

A.I.D. RESEARCH 1971-1973

AGRICULTURE

HEALTH

POPULATION

NUTRITION

EDUCATION

**SCIENCE &
TECHNOLOGY**

ECONOMICS

Agency for International Development

DECEMBER 1973

COVER —
Space view of planet earth.
Remote sensing of our globe's resources is
an aid to the process of development.

This report was written by Mr. Malcolm H. Oettinger Jr. under a contract with AID. Technical information and review was provided by the AID research project managers. Mr. H. Charles Ladenheim coordinated the production of the report under the direction of Dr. Delbert T. Myren.

A.I.D. RESEARCH 1971-1973

Projects in

AGRICULTURE

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ECONOMICS

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INTRODUCTION

People of the developing countries are faced with problems of a magnitude no longer found in the United States. Hunger, disease and illiteracy are some of the great impediments to development faced by these countries. The goal of the United States Agency for International Development is to help them in their efforts to surmount these obstacles and improve the quality of their lives. To do this, the developing countries need trained manpower, knowledge and adequate resources. Most of the AID effort goes into helping these nations achieve these ends.

In the early years of technical assistance it was thought that most less developed country (LDC) problems could be solved by transferring and applying knowledge and materials already existing in the more developed countries. Over time and through hard experience we found that our existing body of knowledge, fitted as it was to problems peculiar to the more developed nations, was quite incomplete. Technologies and scientific discoveries that had eased problems at home did not work well under the conditions of countries with different resources, climates and ecological circumstances, and with dissimilar social values, educational levels and organizational systems. Above all, the technologies of the more developed countries have been designed to mesh with different relative costs of capital and labor and differences in employment opportunities. Therefore, technologies could seldom be transferred intact.

We found that the great asset that the United States has to offer is a problem-solving ability which can take unusual problems and find useful solutions. This knowledge and expertise is spread among our universities and among governmental and private research institutions. We have used their resources by funding research projects and in the process have strengthened and added to the store of competence available. This has been particularly true in the case of the centrally funded research reported in this publication.

In contrast to AID mission efforts which are country-specific, the centrally funded research program seeks answers to an array of problems which cut across nations and regions. The research project is our unit for approaching a problem. And the difficult part of research management is to estimate the probabilities that a particular approach will indeed produce results. For example, there are literally hundreds of ways to approach the problems of lack of protein and low quality protein in the diets of the poor in the LDCs. Some of the most promising work reported here reflects our decision to attempt breakthroughs in the genetic design of more nutritious food grains.

Our experience to date with AID-funded research suggests that it can be enormously helpful with a variety of difficult problems. Among the highly promising results are those reported here to: create new vaccines to prevent man's diseases and those of his cattle; bring into existence higher yielding crop varieties with better protein to nourish his body; design better systems for carrying knowledge to students; discover methods by which individuals can plan the size of family they wish to have, and produce better understanding of desirable economic and social relationships.

In deciding whether to proceed with specific research, AID looks first at the urgency of the problem and then, with the assistance of a Research Advisory Committee (RAC) made up of specialists in many fields, estimates the prospects of success of the proposed project. The bulk of the research funds are committed to projects that can reasonably be expected to produce high returns in a relatively short time. This does not mean that no risks are ventured nor that all efforts are short run. There are problems of such importance that projects are undertaken even though success cannot be assured.

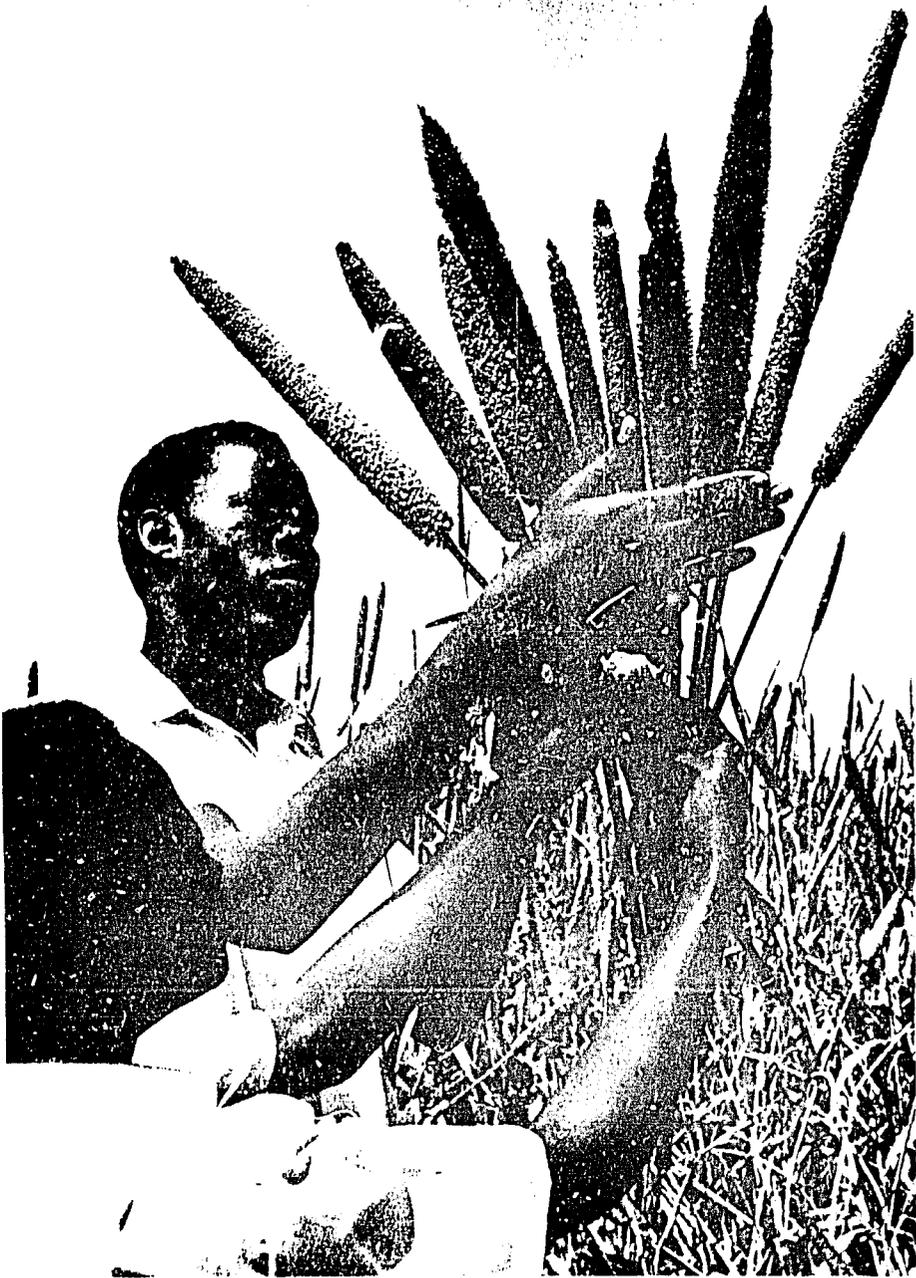
The research reported here is carried out primarily by U.S. universities and government agencies under contracts with AID. Less frequently, LDC universities, private agencies and foundations or other international development agencies have been chosen to undertake the research tasks. The contractors are selected on the basis of established competence in the field being explored. Many U.S. universities have long experience and expertise in areas of knowledge that bear directly on the needs of developing countries. In short, AID is able to rely on specialists who are leaders in their fields.

