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This paper provides a scenario for world food productivity into the 21st century. Emphasis is directed to the increasing competition in world markets and the risk and uncertainty that rising productivity in other countries brings to the United States food and agricultural system.

The Global 2000 report (1), which indicates a potential future growth rate for agricultural output that is inadequate to prevent higher food prices in the long run, was not only wrong but radically wrong. The world is going to be able to feed its growing population, and feed it quite well. While most of the world seems to have been preoccupied with Africa's short-run drought problems, the productivity of the world's farmers has begun to surge upward again. New technology, additional investments and incentive-oriented national farm policies all have helped to lay the groundwork for this important development. This will mean improved nutrition for many of the world's poorest inhabitants, especially since the most rapid progress is likely in the developing countries.

Rising agricultural productivity in most of the world implies that US farmers can expect increasing competition in world export markets, and intensified trade conflicts with other farm exporters. In a world where the commercial demand for farm products already is fully met and major surpluses of grain and livestock products already have accumulated, this surge of productivity will put tremendous pressure on farmers' incomes, and on government policies designed to protect them.

Sources of Higher Farm Output

Farmers, in their more chauvinistic moments, may speak as though rising crop yields are due solely to their own hard work. But few work harder than a peasant farmer in a primitive agriculture, and his productivity is terrible. Modern high-tech farming depends heavily on effective off-farm support -- in such forms as research, machinery, chemicals, communications and marketing. Productivity in modern agriculture derives less and less from such traditional agricultural resource as land and climate; it depends more and more on technology and capital investment which raise the "carrying capacity" of the world's farms.

Improved Farm Technology

The single most important element in rising agricultural productive potential is

evolving scientific knowledge. Agricultural science is the force that T. R. Malthus could not see from his viewpoint in 1800, and it is the principal factor keeping world food production ahead of population growth in most of the world today. Farmers around the world continue to adopt evolving technology on a broader scale, thanks to literacy programs, extension efforts and improved communications. In addition, agricultural science continues to progress in tandem with other kinds of knowledge. One of the most important recent factors has been the success of the new Third World agricultural research institutions. What follows is only a partial list of the scientific developments just beginning to impact on world agriculture:

* Some US farmers this year planted the world's first successful hybrid wheat, with yield increases of 25 to 30 percent. Foreign seed firms are already seeking joint ventures to adapt the hybridization technique for their own wheat. Eventually, wheat breeders should be able to hybridize wheat for most of the world's major producing regions, boosting world production from the current 500 million metric tons (mmt) to as much as 650 mmt virtually by itself.

* New growth-regulating chemicals can shorten the soybean growing season by two weeks -- permitting double-cropping of soybeans and wheat as far north as central Illinois in the US, and increasing the double-cropping potential of Chinese and Latin American soybean growers as well.

* Cornell University has discovered that additional doses of bovine growth hormones stimulate dairy cow production by 15 to 40 percent with no change in feed rations. Michigan State University has identified high-efficiency rumen bacteria that can help wring ten percent more feed value from the cow's diet.

* High-fructose corn sweetener, a high-technology sugar substitute, has already taken 29 percent of the U.S. sweetener market, and is cutting into US sugar consumption at the rate of nearly 500,000 tons per year.

* The U.S. Department of Agriculture has announced the world's first viral insecticide. It attacks the larvae of the Heliothis insect family -- which includes world-wide pests such as the corn earworm, tomato hornworm, soybean podworm and tobacco budworm. The new insecticide promises to sharply reduce losses to these pests, raising yields with virtually no negative environmental impact.

* New conservation tillage techniques are replacing the traditional moldboard plow, reducing planting costs and greatly reducing soil erosion. The techniques are designed to incorporate crop residues in the top few inches of soil, slowing water runoff and encouraging absorption. Conservation tillage is already in use on as much as three-fourths of the US Corn Belt.

* U.S. farmers are planting the new long-grain Lemont rice variety, raising yields by 25 to 30 percent. The International Rice Research Institute, which produced the high-yielding Green Revolution rice varieties, has now released its "Third World" variety, which needs only two-thirds as much nitrogen fertilizer and one-tenth the pesticide protection to achieve the same yields as the other high-yielding varieties.

* A new seed treatment defeats "take-all" disease in the US Pacific Northwest wheat crop, and is expected to boost already-high yields in the region's irrigated wheat by 20 to 40 percent.

* Fish farms now supply 11 percent of the US fish supply, with feed efficiency rivaling that of broiler production.

