Food Production in
a Fertile, Unstable World
by Dr. Norman E. Borlaug

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Dr. Norman E. Borlaug

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Norman E. Borlaug has long been an agricultural scientist of international stature and, especially since receiving the Nobel Prize for Peace in 1970, a famous and respected personality as well. Millions have been introduced to him in such publications as National Geographic and Reader's Digest and through newspapers, television and film. A native Iowan, Borlaug has since 1964 headed the Wheat, Barley and Triticale Research and Production Programs at the International Center for Maize and Wheat Improvement (CIMMYT) in Mexico.

Dr Borlaug was born on a farm eleven miles northwest of Cresco, March 25, 1914 to Henry O. and Clara V Borlaug. He graduated from Cresco High School where Dave Bartelma, principal and wrestling coach, "took the time to shake the hayseed out of my hair" and get Borlaug "academically oriented." Borlaug studied and wrestled at the University of Minnesota where he graduated with a B.S. degree in forestry in 1937 He also received the M.S. (1940) and Ph.D. (1941) in plant pathology from the University of Minnesota.

Although his accomplishments and honors are numerous, Dr Borlaug, a geneticist, won his greatest recognition for development in the 1950's of "miracle" strains of wheat that launched the Green Revolution in many countries. Although he holds scores of prestigious awards and honorary doctoral degrees, he has been known to yoke himself to a plow to till a test plot. The day he learned he had won the Nobel Prize, he was working in the field and only reluctantly left his work to accept the world's acclaim.

THE WORLD
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The World Food Institute of Iowa State University was officially established in 1972 by the Iowa Board of Regents to focus Iowa State University's "competencies and leadership upon the provision of adequate and nutritious food supplies for the world's peoples through research and education." The Institute supports efforts aimed at alleviating hunger and continues to assist various teaching and research projects. Two of its more conspicuous projects have been The World Food Conference of 1976—a unique gathering of food scientists from throughout the world—and the Annual World Food Institute Lectures.

Food Production in a Fertile, Unstable World[1]

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I would like to take you with me this evening on a short trip to look at some of the complex problems that relate to producing food for 4 billion, and what is more, a population that is growing at the rate of about 75 million each year. Iowa, I believe, now has approximately 3 million people. The world is adding, essentially, 25 times the total population of Iowa to the total population each year. Theirs are the demands we must meet if we are going to produce and maintain a stable world in which all of you young people, especially, will live.

It is my firm belief that it is the moral right for all who are born into this world to have six basic ingredients which are essential for a decent, humane life. I start my list with food, and then a shirt over your back, and a roof over your head, and a job to gain your livelihood, and I am convinced that the best medicine that God ever gave man and woman was constructive, creative work. Then there is the basic necessity for schools to educate the young so that they can develop their inherent abilities to the maximum. And of course, medical care when we are ill.

Today, of course, in affluent nations, many other things are considered of basic importance. Certainly in the U.S.A., recreation would rank very high because shorter work weeks and higher incomes permit travel and all sorts of recreation, both indoor and outdoor. But most of the underprivileged people in the developing nations do not know what the word "recreation" means. They are too busily engaged trying to scratch out and eke out a living. Today, from our high levels of government, we hear a great deal of talk about human rights. But for most of the underprivileged people in most of the developing countries, human rights to dissent and to freedom of expression have no significance, at least until these six basic rights have been fulfilled.

I am going to confine most of my remarks to the question of food and population. When you talk about food, you have no choice except to talk also about population if your examination of the need for food is to be meaningful. They are two sides of the same coin; or, they go together like the horse and carriage. Unfortunately, sometimes the carriage seems to get before the horse.

Let's take a look at what has happened to population since the time of the first two, whom we in the Christian world generally know as Adam and Eve. Just when they came onto the planet Earth is not entirely clear. The dates keep shifting further and further backward. Most of the best archaeological evidence today has come out of East Africa where the Leakey family and many of their colleagues have spent lifetimes digging for remains of human skulls and bones and habitats. Our ancestors apparently were roaming the earth at least 3 million years ago. During most of the time, from the beginning 3 million years ago until a short time before written history, man lived largely as a hunter, gatherer, and fisherman. Agriculture was begun only 10 to 12 thousand years ago when about 15 million people inhabited the earth. From that time until the time of Christ, the population doubled four times to about 250 million people, a figure which most demographers generally have accepted. It has doubled four times since the time of Christ. The first doubling, from 250 million to 500 million, required 650 years. Life was getting a little better, food was somewhat more abundant, and man and woman had learned to protect themselves a bit better from the environment. The second doubling required only 250 years. Thus there were about 1 billion people in 1850, when the birth of modern medicine, that

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is, the discovery of the cause of infectious diseases, resulted in reduced death rates. The third doubling took only 80 years, and was reached in about 1935, about the time of the advent of sulfa drugs, shortly before antibiotics and better vaccines. Again, the death rate plummeted and life expectancy was greatly extended. The last time it doubled, from 2 billion to 4 billion, required about 40 years, to late 1975 or early 1976.