Whenever feasible, AID projects are meshed with the research and development efforts of other national and international organizations and the LDCs themselves, to obtain the critical mass necessary. Frequently, AID helps to establish or strengthen network arrangements linking the work of developed and developing countries on LDC problems. In such cases the United States may finance only a small part of the overall effort, but may still provide the impetus and scientific skill essential for success.

Although the fundamental purpose of AID research is to help solve LDC problems, it frequently results in rewards for the donor. Plant and animal disease resistance factors discovered in developing countries are important to American farmers when the disease breaks out in the United States. High protein cereals benefit American consumers—both directly and by lowering the price of animal feed. The search for safe, effective and inexpensive methods of contraception may lead to discoveries that will vitalize family planning programs everywhere. The scientific breakthroughs in identifying effective herbicides and producing biodegradable DDT reported here will have universal application.

This report of the centrally funded AID research programs covers projects underway at the time of publication or completed since the prior report (*The AID Research Program, 1962-1971*). For reasons of space the objectives and results are presented in summary form with little statistical data or ancillary findings. Those interested in greater detail will find the names and addresses of the contractors and principal investigators in the appendix of this volume.

AGRICULTURE



AGRICULTURE

In developing countries, which account for over 70 percent of the world's population and two-thirds of its land surface, the critical problem is how to produce enough food to stave off malnutrition, even starvation. Some 1.5 billion people in these countries do not have adequately balanced diets; their diets are particularly deficient in protein. And between 300 and 500 million of these people do not get nearly enough food of any type.

Populations increase; the land surface does not. This fact is central to the problems of the developing world.

Despite a remarkable 35 percent increase in food production over the past decade, population increases have been so great that the per capita food production is barely keeping up. This balance is so precarious that even a slight shortfall in production—caused by drought, flood, crop disease or other conditions—can create severe hardships to millions of people.

Improved technologies, particularly development of high-yielding grains with better nutritional value, hold promise that some of the problems may be solved. But these improvements must be accompanied by other technological breakthroughs if the increase in food production is to keep pace with the burgeoning population rates. This is where research fits in.

Most of the developing countries are in the tropics and sub-tropics where the problems of crop and livestock production are especially complex. The crops that can be grown most easily on the soils in these environments are usually low in protein—and the protein often lacks the amino acid balance that gives protein its nutritional quality. A diet poor in protein is particularly harmful to infants and children; it is believed to be the primary cause of severe juvenile health problems in developing countries.

Much of the increase in food production has come from sharp yield increases on irrigated land or on especially well-watered rainfed areas. But only about 11 percent of the world's land is irrigated. In Southeast Asia the figure is nearly twice as high, but in that region more land is now irrigated than available water supplies would warrant. In the future, most increases in food production must be achieved under less ideal conditions on the land on which the majority of people in developing countries—and most of the poorest farm people—now live. They cannot depend upon growing crops which require irrigation, such as the improved varieties of wheat and rice. So AID crop research efforts are aimed primarily at improving the protein content and quality and yield of varieties that will grow under these less favorable conditions.

On other lands where the rainfall is not adequate for food crop production, AID research emphasizes improved production from grazing lands. The focus up to now has been on control of major diseases and pests limiting cattle production on the vast grazing lands of Africa and Latin America—tsetse flies, hemoprotozoal diseases, and vampire bats.

In some cases the research is of a very basic nature. But it always has a specific goal—to solve a major problem or take advantage of new scientific knowledge in order to attempt a breakthrough that should benefit large segments of the population in the LDCs. To the extent possible, the research is tailored to the needs of the people facing food and protein shortages. For example, improving the protein quality of sorghum is not of the same direct value in the diets of people in the U.S. where it is used principally as a livestock feed and where protein supplements are relatively plentiful. However, to some 150 million people in developing countries, sorghum is a staple food.

AID has learned through experience that the technologies that are successful in the U.S. usually cannot be directly transferred to developing countries. Not only are the climatic, soil and water conditions different, not only do diseases and pests flourish there that are unknown in this country, but the cultural environments differ and present diverse problems. What does have relevance and can be applied is the basic scientific methodology that worked in the U.S. and must be applied anew, under entirely different circumstances, in the LDCs.

The main discoveries that have led to production increases in the past decade have resulted from close collaboration between scientists and technicians from the more developed countries and the developing countries, involving governments and public and private agencies.

One intangible achievement of the work already done is the change in perception of the possibilities of organized research shared by the developing countries. We now share the view that enormous strides can be made, that the race between population and production is not a hopeless contest with famine the foregone victor. And we have come to recognize the importance of growing crops that will not only produce more food but will also help to close the protein gap.

Success in developing high-yielding varieties with greater nutritive value is providing impetus and focus to research designed to find the answers to myriad problems plaguing the developing world. AID is concentrating on solving practical problems of plant disease and production, of irrigation and fertilization, of increased meat production on semi-arid and tropical grazing lands. New approaches are being taken, because innovation is essential in solving problems that have persisted for centuries and are increasing at a frightening rate.

Improved Plants and Farming Methods

AID has been, and continues to be, a key participant in the improvement of crop production in the LDCs, frequently referred to as the "green revolution." Through its central budget AID provides about one-quarter of the annual funding for international agricultural centers. In addition it has been a leading promoter in many countries of the utilization of the improved varieties and new technology emanating from the centers. Less known, but of equal importance, have been a number of centrally funded research projects at American universities which are making essential discoveries that enable the "green revolution" to move forward.

It was only recently discovered that protein levels and amino acid balance are heritable traits capable of being genetically manipulated to improve the food value of crops by a significant amount. In 1962, the successful transfer of high protein from a soft unadapted wheat variety, Atlas, to a hard winter bread wheat was reported by a U.S. Department of Agriculture-University of Nebraska research team.

In 1963 the possibility of upgrading the dietary quality of cereal protein by breeding was conclusively demonstrated by Purdue University scientists who discovered two genes in corn—opaque-2 and floury-2—which increased levels of two essential amino acids, lysine and tryptophan, and promoted that cereal to the nutritional equivalency of skim milk.

Recognizing that people in developing countries require not only more but better foodstuffs, AID has sponsored research in genetic improvement of basic foods to improve their nutritional quality while at the same time assuring high yields, good agronomic characteristics, and resistance to limiting diseases and insects.

Wheat—Improvement of Nutritional Quality

About 500 million acres of the world's cultivated land are planted to wheat. Measured in pounds, more wheat is produced than any other cereal, although rice is more widely consumed. Like all cereals, wheat is relatively low in protein; it is also deficient in lysine.

Since 1966 AID has supported research at the University of Nebraska to determine the optimum varieties of wheat for growing in LDCs and to develop superior strains through cross-breeding. Nebraska has long been an outstanding research center for winter wheat improvement, contributing to the quality of wheat grown in the U.S. Although the AID research will undoubtedly also benefit American farmers, the emphasis is on meeting the needs of developing countries.



The project's first major task was to analyze some 13,000 common or "bread" wheats from the U.S. Department of Agriculture's World Wheat Collection to find varieties that appeared to have genes that promote higher protein content and better lysine levels than ordinary strains. Promising higher lysine sources were combined with already existing high protein experimental wheat varieties. As quickly as possible, hybrid populations and improved lines were made available to developing countries for evaluation and use.