In the EC (European Community), wheat yields jumped to record levels this year, 18 percent above the previous high, due largely to the introduction of new varieties. British farmers have shifted from spring barley to new winter barley varieties, adding more than a million tons to annual grain output. Europe's new "double zero" rapeseed varieties helped raise British rapeseed yields by 30 percent in 1984. Improved French varieties of field peas and beans helped raise production 20 percent in 1983 and another 25 percent in 1984 -- with more to come.

* Tissue culture experiments in Indonesia and Malaysia are expected to raise yields of rubber and palm oil. The technique permits researchers to produce up to 20,000 identical seedlings from a high-yielding parent in a matter of months instead of decades. Malaysia expects to raise the oil content of its palm kernels from 20 percent to 30 percent.

* A green-Revolution sorghum variety for Africa may have just emerged from plant breeding efforts of the International Center for Research in the Semi-Arid Tropics. The new sorghum could triple cereal production potential in large parts of Africa, and it has far greater drought resistance than current seed strains. The new seeds have just completed their first on-farm field trials in the Sudan with exceptional success.

* Researchers in Peru apparently have solved the secret of permanent cropping in the huge Amazon Basin. They are now in their thirteenth year of cropping the same fields, growing three crops per year of rice, corn, peanuts and soybeans. Yields are averaging ten tons per hectare per year. The secret is trace minerals, such as copper and boron, which leach rapidly out of the acid Amazon soil due to the high rainfall. The researchers add lots of lime and a complete menu of trace minerals before each crop. Local farmers have duplicated the research

success. The project's results may be applicable to more than 200 million hectares of the Amazon. Peru already is developing roads and other infrastructure to support a shift of its farming focus from the Pacific Slope to the Amazon. Brazil is conducting similar experiments in its own portion of the Amazon Basin. The trace mineral approach may also be useful on some of Africa's acid rain forest soils.

The productivity potential of these new farm technologies, great as it is, may be dwarfed by the awesome productivity potential of genetic engineering. Scientists are unraveling the secrets of DNA, nature's hereditary blueprints for plants, animals and one-cell organisms. Aided by such new techniques as cloning, embryo transfer, tissue culture, protoplast fusion and recombinant gene transfer, they are making rapid progress in altering the blueprints to produce organisms vastly more useful to humans. The first results are being achieved in one-celled organisms, with new vaccines and fermentation products. Genetic engineering has already produced the world's first fully safe vaccine against foot-and-mouth disease, one of the most pervasive and costly livestock diseases in the world. Similar research techniques are expected to achieve major victories against such diseases as malaria and river blindness which drain the effectiveness of farm labor forces in Third World countries, and East Coast fever which limits cattle production in East Africa. Genetic engineers have already identified soil bacteria that produce ammonia for their own use; the challenge is to get them to produce extra nitrogen which could nourish plants, sharply reducing the need for chemical fertilizers.

Genetic engineering will tremendously increase our power to tailor plants for greater utility -- perhaps salt-tolerant rice for coastal marshes, drought-resistant cereals, and the first crop plants to offer complete protein. Dramatic progress is expected in forestry, where productivity has been constrained by the slow growth rate of trees. Research will produce faster-growing trees, and perhaps tap biomass energy value from fast-growing shrubs on now-marginal land.

In animals, genetic engineering can contribute to higher milk output, a low ratio of fat to lean meat, and/or genetic resistance to a wide variety of diseases.

New Financial Commitment in Agriculture

While new knowledge is the most important single factor increasing world farm productivity, investment is also playing an important role. Investments continue to be made in machinery, fertilizer, pesticides, irrigation, transportation and storage. Millions of small farmers invest their labor in such efforts as building terraces, planting windbreaks, and draining wet spots in their fields. Here are a few of the impacts of world agricultural investment:

* Saudi Arabia has set a record for developing a grain surplus. Saudi wheat

production has risen from about 150,000 mt in 1975 to 1.3 million mt in 1984. The Saudi government offers domestic growers four to five times the price of the grain on the world market. As a result, major investments in irrigation wells and center-pivot sprinkler systems have literally greened the desert.

* Norway will import no feed grain this year, and only enough wheat for blending, because of a grain crop nearly 30 percent above the previous record. Larger plantings and better wheat varieties point to continued growth in production. For several years, Norway has been gradually substituting domestically-produced fish and rapeseed meals for soybean meal in its livestock rations.