When we talk about food, we need to have some concept about how much food is needed to feed this population of 4 billion and what are the possibilities of producing enough to maintain stability—social, economic, and political—in the next four decades.

When we consider food, we must consider it from three standpoints; from the standpoint of biological need, which should be self-evident, for without food you can live only a few weeks at most, assuming you entered the famine or starvation situation in good health. From an economic standpoint, the worth of food depends entirely on how long it has been since you had your last food and what your expectancies are for food in the future. Let's take a look at the privileged U.S.A. At the end of World War II, the statistically average family spent about 26 percent of its take-home pay on food. With depressed food prices in the 50s and 60s as a result of overproduction and with increasing wages and incomes, the percentage of take-home pay spent on food dropped gradually to about 16 percent by 1971. Then when food shortages occurred in 1972, it began to increase somewhat. There was a great, scandalous outcry, especially from the urban consumer, who had forgotten, after all, that food did not come from the supermarket, and that it costs money, in terms of capital investment, to produce food.

In many ways I am horribly shocked by the breakdown of communications in the U.S.A. about the role that agriculture plays in the nation's total economy. During the last two or three years when I visited the United States, I have asked some questions, especially of urban residents, to find out how much they know about agriculture and what it costs to produce food, how complex the total system is, and what inputs are required from the standpoint of marketing, storage, and distribution until the food reaches our tables, especially in cities. I am horrified by the void that seems to exist. I think there is something wrong in the communication system. I don't know why it is so, and I don't pretend to understand it.

When you look at the economic importance of food in developing nations you will see that the vast majority of people, in years when crops are good, will spend 75 to 85 percent of their take-home pay on food. In bad years when crops fail, it is all of their income—nothing left over—and it is still inadequate. So you see that economic importance varies greatly with the social-economic system in which you are living.

The political importance of food can be observed when stomachs are empty. It makes no difference whether it is a socialistic or communistic system or whether it is a free enterprise system. To illustrate, think back four, five, or six years ago to the devastating drought in the Sahel. You saw the consequences on your television screens—the misery and poverty and hunger. Six governments fell as a result of the shortages of food and the misery and suffering of their masses. One of these countries is still creating headlines on the front pages of your newspaper. I am referring to the situation in Ethiopia, which deposed its leader, and where internal civil war continues and threatens to embroil a number of other countries. Time and again, when there is a shortage of food, there is political instability. And when there is political instability in food-deficit countries, I have learned firsthand that it is impossible to do anything then about increasing food production.

The production of food is not simple. It involves land, technology developed through research, and education extension systems to transmit technologies to the farmer. Let us remember always that the farmer and the rancher produce food. It is not agricultural scientists or educators. If they are doing their job well, then they are assistants, if you will, of those who actually produce the food.

I think one of the reasons there is no appreciation of the importance of agriculture is the false idea that anyone is intelligent enough to be a good farmer or a good rancher. That is absolute nonsense. Yet, I sense it everywhere in the world, including in the developing nations where this false attitude often prevails among the privileged classes and government leaders.

There are two problems when we talk about food in this unstable world of ours and about its necessity for peace and stability. One is how to produce enough food, but equally important and equally complex is the problem of distribution of that food equitably among those who need it. It seems to me that free enterprise systems have great advantages in expanding and increasing food production and improving agriculture. But I see many grave defects in their ability, as a group, to distribute food equitably, and to do this without destroying the initiative of those who receive the food to earn a livelihood through creative work.

What is the food production base of our world? I think that we inhabitants of the planet Earth, for the most part, are very egotistical. We think of this planet as an enormous thing, the center of our own solar system. Of course, we know this isn't so, but it is even worse than that. We go outside on a clear evening before sunset and see the sun going down; then in a few hours we can see our sister planets moving around us, and we think we are the all-important part of this solar system. But a couple of hours later if we glance up into the heavens, if it is a clear, cloudless night, we see the vast number of stars, each one a sun like our own, perhaps many of them with planets like ours rotating around them. We look beyond and we see, also, the Milky Way and all that it implies. We are really nothing but a speck in the total universe, despite our self-centered egotism.