Nebraska researchers systematically coordinate their efforts with those of CIMMYT, the leading center for spring wheat research, with the United Nation's Food and Agriculture Organization (FAO), and with plant scientists from LDCs. To determine which lines were adapted to the varying environments of LDCs, their scientists were encouraged to conduct uniform yield trials on a series of standard collections of varieties distributed by FAO including the new varieties with improved protein.

Through an International Winter Wheat Performance Nursery (IWWPN) involving the major winter wheat breeding stations in LDCs, the new improved wheat lines have been included in 52 nursery sites in 33 countries. As a result of the network program, foreign cooperators have sent more varieties for inclusion in the IWWPN than could be accommodated for immediate testing. In 1971, it became necessary to set up a preliminary screening nursery to identify the best entries for inclusion in the advanced field trials.

The nurseries of the IWWPN include the most advanced of high-protein, high-lysine wheats that have resulted from crosses with known high-yielding varieties. Ultimately the researchers expect to be able to regularly breed high-yielding wheats with at least 25 percent more protein than their commonly cultivated ancestors and with significantly higher lysine levels.

Scientists from the University of Nebraska have unlocked some of the genetic mysteries contained within grains of wheat. After studying characteristics of thousands of strains of wheat from around the globe, they have bred varieties that not only yield more per acre but also produce wheat of superior nutritional value. The varieties contain more protein and more lysine, an essential amino acid in which most wheats are deficient.

Christopher Columbus was looking for India when he found America. Lowell Klepper, an assistant professor of agronomy at the University of Nebraska, was searching for wheat strains with high protein value when he discovered an important secret of plant life that opens the way for improved herbicides.

Working under an AID research contract, Klepper knew that the protein content of the same strain of wheat could vary from as low as 8 percent to as high as 18 percent, depending upon where and how it was grown. One factor determining the protein content appeared to be the amount of nitrogen the plant received. Klepper's scientific curiosity led him deeper into the secrets of how plants convert nitrogen to protein, one of those processes that scientists recognize without fully understanding.

In his study of metabolism in high protein wheat varieties, Dr. Klepper experimented with herbicides that block a step in protein synthesis, whereby the plant converts nitrogen into ammonium compounds from which amino acids can be formed. Amino acids are the building blocks of protein essential to human and animal nutrition.

In protein synthesis in wheat, as in any other crop, nitrite is an intermediate form of nitrogen in this process and is not normally detected in plant tissue because it is reduced very rapidly to ammonia. But Dr. Klepper learned after testing 90 percent of the chemical classes of commercial herbicides that essentially all cause a buildup of nitrite.

"Nitrite is really the perfect murderer for plants," Klepper said. "It does its work and disappears quickly. And apparently no one has ever suspected it."

The traditional method of developing herbicides has been through laborious trial-and-error processes involving extensive screening of thousands of chemicals and lengthy field testing. The technique developed by Dr. Klepper should compress the time necessary for screening and identification of which herbicides are most effective for specific weeds. Some tests that previously required months or years may now take only hours.

Another advantage of his technique is that it should reveal the exact amount of herbicide necessary to kill a specific weed, which would reduce to a minimum the effect the herbicide will have on the environment.

Dr. Klepper's procedure uses herbicides combined with surfactants, substances that make it easier for chemicals to penetrate surface films of water surrounding the plant's skin. With surfactants, smaller amounts of herbicide will be needed.

The importance of these findings can be illustrated by the fact that crop losses due to weeds are estimated in billions of dollars per year in the United States alone. In developing countries, where crop yields often determine whether thousands of men, women, and children will go hungry or not, annual crop losses directly attributable to weeds can run as high as 50 percent or more.

In addition to reduced costs for weed control, the Nebraska findings will lead to more efficient use of fertilizer and water, and a decrease in environmental pollution through better herbicide management. AID has assisted the University of Nebraska in getting the new techniques patented in the public service so the benefits will be available to all who wish to use the process without payment.

Cooperation from plant scientists in many different countries is essential because environment has a strong effect on protein level of wheat. The average wheat contains about 12 percent protein. But a single variety may vary from as low as 8 percent to as high as 18 percent, depending upon the conditions under which it is grown. The IWWPN enables scientists to determine which of the variations in protein content are truly genetic and which are simply the result of environmental influence.

Success stories from the nurseries are quickly transformed into crops in countries that need them. For example, through the IWWPN the Russian wheat Bezostaiia was shown to be especially superior for broad adaptation and yield; as a result of the comparative trials it is now being planted in central Turkey and neighboring countries to the extent that it has become one of the most widely grown varieties in the area.

Scientists at Nebraska have sought shortcuts to determine early in plant growth the likely protein content of the wheat, to avoid the laborious process of trial and error as far as possible. By answering basic questions about how plants convert nitrogen to protein, researchers came up with vastly improved tests for herbicides (see Page 4). They are also perfecting rapid screening tests for leaf enzymes that will enable scientists to identify plants with a superior ability to produce protein in the vegetative phase of the plant's growth, before flowering. In less than a year, the Nebraska team found that in the Atlas derivatives these superior seedling protein fixers usually developed the highest protein content and quality of grain at harvest time. This was further substantiated through feeding trials with small animals.

Because of this finding the plant breeder can determine the protein content by examining seedlings instead of waiting for the plant to produce grain. Consequently, in a brief period of time, he can select those seedlings that show promise of high protein content and discard those that do not.

Corn--Improvement of Nutritional Quality

Maize or corn is another cereal basic to the diet of many people in developing countries. It is also widely used to feed animals. It is naturally low in protein — more so than wheat — and like most cereals, it is deficient in two essential amino acids, lysine and tryptophan.

Attempts to improve the nutritional value of maize were considered impractical until 1964 when scientists at Purdue University identified the opaque-2 gene, which markedly increases certain amino acids, particularly lysine and tryptophan, thus improving the nutritional quality of the corn. Subsequently, they reported that a secondary genetic character, floury-2, was intermediate between opaque-2 and normal corn in its amino acid content and had increased quantities of methionine, another amino acid essential to human and animal nutrition.

The discovery of the opaque-2 endosperm character immediately received wide publicity. A U.S. seed company rapidly began to breed the first commercial opaque-2 hybrid. Seed samples of the hybrid were supplied through AID missions around the world to countries interested in evaluating and possibly planting this new type of corn.

Yet, despite superior nutritional qualities, the new opaque-2 hybrids had some serious defects compared to ordinary corn. Among them were lower grain yield; greater susceptibility to disease, particularly ear rot; higher moisture content at harvest; soft starch that was unacceptable for local recipes; poor storage quality, and low germination. These deficiencies made it plain that if the production potential for improved protein corn was to be realized, considerable additional research and development would be required. But at least Purdue proved that corn could be improved nutritionally through breeding.

In 1969 AID initiated a contract with Purdue to try to find other genes and germ plasm that would provide improved nutritional characteristics of maize, and for a breeding program to overcome the defects of opaque-2. Cooperating with other world maize research centers, such as CIMMYT, the Purdue scientists have identified a series of endosperm of opaque-2 corn in hard crystalline varieties.

These types of opaque-2 cannot be distinguished from ordinary flint corn. They have the processing qualities of normal maize and they are equal to the normal types in harvesting and keeping qualities. They also germinate normally in the field. Animal feeding trials indicate that these modifications have resulted in no serious loss in the opaque-2 nutritional values. Tests with young children in Guatemala and Colombia have demonstrated that opaque-2 is the nutritional equivalent to skim milk when fed at an adequate level of diet. It can cure kwashiokor, a disease resulting from severe protein deficiency, when it is the only protein source. A recent finding of great potential value to maize nutrition improvement is the discovery of a sugary gene which combined with opaque-2 has resulted in a grain with improved consistency as well as easier digestibility of the protein contained in the present opaque-2.