* Thailand has developed a new palm oil industry to meet its domestic vegetable oil needs, displacing imported vegetable oils. Palm oil production rose from 15,000 tons in 1980 to 55,000 tons in 1984 -- with 75,000 mt projected for 1985. Research is expected to increase Thai palm oil output further in the coming years, by raising oil content and introducing weevils that pollinate the palms more effectively.

* The EC has produced a huge swing in world grain flows -- moving from net imports of 20 mmt per year to net exports of 15 mmt -- primarily on the strength of high price guarantees to its farmers. EC farm production per capita has increased more than 25 percent since the Common Agricultural Policy was installed in 1962. Most of the increased production has displaced imports or has been exported under subsidy.

Productivity-Oriented Farm Policies

Development experts are now beginning to recognize the pervasive influence of national policies on farmers' use of their time, land and technology. Small farmers have proved, in country after country, that they will eagerly seek higher productivity -- if they can improve their standards of living by doing so. The experience of the centrally-planned economies, and too many of the lesser developed countries, has also proven conclusively that the lack of farmer incentives will doom any effort to raise farm output. Among the outstanding recent farm policy developments:

China has recently conducted the most dramatic farm policy shift since Stalin's collectivization of Soviet farms. In the 1970s, Chinese agriculture was stagnant, unable to keep up with the country's population growth. Starting in 1979, Chinese leaders scrapped the communal farms which had been the central element of Communist agriculture and abolished most central controls on farm management. In a two-year period, most of China's farmland was leased out to individual families and small production groups. Price incentives were increased about 25 percent. As a result, farm output has risen more than 40 percent in five years. Grain output has achieved new records in four straight years -- even while grain hectares have been reduced to make room for

larger crops of oilseeds, cotton and sugar. Chinese diets have improved, dependence on farm imports has been reduced, and China has even shifted from a major importer of cotton to a significant exporter.

Increases Already Evident

World farm productivity has increased impressively in recent years. Between 1971 and 1982, world agricultural output rose 25 percent, according to FAO statistics (2). Farm output in the lesser developed countries rose 33 percent, compared with an increase of only 18 percent for developed-country farmers whose markets were growing much more slowly. Per capita food production rose 16 percent in South America and 10 percent in Asia during the period. Only in Africa and the Caribbean region did per capita consumption fail to increase. Africa does not lack agricultural resources but has been struggling with a high population growth rate and national policies that too often discouraged productivity. In some Caribbean/Central American countries, social upheaval disrupted much agricultural activity; however the region had a fairly good record of output increases in non-food crops, suggesting that there may have been a lack of farmer incentives for food production.

The rate of growth in LDC agricultural productivity has been not only high but rising -- from 2.7 percent per year in the 1971-77 period to 3.3 percent annually in 1977-82. (The Global 2000 Report projected agricultural growth rates of 2.2 percent per year, with rates of increase somewhat higher in the developed countries and somewhat lower in the LDCs -- just the opposite of what happened.) The growth rate would look even better if the averages had not been pulled down by major farm policy failures in the Soviet Union, Poland, China before 1979, and subSaharan Africa. (Zambia's farm productivity dropped 18 percent between 1977 and 1982, Zimbabwe's fell three percent in that time period, and Ghana's has risen only one percent since 1971.)

Why the Growth Will Continue

Farmers in the developed countries are implementing major new technologies. Government farm subsidies and trade protection increase their incentives to boost productivity, and they receive strong support from highly-developed infrastructures. Thus developed-country farm output potential is likely to rise significantly in the next few years.

Few of the mid-level developing countries can afford farm subsidies, but their high debt structures are forcing them to maximize farm exports and minimize imports. Thus, Brazil is moving to expand corn and soybean production as well as production of such specialty crops as cocoa and citrus. Argentina reduced its farm export taxes to encourage production, and Thailand is opening half a million hectares of cropland per year. All of these countries are using improved varieties, more fertilizer and better pest control, along with a variety of

productivity-enhancing techniques adapted to their agricultures.

In the 1970s, LDCs imported increasing amounts of food rather than trying to raise their domestic food output. Rising populations and the scarcity of foreign exchange now are forcing these countries to turn inward -- and they are finding important farm productivity potential when they support their farmers with incentives and inputs. Productivity is likely to rise at more rapid rates in the LDCs than in the developed countries during the rest of this century. LDCs have far more potential to gain from currently-available technology. In addition, LDC national expenditures on agricultural research tripled during the 1970s -- to a level exceeding similar expenditures by the national government of North America.