In the total plan of things, our earth is very small. On the surface, more than three quarters of it, approaching 78 or 79 percent, is water, most of it salt water or ocean. Some is inland water, sweet waters, and lakes. We have less than one quarter of the surface as land. Some of that land is bad real estate, too, when we examine it. As far as arable land is concerned, only 11 percent of the total land area is classified as suitable for agriculture. Another 22 percent is classified as suitable for grazing and animal industry. Both of these agricultural uses account for about 33 percent of our total land area. An additional 30 percent is classified as forest land and woodlots. The remaining 37 percent is called "other." "Other" means mostly wasteland, arctic tundra, deserts, rocky mountain slopes with very little soil on them, or good agricultural land that has been covered over by cities, pavements, and highways. We continue to do this at an appalling rate in many parts of the world, not only in the U.S.A. Several millions of acres of good land go out of production each year because it is easier and less costly, apparently, to build on flat land than on sloping land. On the surface, at least, this seems to be the case.

If we look closer at the land classified as arable, and at forest land and grazing land, also, I have reservations about the accuracy of that classification. In many countries short of land, I have seen political leaders dividing land to give small family farms to landless peasants. The land is so poor in quality and generally so short of moisture (rainfall) that it is not capable of producing enough food for a good-sized family of grasshoppers, much less a hungry family of people. But it is classified, once and for all, as arable land once it has been divided. And so it is with grazing land. Much of that land is semiarid and has a very low carrying capacity. Perhaps 100 or 150 or more acres are needed to provide food for one cow or steer. With respect to forest land, sometimes you may find a few lonely juniper or pinion pine in marginal rainfall areas in a vast expanse of sagebrush. So be careful how you interpret the land base available for food and fiber production. It is probably exaggerated.

How much food do we require to feed 4 billion people? In 1975, without correcting for differences in moisture content, there were about 3.3 billion metric tons of food of all kinds produced around the world. Ninety-eight percent of that food came from the land, and only two percent from the vast expanse of ocean and inland waters. The false idea seems to exist that once we run out of our ability to produce enough food on the land, we will always be able to tap a largely unutilized ocean reserve. I had this brought home clearly to me just a little more than a year ago when Phillipe Cousteau, the son of Jacques-Yves Cousteau (Phillipe was raised from the time he was eight on the Calypso I with his daddy, the famous oceanographer), came to Mexico specifically to talk to us at our research station. He said, "We need your help. We have overbuilt the beauties of the sea, and we seem to have fallen into the trap that the food supply for the future is very great indeed, from the ocean." He said, "We know, as well as you know, that this is not so."

Let us examine what happened to fish production following World War II up until about three or four years ago. The food catch, that is fish, crustaceans and other species from the ocean and inland water, increased in a straight line as long as we were developing better technology and better fishing fleets; however, it leveled off at about 70 million tons and then decreased for the species that are being utilized and harvested now. Although other species might be used for food or for meal in rations for livestock, most authorities say that perhaps we can double or triple the total take of food, over two or three decades, from the ocean. Even that amount would be a very small percentage of the total food available for humans. Modern technology, fish culture, and fertilization may increase production in streams, ponds, or small lakes, and also in estuaries that can be fenced off, protected, and cultivated as we do the land. But again, the total potential seems to be limited. So, land is going to be the major source of our food supply.

Some of you will say, "What about single-cell protein and fermentation of other products to produce protein?" Yes, in small quantities these have been produced, but, recognizing the built-in resistance to changes in food habits, I think it will be a long time before any substantial quantities of these foods will be consumed directly by humans.

The biggest portion of the 3.3 billion metric tons of foods produced in 1975 was cereal grains. When I say cereal grains, I mean wheat, rice, corn, sorghum, millet, oats, barley, and other minor grains as well. Together, they constituted approximately one-third of the total tonnage; because they are low in moisture content compared with many other foods, they contributed more than one-third in food value, however.

Why are the cereals particularly important? Approximately 50 percent of all the cultivated land area of the world produces grains. The importance of the various grains varies with climate, soil, and different biological conditions such as diseases. In addition to the large amount of arable land that they occupy, they produce approximately 50 percent of the direct caloric intake in human diets around the world, and up to 62 percent in the developing nations where people are not privileged to have high enough incomes to consume much meat or animal protein.