Another important success of the project to date has been development of a positive test for the chemical identification of high-lysine opaque-2 maize. Because the new corneous endosperm opaque-2 varieties looked so much like ordinary corn, neither the housewife nor the farmer was willing to pay the extra price for the superior corn, without some form of assurance that it was indeed improved. The Purdue identification test, using simple laboratory procedures, according to the scientists who developed it, should quickly identify high lysine content regardless of the physical appearance of the corn.

Brazil, one of the most advanced LDCs, is utilizing this new discovery; in 1972 some 400 tons of opaque-2 seed, an amount sufficient to plant about $\frac{3}{4}$ million acres, was produced and distributed. The new crystalline opaque-2 varieties which have normal grower and consumer acceptance, will be introduced there soon. They are also being produced in Mexico, Colombia, and Guatemala, and to a lesser extent in countries in Africa and Asia. It is expected that the hard kernel type of opaque-2, in addition to its use as a livestock feed, will also be used to improve the protein quality of many corn products such as corn meal and snacks made from corn.

Research results from this project are disseminated rapidly to interested research personnel through the world in the form of seed material and through newsletters and scientific journals.



Corn, a basic food for millions in developing countries, is naturally low in protein and deficient in the essential amino acids, lysine and tryptophan. AID funded research at Purdue has led to the discovery of genes that can correct these deficiencies.

Sorghum—Improvement of Nutritional Quality

Sorghum, the fourth most extensively produced cereal grain, is the primary source of calories for more than 150 million people in India, Africa, and parts of the Far East. In some developing countries, people derive 60 percent or more of their protein intake from sorghum. These are generally the poorest people in the poorest countries — largely because sorghum can be grown on land too dry and often too infertile to grow other cereals. If these people are to live more productive lives, and if their children are to achieve their full mental capabilities and be receptive learners in the emerging nations' school systems, a primary food need is increased intake of usable protein.

Project scientists at Purdue screened some 10,000 varieties of sorghum from the world collection to find those with the most protein and the highest nutritional value. They sought lines with genetic characteristics that could be crossed with hardy lines capable of survival under the climatic and soil conditions of LDCs. They confirmed that most sorghum varieties contain only about 10 percent protein, are relatively low in lysine, and generally poor in amino acid balance. Yet they found that different types of sorghum can vary widely in protein amount and quality. Total protein values may range from 8 percent to more than 25 percent from the worst to the best lines.

The painstaking analysis uncovered two lines of sorghum from Ethiopia that are definitely superior both in the amount of protein they contain and in the quality of that protein. They contain nearly twice as much protein as the average sorghum and the amount of lysine in that protein is 50 to 70 percent higher. In three to five annual growing seasons, the scientists believe, these lines can be crossed with hardy, high-yielding varieties of sorghum to incorporate the best qualities of each through breeding. They will also try to produce sorghum with superior milling qualities.

In the course of the AID project, Purdue scientists discovered why milling can be so

important. The researchers had been feeding small animals grain from varieties of sorghum that showed relatively high nutritional value in chemical assays in the laboratory — yet these superior values were not always reflected in animal growth during field trials.

The scientists explored several possible explanations for these results: perhaps chemical analyses had been faulty; or, the animals used may not have been good experimental models (digestive systems vary greatly in laboratory animals); special toxins or other dietary disadvantages in sorghums may have cancelled any protein improvement; some unknown factor in the sorghums might have made protein unavailable to the animal eating them, even though high protein was detectable through chemical assay.

Repeated experiments seemed to point to the last reason, the unknown factor, and the team concentrated on learning what it was.

The clue that led to the breakthrough came from chemical comparison between lighter and darker colored varieties of sorghum. For many years breeders have selected varieties of sorghum with colored seeds, brown or red pigmentation, because they contain tannin. This substance is bitter and unattractive to birds. In all areas where sorghum is grown, birds are a serious pest. They can devour much of a crop in a single day and destroy most of that which they do not eat. The brown or red sorghums are not only distasteful to birds, but when they mature under humid conditions, they are also less likely to mold, and they tend to be more resistant to grain insects in storage. Although white-seeded sorghum is generally preferred for the human diet and yellow endosperm varieties are favored by the feed industry because they have a somewhat better feed value, the pigmented varieties constitute by far the largest percentage of all commercial sorghum hybrids.

Further tests clearly implicated tannin as the "unknown factor." High-tannin varieties of sorghum caused rats to lose weight (even to starve), moderate amounts of tannin in grains of comparable protein composition caused slight weight gain in rats, and samples containing no tannin resulted in animal growth gains considerably greater than those for rats eating moderate-tannin sorghum.

As a clincher, when the pigment-bearing outer layer of the grain is polished away, pigmented varieties have essentially the same nutritive value in animal-feeding trials as the non-pigmented types. Chemical tests showed that solubility of protein was slower for high-tannin than for low-tannin varieties.

Milling the tannin is not an insurmountable problem. Tannin is contained in an extremely thin layer, one or two cells beneath the pericarp or "skin" of the kernel. Its presence has been found to be due to a single, dominant gene, so it could be bred out of the sorghum. But this would not remove the hazard of the predatory birds. If they destroy the crop before harvesting, its protein value is moot.

Research is proceeding on three fronts (not all associated with the Purdue project): controlling birds, developing inexpensive processes for milling sorghum, and searching for another genetically controlled agent that, like tannin, is distasteful to birds, but which does not tie up protein for human or animal consumption.

Discoveries already made by the Purdue scientists about the nature of sorghum and ways to increase its nutritive value will greatly enhance the quality of the food of a large number of people living in areas of developing countries where other cereal crops do not thrive.

The project's findings will be of importance not only to people who depend upon sorghum for food, but also to those who grow sorghum for livestock feed. Purdue has worked with 61 major cooperators in 53 countries and several others have asked for similar cooperative research. Data on the chemical composition and agronomic characteristics of over 800 lines have been summarized for distribution to persons working with sorghum throughout the world.

Pulses—Improvement of Yields

Pulses, the edible seeds of a variety of legumes such as beans, chickpeas, cowpeas, lentils, mung beans, peas, and pigeon peas, are considerably higher in protein content than most cereals. Pulses usually contain 20 to 35 percent protein, compared with 7 to 12 percent in ordinary cereal grains.

Pulses have benefitted little, if at all, from the great research efforts resulting in the recent breakthroughs in cereal crops. Because of high susceptibility to disease and insects, poor cultivation practices, and characteristics inherent in many varieties of pulse, the edible legumes usually produce very low yields. Sometimes the reduction in yield due to insects and diseases alone exceed 30 percent of the crop.

So while research on cereals has centered on improving their protein amount and quality, pulse research concentrates on improving yield, since the plants are already comparatively high in protein.

Under a contract with AID, the Agricultural Research Service of USDA established a pulse research center in Iran in 1965 and another in India in 1966. At these centers germ plasm of the several species of pulse grown in each region was collected and analyzed; important diseases threatening the plants were determined along with measures to breed resistant varieties; primary insect foes were identified and control programs suggested. The best cultural practices for each crop were also determined. The centers trained local researchers in modern techniques, including soil management practices to maximize yields.

