, through the introduction of new proteins to foodstuffs. Other fears have less scientific basis. There is no reason to suppose that the process of gene transfer itself confers a health risk. Neither is there any a priori reason why ingesting pieces of transgenic DNA is likely to be hazardous, any more than the large quantities of DNA from numerous sources ingested every day in normal diets.

More important than the potential hazards is the question of who benefits from biotechnology. So far, 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. But they are now turning their attention to the developing countries and embarking on an aggressive policy of identifying and patenting potentially useful genes. Part of the answer to this challenge lies in public-private partnerships whereby genomic information and technologies are donated to public plant breeders and agreements are struck that ensure that new varieties are freely available to poor farmers in developing countries.

The Application of Ecology The second development is the emergence of modem ecology, an equally powerful discipline that is rapidly increasing understanding of the structure and dynamics of agricultural and natural ecosystems and providing clues to their productive and sustainable 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 factors present.

As practiced today, it combines modem 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 conventional pesticides.

A recent, highly successful example involves 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 more than four to less than one per season, while yields have grown from 6 to nearly 7. 5 tons per hectare. Since 1986, rice production has increased 15 pecent while pesticide use has declined 60 percent, saving $120 million a year in subsidies.

The total economic benefit up to 1990 was estimated to be more than $1 billion. 18 The farmers' health has improved and a not insignificant benefit has been the return of fish to the rice fields. The next challenge is to extend the principles of integration established in IPM to other subsystems of agriculture, nutrient conservation, and the management of soil, water, and other natural resources such as rangeland. Of great potential value is the development of highly integrated crop-livestock systems, where soil structure and nutrients benefit both from livestock manure and the nitrogen-fixing capacity of forage crops. As African scientists have shown, use of inorganic fertilizers alone can lead to stagnation of crop yields but, if combined with manure, can sustain steady yield increases.

Careful ecological management of crop-livestock systems can create virtuous circles: Cowpea thus feeds people and animals directly while also yielding more milk and meat, better soils through nitrogen fixation, and high quality manure, which, used as fertilizer, further improves soil fertility and increases yields. 19 Forages identified by the International Livestock

Research Institute (ILRI) for intercropping have led to 30100 percent wheat yield increases and up to 300 percent increases in fodder protein while fixing 55-155 kg of nitrogen per hectare. 20 Participation of Farmers However, a successful Doubly Green Revolution will not come from the application of biology alone. The first Green Revolution started with the biological challenge inherent in producing new high-yielding food crops and then looked at how the benefits could reach the poor.

But this new revolution has to reverse the chain of logic, starting with the socioeconomic demands of poor households and then seeking to identify the appropriate research priorities. Biologists will have to listen as well as instruct. There will be no easy solutions and few, if any, miracles in the new revolution. Greater food production will come from targeting local agroecosystems and from making the most of indigenous resources, knowledge, and analysis. More than ever before, it will be important 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. Experiments in many parts of the developing world are showing 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 involved farmers very early in the breeding process. 21 Beans (Phaseolus vulgaris L.) are a key component of the Rwandan diet, and there is an extraordinary range of local varieties-more than 550 have been identified. 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 own criteria to reduce the number of lines. The farmers tagged favored varieties on the station with colored ribbons. A set of 20-25 lines was then taken to field trials on the farmers' plots.

The farmers then chose the best performers and were responsible for multiplying and disbursing them to their neighbors. Participation has long been a slogan of development. For the first time, effective techniques can make it a reality. Under the heading of participatory learning and action (PLA), there is a formidable array of methods that permit farmers to analyze their own situations and, most important, to engage in productive dialogue with research scientists and extension workers. PLA arose in the late 1980s out of earlier participatory approaches by combining semistructured interviewing and diagram making. 22 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 than the request to produce a map of the village, watershed, or farm. People who are illiterate and barely numerate can construct seasonal calendars using pebbles or seeds. Pie diagrams-pieces of straw and colored PLA has now spread to most countries of the developing world and been adopted by government agencies, research centers, and university workers as well as by nongovernmental organizations (NGOs). In some ways, it has been a revolutiona 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 outside find themselves, usually unexpectedly, listening as much as talking, experiencing close to firsthand the conditions of life in poor households, and changing their perceptions about the kinds of interventions and research required. In every exercise, the creation of productive dialogues replaced the traditional position of rural people as passive recipients of knowledge and instruction. A recent report by ActionAid describes a very sophisticated use of maps and preference rankings by the Sanaag people of Somaliland for their community-based livestock development.