When we look at the other kinds of foods, I do not want you to misunderstand their importance.

These include root crops such as potatoes and yams, all the pulses and grain legumes, the peas, beans, chick-peas, and lentils, as well as the great variety of vegetables. Nuts and fruits, all of the animal products (such as meat, eggs, and milk), sugar, oil seeds, soybean, mustard oil, and of course, the fish, as well as many others all make significant nutritional contributions.

But the cereal grains quantitatively are the most important. Around the world about 40 percent of them are fed to livestock to produce the eggs, meat, and milk. The remainder are used directly as foods. As the population density increases, however, you will find that a much higher percentage of the total grain produced will be used directly for human consumption rather than converted to animal protein.

Each year, because there are 75 million more people, we must increase world production about 30 million metric tons in cereal grains alone. How can we do this? By expanding the area under cultivation, or by increasing the yields in areas now under cultivation, or by some combination of the two. If we were to increase the area of cereal culture sufficiently to produce 30 million extra metric tons each year, we would have to add about 40 million more acres of land around the world assuming a continued average yield of all the cereals. In many countries where the food shortage is the gravest, there is a shortage of land and very little new land that can be brought under the plow without huge capital investments, irrigation systems, and drainage systems. Frequently agreements among several nations which share large watersheds associated with rivers will be necessary. We cannot meet the growing demand with this approach alone.

I recognize that there are presently in the audience many students, including some from developing nations. Those of you from the United States are very privileged, indeed, from the standpoint of the agricultural base we inherited when our borders were drawn. We have a vast amount of good land, with good climates that have favored the development of agriculture, and creative, hardworking farmers who have improved production over several generations. Our government, at least over the past 100 to 150 years, established and maintained agricultural policies that stimulated the development of our agricultural resources and permitted the growth in production and the efficiency that we take for granted today. The United States is the largest exporter of food, by far, of any nation in the world today. One important piece of our government's legislation, it seems to me, was the homestead act, which gave land free to individual families who settled on it, lived on it, and opened it to cultivation. I am sure this act reflected the vision of good political governmental leaders of that time.

Just to show that it does not always happen, I have spent endless hours over the last three or four years trying to get similar legislation enacted in Brazil where vast central well-watered areas are being opened. But I am a voice in the wilderness. Instead, huge tracts of land have been developed while many people are still landless.

The land-grant colleges and universities (of which Iowa State University was one of the early ones) were also established by federal legislation and have played a vital role in developing the science and technology in agriculture, home economics, and engineering. These areas have contributed to the food production potential of this nation. Somewhat later, another act established the experiment stations and expanded the network through which research has become evermore effective in opening new horizons for agricultural production. In more recent years, the private sector, the agribusinesses, have played a vital role in improving our agriculture, also. In most of the developing nations, this has not happened, either.

In the developing nations, agriculture has no prestige. Those countries are unlike our own, where today less than four percent of the residents in the U.S.A. live on the land and work the land; only approximately four million farm workers produce an abundance of food. In developing nations, 75 to 80, 85, or even 90 percent of the people live off the land in a subsistence-type agriculture. But they have no political clout. I should have said at the outset that if you want to examine the number of people engaged in agriculture around the world, it is approximately 50 percent. They are the poorest people in the world.

When 70 to 90 percent of the population live on the land, mostly in subsistance agriculture, miserable standards of living, stagnant production in agriculture, and extremely low yields result. Very little relevant agricultural research has been done; there are not effective extension systems to extend the new knowledge, were it available. Generally extension systems have not functioned well in developing countries, but it may not be their fault. If research organizations have not been capable of developing new technology that is worth applying, then the extension people should not be blamed for not changing the traditional agriculture. Instead, the fault may lie with research organizations themselves or with the agricultural policies of the governments. In addition, the young women or men who have talent want to become doctors, dentists, lawyers, engineers, chemists—anything but agricultural scientists. This is a monstrous obstacle to overcome when one tries to transform agriculture.

Inputs, such as fertilizer, are not available in most developing countries, and the land ownership is in a state of flux. Often properties are so small that they can never become really viable economic units.