The research teams completed six seasons in Iran and three seasons in India before the countries took over support of the projects themselves. Under the project, researchers were able to select, develop, and multiply seed of eight varieties of pulse including chickpeas, pigeon peas, lentils and mung beans that yield 20 percent more than the previously planted pulse crops. At both centers, scientists adopted a "package" approach of recommending fertilizers, methods of insect and disease control, irrigation and other farm management practices which doubled the crop yields of beans, cowpeas, lentils, and chickpeas, in some areas. This

"package" type of management was successful except where inhibiting soil factors or environmental impediments intervened.

In their testing, scientists found a variety of mung bean that matures in 70 days and yields about one ton per hectare (2.47 acres). In the past, farmers in northern India kept land fallow during the summer months, even with irrigation, because they were unaware of any pulse crop that could mature within the short, hot period available between the winter and monsoon crops. With the introduction of the early-maturing mung bean, a farmer can increase his income greatly by growing four crops a year: wheat from December to April, mung beans from April to July, corn or rice from July to September, and potatoes from September to December.

Other studies have uncovered varieties of pigeon peas that mature in 4 to 5 months, compared with the 8 to 10 months it takes traditional varieties.

In September, 1969, exploratory research on beans and cowpeas was initiated at the Federal Experiment Station, Mayaguez, Puerto Rico. Here scientists have concentrated on the development of pulse germ plasm resistant to limiting diseases caused by viruses, fungi, bacteria, as well as insects. Tropical conditions in Puerto Rico make the island an excellent experimental setting. All major bean and cowpea diseases are present, often in epidemic proportions. Virus diseases are severe because of the large populations of insects that transmit a number of them. And the year-round growing period permits growing and screening of several generations a year.

In three seasons, a short period for such research, progress has been very promising. Varieties of beans, cow peas and pigeon peas highly resistant to a number of prevalent diseases, and one variety resistant to the white fly, have been developed. These are being made available to interested national and international agricultural organizations. Project linkages are planned to include most of the countries of Latin America. Technicians from the project are providing guidance and counsel to LDCs that is not available elsewhere. Throughout the project, findings have been published, and workshops and technical meetings have been held with cooperators.

Cassava: A Search

Cassava is a tropical root that is grown abundantly under conditions that would discourage most food-producing plants. It is one of the greatest producers of calories per acre planted. It is the seventh largest staple food in the world. Unfortunately, its nutritional value, in terms of a protein crop, is very low. In the U.S. cassava is used primarily as a basic ingredient in tapioca.

World cassava production has been steadily increasing — from 62.5 million metric tons in 1955 to 85.6 million in 1968. Scientists have been speculating whether the crop can be improved nutritionally since it is so abundant. AID sponsored a project by the University of Georgia from 1969 to 1971 to compile the available literature on cassava and to make recommendations for research to improve it.

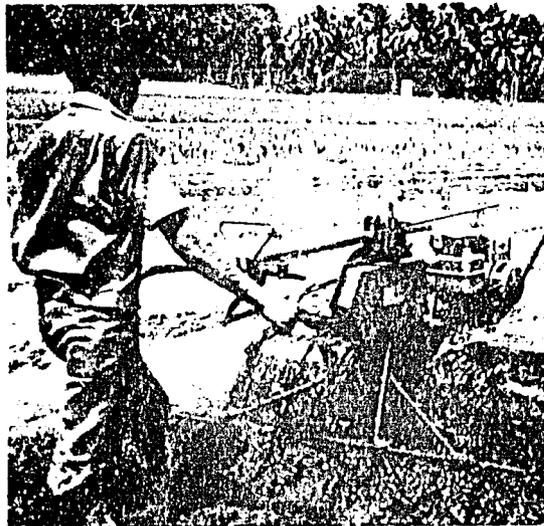
The cassava publication has had wide distribution and is providing guidance as to the state of knowledge concerning this crop to investigators throughout the world.

Georgia recommended that the crop be studied with a view toward increasing yield, protein and starch quantity, to develop increased resistance to drought, insects and diseases, and to modernize processing and fortification for both human and animal consumption. The university also recommended establishment of germ plasm banks in Africa, South America, and Asia, as a source of germ plasm for breeders and producers throughout the world.

At the present, world food organizations are stressing the value of cassava as one of the primary food crops for increasing caloric intake. Emphasis on improved protein quality still centers on legumes and cereals. Nevertheless, the potential for cassava, enriched either through selective breeding or fortification, will continue to be explored. The leading centers in the improvement of this crop are the international centers in Colombia (CIAT—International Center for Tropical Agriculture), where Canada is financing a major program in cassava production and improvement, and Nigeria (IITA—International Institute for Tropical Agriculture). Both institutes are concentrating on different aspects of improving the crop, especially the control of certain limiting diseases caused by viruses and bacteria.



A portable table thresher that can handle either moist or dry rice grain in the field is being tested in the Philippines. This relatively inexpensive machine separates grain from chaff and straw, combing and shearing the rice plant in a way that combines features of a cotton gin and a conventional thresher. Two Philippine firms are manufacturing the machine which was developed by the International Rice Research Institute (IRRI).



Simple farm machinery has been designed by IRRI to perform arduous tasks peculiar to rice farming. This five-horsepower tiller is used for wetland plowing, and puddling. The tiller, fabricated from locally available materials in small machine shops, simplifies repair and servicing problems.

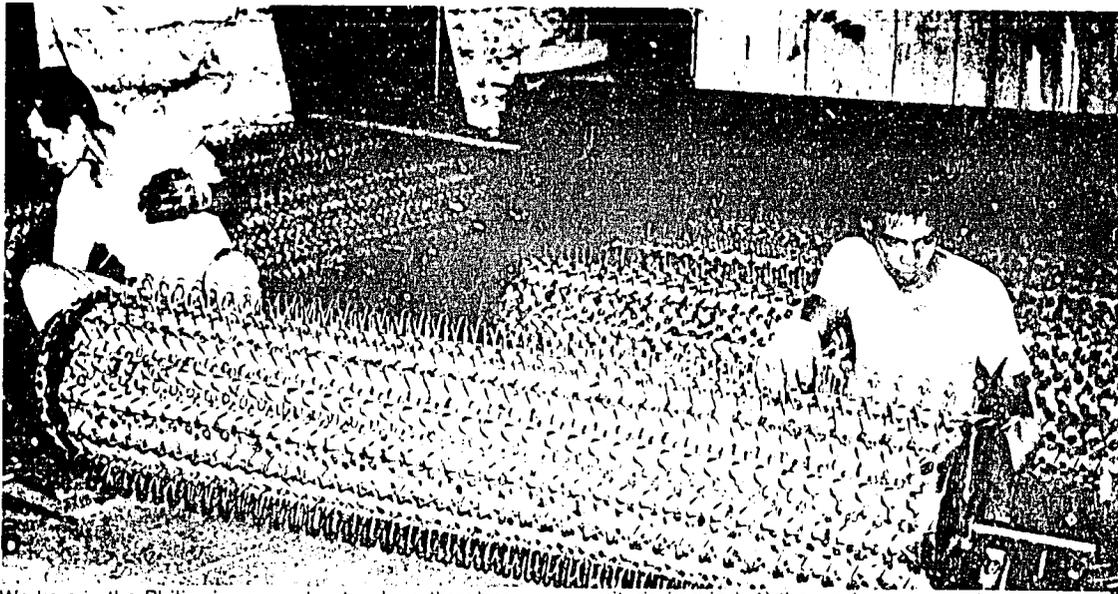
Small Machinery for Rice Farming

More people depend upon rice as a staple in their diet than upon any other food. In most countries in South Asia, more than half the population is engaged in agriculture with rice easily the major crop. Both land and labor productivity in agriculture are low, resulting in a poor living for a majority of the rural population. However, the development of high-yielding, fast-maturing rice varieties during the past decade has provided an incentive for farmers in the tropics to grow multiple crops and improve not only their productivity but also their diets.