The internationally-funded Consultative Group of International Agricultural Research (CGIAR) has become perhaps the most remarkably successful agricultural institution since the development of the US land-grant college system. CGIAR focuses the efforts of its 13 institutes almost exclusively on LDC problems. CGIAR institutes have already produced the Green Revolution wheat and rice varieties, and may now have produced the breakthrough sorghum variety for Africa. The institutes are working on a wide variety of LDC food production technologies.

Many LDCs are also likely to pursue more effective farm productivity policies in the future than they have in the past 20 years. Africa, particularly, was hampered by achieving independence at a time when central planning and industrialization were the fashionable development models. More and more LDC governments are recognizing the limitations of such approaches in this era of rising populations and foreign exchange constraints. Effective agricultural development policies have been demonstrated in China, Kenya, Bangladesh and many other LDCs. Aid donors and such development institutions as the International Monetary Fund now often demand realistic farm policies as a condition for aid.

What Global 2000 Missed

Obviously, my central conclusion -- that world farm productivity is rising rapidly and can rise fast enough to feed the growing world population without higher food prices -- differs sharply from many previous assessments. However, it is becoming the prevailing view of the world's agricultural experts.

The pessimists relied too heavily on shortages for a short time period during the mid-1970s. Agricultural output is highly variable, due to weather, pests and a highly variable rate of year-to-year progress in technology and policy. It is easy to make major errors in agricultural projections if the wrong years are selected as a base. In addition, the agricultural output statistics used by the Global 2000 Report contained at least three major biases toward pessimism:

First, farm productivity in many of the LDCs have never come anywhere near its potential even with existing technology. It is mind-boggling to realize, for instance, that few African food crops have ever gotten any chemical fertilizer (outside the nation of South Africa). And the seeds most African farmers are still planting are the horticultural equivalent of Indian corn. Second, the output of many farmers has been held back by national policies: Some of the developed countries, such as the US, Canada and Australia, have deliberately diverted farm productivity in an attempt to increase farmer incomes. Developing countries have kept farmers crop prices low to favor their urban consumers. In the centrally-planned economies, farmers have lacked incentives and the necessary off-farm support industries to implement high-technology agriculture. Such policies can be changed under the spur of necessity. Third, and most important, the historical farm output averages do not project man's increasing power to create new "resources" through science -- one of the most important trends in our time.

The Problem in Africa

Africa is everyone's hunger concern -- but not because Africa is lacking in resources. The real problem is that most of Africa has continued to practice its traditional, primitive, shifting cultivation. Population pressures now force shorter and shorter fallow periods, and yields have suffered accordingly. The obvious answer is to modernize agricultural methods, with improved varieties, increased commercial fertilizer, and pest control. Research has only recently begun to focus on Africa's food problems.

Ethiopia is a case in point. That poor country is currently beset by ignorance, poverty, Marxist farm policies, open warfare, and more recently by the drought. It is no wonder a famine is in progress. However, Ethiopia has some of the best agricultural resources in Africa, however, Ethiopia's struggling agricultural research facility produced new varieties 10 years ago -- and those improved seeds were capable, when combined with a little fertilizer, of doubling yields on Ethiopian farms but low prices and inadequate seeds and fertilizer minimized their impact. Potatoes are well adapted to the country's high plateaus, and have yielded as much as 50 tons per hectare, but there has been no leadership in making potatoes an important crop or a significant part of the diet. Important progress is possible in Africa, however, and I think it will begin to show in this decade.

Farm Dilemma for the Developed Countries

The increased food productivity in LDCs will be felt primarily in improved diets within those countries. The result of increased food productivity in the developed countries, however, will be surpluses and intensified competition among world food

exporters. Effective demand in most developed countries is already satisfied and virtually all of the trade opportunities already are exploited. (New productivity could also increase LDC farm exports). The developed countries are thus confronted with a serious policy dilemma. There is unlikely to be enough market demand for all the farm products that can be produced at current price levels. Moreover, by the time the huge new populations in developing countries can bid effectively for better diets, their own farmers may well have the productivity to meet the demand domestically. This means we are in for an intensely competitive decade, with farm policies and budgets under heavy pressure. This will further complicate the international trade problems already generated by such practices as export subsidies, subsidized credit, import quotas, and volatile exchange

rates. Technology has apparently presented farmers and city dwellers alike with a farm policy problem far different than the Global 2000 report led us to expect.

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Notes

- (1) Barney, Gerald O., Study Director. The Global 2000 Report to the President - Entering the Twenty-First century. Prepared by the Council on Environmental Quality and the Department of State. (1977). Two volumes.
- (2) Food and Agricultural Organization, Production Yearbook. 1982. Vol. 36.