What can you do about this? Over the last third of a century I have struggled with these problems in many different countries, very ineffectively—and not alone, but with my colleagues. The first foreign technical agricultural assistance program was established in Mexico in 1943 at the suggestion of then-Vice President Henry Wallace. I knew him well and owe him a great deal because he encouraged me to work in international agriculture. He came to Mexico for the inauguration of the late president Avilo Camacho in 1941. Following the inauguration, Vice President Henry Wallace was invited by the outgoing president, Lazero Cardenas, and the the incoming Secretary of Agriculture M. R. Gomez, himself an Ingeniero Agronomo, to visit the old colonial central part of Mexico to look at its agriculture. A few days later, after they returned to Mexico City, a formal request was made to the U. S. government for technical assistance to improve agricultural production, to establish a network for agricultural experiment stations, and, at the same time, to train a whole new generation of young Mexican scientists.

When Henry Wallace returned to Washington, it was about the first of December. You will remember there was a little event called Pearl Harbor shortly after that, and of course it was impossible to launch technical assistance programs with the shortage of manpower and the chaos that existed at that time. In any event, Wallace called the president of The Rockefeller Foundation and said, "A request has been made to the U. S. government. In reflecting on it, I believe that it might be advisable (to involve) The Rockefeller Foundation, because you have had 25 years of experience working with 25 different governments around the world to improve public health by sending in sanitation engineers, entomologists, and medical doctors. You have a lot of valuable experience and the U. S. government has none in this field."

The Rockefeller Foundation sent a committee and decided to launch a program. Dr. J. H. Harrar and Dr. E. J. Wellhausen, both of whom received advanced degrees at Iowa State University, were the first two members of this program. I was the third.

What do you do in stagnant, traditional agricultures? First, you must start with research. You need to find out why the soil is so poor, assuming that you are in areas that have adequate rainfall or that have irrigation. Agriculture is old in most developing countries. The soil has been mined without returning any fertility to it over decades and hundreds of years. Production is very low. All the different organisms that are trying to live from that piece of land will be unable to do so. It makes no difference whether you are talking about the wheat plant, or about the weeds that are growing between the wheat plants. They are equally miserable. The aphid that is trying to eke out a living on that woody weed is scrawny and emaciated and miserable also. So is the rust pustule that is trying to eke out a living on the green leaf; but it can't create an epidemic, either. Can you imagine what it is like for the man and woman and their children trying to eke out a living at the end of the food chain? Pretty miserable, too.

We must restore soil fertility first. The depletion of nutrients is different in different soil types and in different climatic zones. It requires experimentation to find out what factors are limiting, what fertilizer needs to be added, in what proportions, and when. I might add that fertilizers must be provided as economically as possible and without contaminating the environment any more than is necessary. Next you have to improve cultural practices—how to prepare the land, how to handle moisture, trying to conserve it, whether it falls from the heavens or whether it is applied from irrigation ditches, and how to control weeds insofar as possible, mechanically.

Whether one grows wheat or corn, different varieties may be required to utilize improved cultural practices so that more grain is produced. Grain is the part of the plant that humans and animals, for the most part, consume. We human beings haven't learned yet to eat straw or cellulose from trees.

The variety of grain must have high yield potential under improved cultural conditions, must utilize fertilizer more efficiently, and convert it to grain that can be used for human consumption, or for producing animal products. And it should have, as far as possible, built-in disease resistance and insect resistance. These shifty little enemies, however, present a never-ending series of threats to our world food supply. If it were as easy as it seems from the sidelines, all of these problems would already be solved. But these little enemies mutate and change, and they have a tremendously high reproductive potential. As an example, if I remember correctly, from one fertile aphid, at the beginning of the spring of the year, if all of its survivors lived, there would be 1,560 X 1,021 aphids. Is there any wonder that we cannot build in and maintain resistance when insects have this kind of a reproductive potential? For the same reason, medical people have never been able to develop effective vaccines against certain viruses such as that causing the common cold. Some of our animal vaccines, for example, for hoof-and-mouth disease, are only partially effective because the virus mutates and changes.

When we are developing crop varieties, we must find out how to control insects and diseases not only by the varietal resistance, because sometimes this is not feasible, but by other methods, such as cultural practices, and chemicals used in the proper way when necessary. Then, we will need an extension service that has the will, the experience, and the background—that knows the new technology that has been developed through research. There is too much research done (and in some cases, in affluent nations) that never migrates to the countryside. It stays in the laboratories, or in the experiment stations too long. This we cannot permit in the developing nations with the urgency for more food production at the present time. So extension demonstration programs become very important.

New technology, once it has been developed and checked in many hundreds of places in a country (and this has to be done for each crop and each soil type), has to be married to what I call "Sound Economic Policy" that will promote the production of more food. Inputs such as fertilizer must be available at the village level, on time, at the right season of the year. Small farmers must have credit so they can purchase fertilizer. In addition, the government must assure these farmers a reasonable price for their grain through the marketplace.