To develop and realize the full potential of the new seed-fertilizer technology, more intensive production practices are generally necessary. In many countries of Asia, labor shortages are beginning to occur in periods of peak labor demand. Many farmers are finding that they cannot effectively till, plant and harvest their crops with traditional methods and take advantage of the new technology. For such farmers mechanization is becoming a means of supplementing both available labor and land resources. The rise in seasonal labor costs in many Asian countries has created a favorable climate for agricultural mechanization.

Some economists might argue that labor productivity could be increased through the introduction of more intensive manual cultivation practices. This approach has many limitations: the high cost of human energy, the seasonal nature of demand for farm labor, the critical necessity for timeliness in agricultural operations (particularly in multiple cropping areas), for example. The potential for supplying additional power from animal sources is also rather limited. Besides, animals usually compete with humans for scarce land resources.

The drudgery of manual wetland rice farming has driven many farmers to the cities of Asia, where their lot is no better. Now that seed-fertilizer technology is available to produce greater yields from the land, highly specialized equipment is needed to realize the benefits. Japan already uses specialized machinery on small farms. But the equipment for farmers in LDCs, if it is to be economically practical, must be tailored to their



Workers in the Philippines construct a drum thresher that will make the rice farmers' job easier and more profitable. IRRI has developed improved machines for most aspects of rice culture always with two key

criteria in mind: 1) the equipment must be easy to manufacture in the countries where it is needed, and 2) the cost to the farmer must be low.

needs, inexpensive, and manufactured in their own country. The equipment is needed for the intensified operations of land preparation, transplanting, weeding, harvesting, and threshing. Fast and efficient equipment for drying and processing is also needed.

AID contracted with the International Rice Research Institute (IRRI) in 1965 to develop the necessary equipment for the production of rice and associated food crops on the small farms (5-25 acres) of the Far East and South Asia. At its headquarters in Los Banos in the Philippines, IRRI has been developing and testing agricultural machinery suitable for use and manufacture in the tropics.

IRRI engineers faced the following challenges. The equipment must be easy to manufacture in the countries where it is needed. The cost to the farmer must be low. Tillage implements must be able to work in soupy, glue-like soil, often under water. Special threshing equipment must be developed that will handle wet grain so harvesting can be done quickly and the field can be replanted soon for multiple cropping.

Throughout the project researchers have been obliged to balance mechanical ingenuity with economic pragmatism. The equip-

ment has to be profitable to both farmer and manufacturer. Therefore input-output analysis of all alternative approaches and designs is required. The equipment has to be tailored to particular circumstances; simply scaling down existing equipment would not be satisfactory.

Engineers quickly determined that draft tractors pulling weeders, threshers or combines would become mired in the sticky soil. They designed small power-driven implements that would lift themselves upward and forward in the process of doing their job. For example, they came up with a power-driven paddle wheel weeder which can extricate itself from gunky fields as it weeds. The farmer, who pushes it like a large lawn mower, can adjust the angle of the rotary for depth of weeding, overcoming the drag factor and reversing course without damaging the rice plants.

The power weeder is being manufactured by two Japanese firms; some 6,000 units have been sold, half of them in 1972. Three Philippine manufacturers have marketed about 600 six- and eight-row seeders for approximately \$50 each for seeding pregerminated paddy rice seed.

Two revolutionary new designs of threshers that will thresh both wet and dry grain have been developed. One is a drum-type thresher; the other is a portable table power thresher with an air-cooled engine. These machines separate the grain from the chaff and straw, combing and shearing the rice plant in a fashion that combines features of a cotton gin and a conventional thresher. Three firms in the Philippines are marketing the drum thresher. Models have been shipped on request to other countries for testing and evaluation. The table threshers are being produced by two Philippine firms (one of which sold 50 in that country in 1972) and one Australian company.

A tractor-plow-tiller combination that will not bog down in paddies is being produced by a Philippine firm to sell for approximately \$500. Present production is about 180 machines per month, but the manufacturer intends to expand to 600 per month.

The project has been successful in taking some products from the drawing board to the field in as little as 18 months. Not every design accomplishes its purpose, of course, and some equipment that would be very useful is nevertheless uneconomical.

Machines continue to be developed and tested that would solve a number of the rice farmer's problems. A machine for spreading anhydrous ammonia fertilizer in puddled fields without loss of ammonia or mechanical problems has been successfully tested. Similar equipment for fertilizer spreading is in the works. Other products include a stripper-harvester combine, a multi-crop thresher, a centrifugal miller, drying and parboiling equipment, a multi-hopper seeder, and a 4-to-6 horsepower tiller.

Cooperative arrangements for testing machinery, involving governments, public institutions, and private companies, have been made in Pakistan, India, Indonesia, Korea, Sri Lanka, Malaysia, Bangla Desh, Taiwan and Thailand. The adaptability of the IRRI machinery for farming in Latin America and Africa is being explored.

Weed Control

Just as medicinal drugs have unfortunate side effects, so in agriculture the improved crop management techniques, superior fertilizers and methods of irrigation have increased the prevalence of a crop no one wants: weeds.

The problem is most acute for the impoverished farmers in tropical developing countries where numerous weeds grow at phenomenal rates. Under an AID contract, Oregon State University, in cooperation with its International Plant Protection Center, is seeking the most inexpensive but effective methods of cultural, chemical and biological control of weeds of economic consequence found in the LDCs.

OSU's field research emphasizes integrated methods that are expected to result in more complete and economical weed control through combining the most appropriate herbicides with labor intensive methods. The measures, which include social, economic and ecological considerations, are being tested in Central America, and most recently Brazil; the results may prove valuable worldwide. The Latin American research by OSU began in Colombia and the highlands of Ecuador in 1967, where researchers trained local research personnel and helped establish programs to pinpoint the major weed control problems of those two countries. They assessed the magnitude of losses under the existing agricultural production practices and recommended new methods for weed control.

The approach proved successful, and two years later field research was expanded to Central American countries and the Ecuador lowlands. Results indicated that crop yields could be doubled, and costs of weed control reduced by 50 percent or more. In addition to protecting food crops, the researchers were able to identify poisonous weeds in pastures, which had been taking a huge toll in livestock, and to find means to destroy them.

The Latin American research conducted by Oregon State University provided a model for integrated field studies that should build a body of knowledge on weed control in the tropics.



New methods of irrigation and improved fertilizers have made food crops flourish in parts of Latin America. Unfortunately, weeds also grow faster. The AID-Oregon State University weed control project provides a model for integrated field studies that will

contribute significantly to agronomists' knowledge of weed control in the tropics. The project works closely with researchers in several Latin American countries to find the most inexpensive but effective methods of cultural, chemical and biological control of weeds.

Having established a workable means of gathering data on herbicides specific to various plants and conditions, the Oregon center requested several international agricultural organizations to supply such data from developing countries where they operate. In turn the Center would share information it had collected elsewhere. For example, the findings from various regions of Colombia on how different crops responded to various methods of weed control (taking into account the variants of soil, temperature and rainfall) were sent to agricultural chemical companies in the United States, Europe, and Japan through a new product and practices research program.