Until ten years or so ago in the Orient, especially in South Asia, when the farmer adopted new technology, bought the fertilizer, used new varieties, and increased his production enormously, who profited most? The grain buyer. The price for grain in food-deficit countries is always very high prior to harvest. As soon as harvesting begins, prices plummet. The grain buyer, incidentally, in most cases, also happens to be the money lender. If so, he gets it coming and going.

It is gratifying to see changes take place. Let me cite the case of Indian wheat production. I began working on it at the invitation of the government of India, first in 1960, and again in 1963. I thought I saw possibilities to use much of the know-how, including the technology and the seeds that had been developed in Mexico, in India. The wheat-producing areas were similar in many ways. To make a long story short, we started to collaborate. Two of our scientific staff went to India in 1963. In a short period of time, after the necessary testing that I mentioned earlier and after developing some organizational structures to stimulate production, I saw Indian wheat production grow from 400 million bushels to a billion bushels in the short period from 1968 to 1972. Then production leveled off and actually dropped because they had to import virtually all of their petroleum and virtually all of their fertilizer at that time. As the squeeze with OPEC has lessened, in the last two or three years, production has risen again.

The potential is there if there is political will, and if there is economic realism, and if political will is not destroyed because we dump surplus grain under the PL 480 program. The recipient government, all too often, took the grain and established sales outlets at ridiculously low prices, so low that its farmers could not afford to adopt new technology. The purpose of the U. S. program, therefore, was negated.

Because 70 to 90 percent of the people live on the land and because most countries have free governments, the power of the ballot box should be controlled by the vast rural majority. But it is not so. Instead, political policies are tilted toward the 20 percent of the population who are urban. The reason is that the urban population is organized; at least part of it is. There are well-organized trade unions that speak in a loud voice disproportionately to the population they represent.

During the same period that Indian wheat production increased, Pakistan wheat production doubled, also. Technology was transplanted from Mexico, checked out locally, and modified to fit local conditions. It was the first time anything of this magnitude had ever been transferred halfway around the world so rapidly. At the same time, we helped reorganize their research programs to assure a sound base on which to build the future. The Indian wheat breeding program today is the largest and most diversified in the world. Programs have also been increased considerably for a number of other crops. In the next ten to fifteen years, the production of wheat and rice in India could be doubled again if the political will and the economic policies are right. I have serious doubts that this will happen.

I could mention many similar cases, but will not do so. Of course, whenever you make such changes, you do not create a utopia. We have been criticized for making the rich richer and the poor poorer. You have read it in many slick scientific journals. But let me give you a little insight on this criticism.

I have studied hundreds of millions of individual plants. In no case would a single wheat variety produce ten tons per acre on a ten-acre farm and, with the same technology, produce one ton per acre on a 100-acre farm, so that each farm would end up with 100 tons of grain. It would be much easier for social scientists and political leaders of governments if it were so because they would not need to be responsible for doing the nasty job of distributing benefits.

As we look ahead, then, there are other problems that must be addressed. Some people believe we do not need to use fertilizer, even on worn-out soils. They have never farmed. They think that we are putting something back into the soil that was never there in the first place. If you stop to think about phosphate and potash, these nutrients were leached out of the soil pretty largely in geologic times. Much phosphate has been deposited on the continental shelves. Potash has been deposited as brines, for example, in the Dead Sea or in underground deposits. When you fertilize with phosphorus or potash, you are taking natural deposits and putting them back on the land from which they came originally.

The case of nitrogen is a bit different. In a continuous cycle, green vegetation is produced, decomposed to produce ammonia, and eventually, nitrous oxide nitrogen which is released into the air. Nitrogen is also the first nutrient that is depleted. Without adding it, and sometimes minor elements in the right proportions, you cannot increase production.

There are some who think that organic gardening is very effective when they grow three beautiful staked tomato plants and six lovely rose bushes in their back yards. For that purpose, it is, but it is no darn good at all for trying to feed 4 billion people! The best artisans in the world in the use of organic waste—and I don't mean it isn't important—are the Chinese. Over hundreds of years they have decomposed all of their organic waste from humans, animals, and plants, and put it back onto the land. Consequently, the yields without chemical fertilizer in the People's Republic of China are better than those of India where nothing or virtually nothing of the organic waste goes back onto the soil. The forests were depleted and denuded decades ago, so cattle dung has been burned for fuel. The difference in yield without chemical fertilizer, between India and China, is about six to eight bushels of wheat, in favor of the Chinese.

Prior to 1959, no chemical nitrogen, or fertilizer, for that matter, was used in the People's Republic of China. Then they got very busy, and from 1959 to 1972 they had installed 1,200 small anhydrous ammonia plants. The fuel for these factories was coal. At the same time, they began to import large quantities of nitrogenous fertilizer, and before the OPEC embargo, were importing more than any other nation in the world. It came from Japan. When Japan felt the effect of the embargo on petroleum exports by the Arab countries, the People's Republic of China, within six weeks, decided to install ten 1,000-ton-a-day anhydrous ammonia plants with the corresponding converters to make urea. They contracted with the best engineering concern in the world, Kellogg Engineering of Houston, Texas. That was the largest single investment ever made in chemical fertilizer plants and demonstrates how important chemical fertilizer was to them for growing food for their needs. Without it, they would never have made the progress that they have made.

Were there enough organic wastes—animal wastes, let's say—to produce the amount of chemical nitrogen that is being produced in the world today, it would require about 3.2 billion tons of all kinds of animal manures, dried down to low moisture content. If you can visualize it as a highway built of manures that would go around the earth at the equator, it would be six feet deep and a bit wider than the length of an American football field, about 325 feet across. But in order to do that, assuming that you could collect it from the ranges and pastures, including those in remote locations, we would have to increase large animal production by about 60 percent. Already, overgrazing is one of the real problems of the world—and think of the cost!

We also hear great criticism today about the methods that are used in modern agriculture to control pests, insects, and diseases. I have mentioned already that resistant varieties alone are not adequate against all diseases. Some organisms are stable and resistance can be maintained against them for many years, even decades. But the most dangerous ones are highly variable and a resistant variety remains resistant for only five or ten years or even less, in some cases. We can reduce losses by cultural practices and rotations. Traditional farmers have done this for hundreds of years. Today biological controls have become popular to solve these problems. Sometimes they work, and once in a while have stabilized the situation for a long period of time. Sometimes they are fantastic, but only for short periods of time.

When the European rabbit was introduced into Australia quite a few decades back, it became one of the worst pests in Australia. It devoured vast amounts of forage and reduced the number of sheep and cattle that could be produced on the same amount of land. It competed with the herbivorous native animals. Australians tried trapping, poisoning, and shooting, ineffectively. The rabbits just overran everything! Finally they brought in the myxoma virus and released it into the wild rabbit population. It was spectacular when introduced in the early 1950s. Ninety-eight percent of the rabbits were killed. Piles of them! Mountains of them! But it was not long before the rabbit population began to increase again. What had happened was that the virus had mutated and produced a more benign, less virulent form. This, when it was transmitted by fleas to the new, young rabbits, was not virulent enough to kill. Consequently, many of them developed an immunity to the mutant just as you would get with a vaccine. Now they use a very complex integrated control system while they search for new virulent forms of the virus. They use trapping, poisoning, and hunting and more or less maintain control. Biological control alone has not been the solution.

In our own western forest, in 1972 the forest service and state conservation departments were using insecticides to destroy the tussock moth that had defoliated about 400 thousand acres of Douglas fir, lowland white fir, and a number of other fir species. Some people were sure that there was no need to spray with poisonous insecticides that had an adverse impact on the environment. They suggested biological control in the second year with certain bacterium and a certain virus that frequently had reduced the population of this insect. But 1973 was a very dry year and the ecological conditions apparently did not favor these predators. And so what happened? The 400,000 acres of firs were defoliated a second time and 300,000 for the first time. Douglas fir generally will withstand one defoliation, but virtually all trees defoliated a second time died. Much of it was 40- to 60-year-old timber. That was a pretty costly mistake.

We never know when biological control alone will do the job and when it will not. We need to combine it with other things. Predators and parasites should be used to control the insect pests until they are no longer effective. Then you must supplement with chemical controls. They must be added in an orderly way and both the population of the damaging insect and the predators should be monitored. When we use chemicals, whether they be insecticides or weed killers, we need to use them as we do medicine. If you have an infection, you go to the doctor. If he is a good doctor, he will diagnose the infection and give you an antibiotic or some other medicine that will alleviate the infection, and may cure you entirely. If you misuse it, that same medicine could kill you. So it is with agricultural chemicals. They have to be used carefully and in the right way.