Under the project, numerous pamphlets and bulletins have been issued, along with three major publications expected to have widespread applicability: "Herbicide Use and

Nomenclature Index," which includes tables of generic and trade names for herbicides, plus a guide to herbicide usage for 68 major food and fiber crops; "Weed Research Methods Manual," a practical handbook with emphasis on establishing new weed control programs that also describes successful methods now in use; and "Manual of Pesticide Application," which describes small scale pesticide and herbicide equipment available throughout the world. The Center distributes a periodic newsletter—"Infoletter"—to weed scientists in more than 100 countries.

As a clearinghouse for information on weeds, pesticides and herbicides, the Center collects data from field trials in other countries, keeps abreast of improvements and modifications in chemical control methods and corresponds with some 3,400 scientists, agronomists and agricultural agents.

Tropical Soils and Water Management

Posing a vast challenge to the agronomist are some 2 billion acres of potentially arable land in the tropics. Native tropical vegetation gives evidence that some plants will grow on this land, but it remains uncultivated for several reasons. Among the reasons are unfavorable geographic location, lack of markets, soil acidity, limited soil fertility, and lack of knowledge of improved soil and crop management practices.

Tropical soils pose special problems to farmers that are not solved by research on the largely temperate zone soils of the developed countries. Natural forces seem to conspire to reduce the fertility of tropical soils. Heavy rainfall may cause leaching of vital nutrients from the zones reached by plants' roots. Surfaces of the tropical soils are scorched by the sun, and the predominating high temperatures hasten the loss of organic materials in the soil. The combination of heat and leaching renders many tropical soils infertile, lacking in life-supporting and growth-nourishing substances such as nitrogen, phosphorus, potassium, sulphur, calcium, and magnesium.

AID has sponsored three research projects designed to explore ways to turn these lands into productive resources.

NAS Review of Soil Research Needs

The first project, now completed, used the expertise of the National Academy of Sciences Agricultural Board to organize and carry out a definitive study of high priority research needs related to tropical soils.

The board produced a comprehensive statement of the current state of knowledge about the composition and types of tropical soil. Among the highlights of this report is a comparison and cross reference of French, United Nations (through the FAO), and U.S. (Department of Agriculture) schemes of soil classification. Collating and comparing this information permitted the authors to identify practices developed under each classification system that could be applied to cultivation of crops on similar soils of the tropical regions. By specifying the minerals, plant nutrients, level of acidity, etc., the surveys can save many weeks of trial-and-error investigation and soil analysis, and will indicate the most likely approach to increasing crop yields from the soils. Emphasis was placed on prompt publication of the complete series of FAO and USDA soil maps of the world.

Many other significant practical problems relating to management of soils in the tropics that require further research were pinpointed: soil temperature relationships and soil water conservation techniques, for example. The research confirmed that reliable methods for predicting soil acidity, liming and ion exchange have different significance in the tropics than in the temperate zones, which indicates that different practices should be investigated.

The report contains articles by 13 experts from the U.S., Great Britain, Belgium, France and Nigeria.

Factors Limiting Soil Productivity

At Cornell University, since June 1969, AID has supported research to determine the factors limiting the fertility of tropical soils and to devise soil management practices that will enable farmers to get maximum crop yield from these soils and yet maintain them in proper condition. Until recently, field research was based mainly in Puerto Rico, with laboratory and greenhouse studies conducted both there and at Cornell. An action field program is now underway in Brazil.

Among the basic questions researchers are seeking to answer are: What are the nitrogen requirements of certain crops? How do they use nitrogen and other chemical nutrients? What are the effects of the soil acidity? Of liming? Of aluminum? What are the crops' phosphorus requirements, and how do lime and phosphorus interact in the soil? What are the residual effects of phosphorus?

Experiments established that post-planting applications of nitrogen fertilizers are superior to pre-planting applications. A surprisingly high level of inorganic nitrogen was found in the typical clayey soils of Puerto Rico, and laboratory methods were found to evaluate the capacity of such tropical soils to supply nitrogen to cultivated crops. The toxic effects of aluminum in the soil solution on root growth of corn and sorghum were confirmed in laboratory and greenhouse tests. It was found that calcium in the soil solution plays an important role in minimizing aluminum toxicity.

Other findings regarding the interrelationships of applications of plant nutrients, lime, and cultivation practices and their effect on soil chemistry substantially increased knowledge about the production potential of acid soils of the humid tropics. A number of conferences on soil management in the humid tropics have been held and papers detailing the Cornell findings have been published and distributed.

Economics of Soil Management Systems

Under a companion project, North Carolina State University is studying the economic implications of different soil management systems in Latin America, to increase the utility and acceptance of agronomists' recommendations based on soil classification and analysis. The North Carolina soil experts worked closely with colleagues from I.D.C.s, concentrating the research on these geographical areas: the Campo Cerrado of Brazil, the Peruvian selva in the upper Amazon Basin, and the areas of Central America rich in soils derived from volcanic ash.

The research team's first step was to conduct and publish a complete review of the literature on soil research in tropical Latin America during the last decade. Results were studied to discover knowledge gaps. A three-phase method of correlating the results of soil tests with actual plant response to fertilizers was developed after soils were analyzed.

The next step was to determine the minimum number of field observations necessary for making soil management recommendations. The fewer the observations required to produce satisfactory results, the faster the land can be made productive, the simpler the process, and the lower the costs. A streamlined procedure of soil classification would be particularly valuable in remote areas. The researchers found that it is possible to make soil management recommendations on the basis of some dozen characteristics of soil (such as texture, depth of soil, drainage of area, and acidity).

The team conducted intensive research into the soils of the eastern slopes of the Peruvian mountains, running down to the basin of the Amazon River, examining and describing the soils of the forest-covered area. The value of this work lies not only in the potential agricultural benefit to the people who might seek to cultivate that particular part of South America (which itself covers an area equivalent to the southeastern United States), but in the similarities of those soils to others covered by tropical forests. These include soils of the Congo basin in Africa, much of the Mekong basin in Asia,



In the jungle areas of the tropics, now being opened to farming, land clearing practices can have a dramatic effect on subsequent crop yields. Research in Peru convinced North Carolina State University agronomists that "slash and burn" methods of land clearing, used by tropical farmers for centuries, are

often more effective than using heavy equipment. The top photograph shows the fuller, more even stand of rice achieved on land cleared by "slash and burn" methods, compared with a mechanically cleared area in the same region, below.

and many of the major river basins in the Philippines and Indonesia. An estimated 200 million people live in these areas and attempt to cultivate these soils.

From the analysis of the soils of the Peruvian selva, North Carolina researchers developed management recommendations, drawn from their technical knowledge and the experience of local farmers and investigators. One of the findings that should have broad application deals with land-clearing practices. For many years, farmers used the "slash and burn" method of clearing the land for cultivation, which was believed by many agronomists to be inefficient and wasteful. Experts claimed that heavy equipment should be used instead. Preliminary findings from the N.C. project suggest that slash-and-burn is often the best method, although investigation of alternative means of land clearing continues.

Another aspect of the study has been more efficient growing of certain crops in the soils of the high plains of Peru. Work to date has concentrated on potatoes, but corn, rice and beans will also be studied. It was found that when farmers followed all recommendations pertaining to fertilizers, selection of varieties of potato, disease control, and timing of planting, the per hectare return to the farmer could be increased an average of \$769 net per year. If, in addition, the farmer would submit a soil sample for testing and follow the recommendations received, he would earn an additional \$94 dollars net per year. Such a soil test would cost the farmer \$5. The significance of this increased income becomes apparent when one realizes that average annual income in this area of Peru is around \$200.