Some of our officials have never dealt with these problems. I mention this because CAST, the Council for Agricultural Science and Technology, was conceived by Iowa State University's Dr. Black to explain agriculture and its associated technologies to the general public. About six months ago, one of our assistant secretaries of agriculture said that many problems, especially of weed control, could be handled in another way. We had so many unemployed people who certainly could go out and help to control the weeds in our agricultural crops. Thus, we would not need to use chemical weed control agents. He apparently did not do much calculating. When CAST did this calculation, and I saw it, I just could not believe my eyes. Assuming that you could get the unemployed into the fields and assuming a ten-hour working day during the peak season for controlling weeds in the U. S. corn crop, it would cost $26 or a bit more per day for each workman. To cover the area that is under U. S. corn cultivation would require 17½ million workers on the end of a hoe, working six weeks. When an assistant secretary of agriculture makes this kind of a recommendation, he has not examined it very carefully!

The worst pollutants, as far as I am concerned, are the pessimism and negativism that have poisoned the minds of many of our youth. It is tragic. Despite the fact that we live longer, more healthful and pleasant lives than our fathers and grandfathers, mothers and grandmothers, great-grandmothers and great-grandfathers, we think that we are all about to be poisoned out of existence the day after tomorrow. It just isn't so.

We hear lots of nonsense about the ozone layer being destroyed by your fluorcarbon hair sprays and by my shaving cream dispensers. The SST Concorde was supposed to be destroying it; at the same time, you never heard much criticism about the supersonic fighters that are all around the world in that same stratum. Now, the nitrogen that is being liberated from fertilizer and from decomposing organic waste is supposed to be destroying the ozone layer. Sometime in the unforeseeable future, we will be getting so much ultraviolet light that mutations will occur, mutations that are almost certain to produce cancer. Contaminants in the air, food, and water all around us are also supposed to cause cancer. My way of looking at these things is that if the system were that unstable, none of us would be here in the first place. At worst, maybe the populations of the world will have darker skins in 10, 20, 100 generations. Darker skins, achieved through a natural selection process, will resist ultraviolet rays better than palefaces like myself.

Then we have such things as the Delaney clause of the Food and Drug Act of 1958. It seems to have led us to injecting our experimental animals with as big a dose as possible of all kinds of chemicals, but, "Don't kill them too fast; don't put too much of it in at one time because then they won't have time to develop a tumor or a cancer. Just keep them alive and see if they will develop a cancer; then ban the product."

Concerns have been expressed about saccharin, about some of the colorants in your hair dyes, and about insecticides. Yet, we seem to ignore one of the best-proven carcinogens of all. In 1964, 511 billion cigarettes were smoked per year. Now it is 600 billion. We are curious beings.

We have a good law that has been prostituted disgracefully—the Endangered Species Act. I like wildlife. I would like to keep all of them around us as long as possible, but recognize that people pressure is the greatest menace to them. The law was an excellent one as conceived, but it has been used to block construction of the Tellico Dam in the Tennessee Valley because somebody was able to add the snail darter to the "endangered species" list. He is a little fish, reputed to inhabit only about ten miles of the stream on which the dam was being built. The dam was 80 percent completed and was estimated to cost $116 million when completed. Construction has been delayed now for about a year and a half. A well-conceived, necessary bit of legislation has been misused, in my opinion.

With tongue in cheek, a few weeks ago I said that the one thing that we should certainly try to do is to prevent the disappearance of one of the most dreaded human diseases. The World Health Organization of the United Nations, twice in the last year and a half, has said that the smallpox virus is on the verge of disappearing from the world. Wouldn't it be tragic if we didn't preserve this species that is on the verge of extinction, because it has played an important role in the development of our society? Wouldn't it be much better if we didn't spend so much of our energy and resources in lawsuits, but instead in expanding wildlife refuges, improving habitats for our wildlife, planting more trees, and replanting eroded lands!

In closing, I will quote from one of my favorite philosophers, Will Durant, who now must be approximately 90 years old. "Man's capacity for fretting is endless. No matter how many difficulties we surmount, no matter how many ideals we realize, there is a stealthy pleasure in rejecting mankind or the universe as being unworthy of our approval." On another occasion, he said this, which I think tells a lot about us as individuals, and also collectively. "When I was twenty, I knew everything, and my father knew nothing. When I was thirty, I was surprised to see how much my father had learned in those past ten years." Then he added, "Now at 76 I know nothing." So education may really be nothing more than a progressive discovery of our own ignorance.