Soil test recommendations are based on data collected by Peruvian investigators over a 10-year period, at 22 separate sites.

Water Management

As part of a research package designed to increase crop production AID has sponsored two projects examining water management practices—one in Latin America and one in Asia—to develop and introduce improved methods.

Because water supplies are limited in many of these areas, the amount that is available must be used in an innovative way, along with improved plant varieties, more fertilizer and pesticides, if the land is to produce maximum yields of food crops.

Utah State is exploring on-farm water management in the arid and sub-humid lands of Latin America; Colorado State University seeks to develop on-farm water delivery systems in Pakistan. The research under these AID contracts will be applicable in principle to other semi-arid lands.

Some 200 million hectares of land are presently being irrigated in the world, 40 percent of the land that *could* be irrigated. In Latin America, approximately 7.8 million hectares are being irrigated. The governments of these countries have plans to more than double the amount of irrigated land in order to meet their increasing domestic food requirements, develop export potential, and provide employment for rural workers.

Such an increase in productive land would be a genuine economic boon to the countries. To reach this goal, researchers have concentrated on studying how water can be efficiently used on the countries' farms; and on training local agronomists and agricultural educators.

Many new areas are coming under irrigation where data is needed to determine crop water requirements, water application rates, and drainage requirements.

Some findings from experiments in Colombia not only will help to solve the water management problems of that country, but are expected to have broad applicability in other LDCs with similar climate and terrain (and even in parts of the United States). It was found that modeling is an excellent tool to simulate the hydrology of an area. This technique has been used elsewhere, but it was new—and useful—to Colombian engineers. One irrigation project in Colombia was used as a pilot project to model the effect of alternative management decisions on the water table in an area susceptible to water-logging.



Arid and semi-arid land in Latin America can produce a bounty of food crops under proper irrigation. Researchers from Utah State University are carrying out research to determine the best methods of on-farm water management. Here a member of the research team is checking the water pressure in a sprinkler irrigation plot in Colombia.

As a result of the analysis of data from several hundred climatological stations in Latin America, researchers greatly improved the standard techniques for determining evapotranspiration, an essential component in calculating crop water requirements. In another experiment in El Salvador they learned that on highly porous volcanic soils using trickle irrigation instead of traditional furrow irrigation can result in water savings of up to 75 percent.

Already some of the project research has produced dramatic results:

- * Production of corn in the Aconcagua valley of Chile was considered satisfactory at 80 bushels per acre, when research on the interaction of corn, fertilizer and water demonstrated conclusively that production could be doubled. The new technology is producing the optimum yields and the technique is being spread nationwide, through Chile's extension service.

- * Advanced irrigation methods increased corn production in the Zapotitan valley of El Salvador, with indications that production may double in this region during the next 2 to 3 years.

- * Irrigation trials on a dozen different crops in northern Colombia show promise of significantly increasing production on an irrigation project of approximately 25,000 hectares over a 5-year period.

- * A digest of water laws compiled under the project contributed to legislation passed by the government of Ecuador. It also provides guidelines to legislators and administrators of other countries on ways to deal with the control of water.

Under the Colorado State project, in Pakistan criteria have been developed for constructing wells to skim fresh water which overlies the deeper layers of salt water in the ground. If crops are irrigated with highly saline water, the moisture evaporates, too much salt gets into the plants' system through the roots—and the plants die.

The research team found that application of phosphate fertilizer serves to combat the deleterious effects of saline water. If phosphates are used, production of some crops can be increased even if the water supply contains what was once considered a dangerous level of salt. Part of the value of this demonstration is that farmers formerly had to go to great trouble to drain off all salty water; now they can turn it into a productive resource. The application of phosphate fertilizers still requires some extra labor—the soils must be kept moist continuously—but it is less burdensome than the previous process of draining salt water and supplying fresh water.



Colorado State University scientists working in Pakistan have found ways to improve poor wheat stands such as this one which has been affected by

saline irrigation water. They learned that application of phosphate fertilizer will offset the depressing influence of the high level of salt in the irrigation water.

Land levelling studies also produced valuable results. Improved stands and substantially higher yields were obtained in properly levelled plots; the experimental plots at Lyallpur were used to demonstrate the benefits of water management techniques to interested Pakistani farmers and legislators. Increased yields and improved water use efficiency on these plots show conclusively the advantages of land levelling.

Seminars to disseminate project findings have been held under the auspices of the Pakistan Agricultural Research Council. In addition, Pakistani farmers have participated in field plot activities. Two motion pictures, narrated in English and Urdu, were produced. They are designed to motivate farmers to improve their lands, and to train technicians to level land for efficient water management.

Under the project, a broad look at Asian water management projects has resulted, again centered on Pakistan where the on-site research occurred. Ways of obtaining an efficient allocation of water were studied. Emphasis was placed on the best means of conveying, delivering and applying water to the farms. It is expected that the research will supply additional supporting data for the verification of the principles, which can be applied to U.S. agricultural problems also. In certain areas of the U.S., for example, the problem of soil and water salinity is constantly increasing and becoming a greater source of concern. Although the situation is more acute in Pakistan, techniques developed could help to reclaim thousands of acres of productive land in the U.S. that are now threatened with becoming agriculturally worthless.

Tailoring Fertilizers for Rice Production

Plants are not gluttons. They can absorb only as much nutrient as they need at one time, and can no more store the rest than a human could eat all the food he needs for a week at one huge meal. For many years the fertilizer applied to rice paddies lacking total water control was largely wasted. The rice plant would absorb a certain amount of nitrogen, a primary plant nutrient in most rice fertilizers, and before the plant was ready for more, the nitrogen would be washed away, leached, or evaporated. This major problem exists in about 75 percent of the rice paddies of Southwest Asia, and in most of the other rice-growing areas of developing countries.

Under an AID contract, scientists from the Tennessee Valley Authority developed a method of providing inundated rice plants with the amount of nitrogen fertilizer needed—at the time the plant could make use of the nutrient.

The fertilizer chosen is urea, which is rich in nitrogen and substantially less expensive than other fertilizers. Uniform small particles of urea are sprayed with molten sulphur to produce pellets ranging in size from a small "o" to a capital "O". Because the pellets are of different sizes, some more heavily coated than others, they release their urea content at various times, working like the "tiny time pills" of antihistamines. The water in the paddies dissolves the protective covering of the sulphur-coated-urea (SCU) at varying rates.



REGULAR CLAY-COATED UREA

SULFUR-COATED UREA

AFTER 6-WEEKS OPEN EXPOSURE (SEPT-OCT,

Sulfur-coated urea (SCU) is a particularly efficient fertilizer for rice paddies, developed by the Tennessee Valley Authority and tested broadly in Asia under AID funding. The tiny pellets release nitrogen at a slow rate, providing the right amount when the plant can best use it. As illustrated, SCU is more durable than traditional urea fertilizer; it resists humidity, will not cake and is better for storage and handling. SCU also provides sulfur that many soils lack.

SCU is more durable than uncoated urea; it handles better, cakes less, and resists humidity. It is also less likely to be used in a manner harmful to the environment. The product costs 50 percent more to manufacture than uncoated urea, but it is twice as beneficial to the rice crop. A farmer can use half as much, because he need not expect nearly the waste.

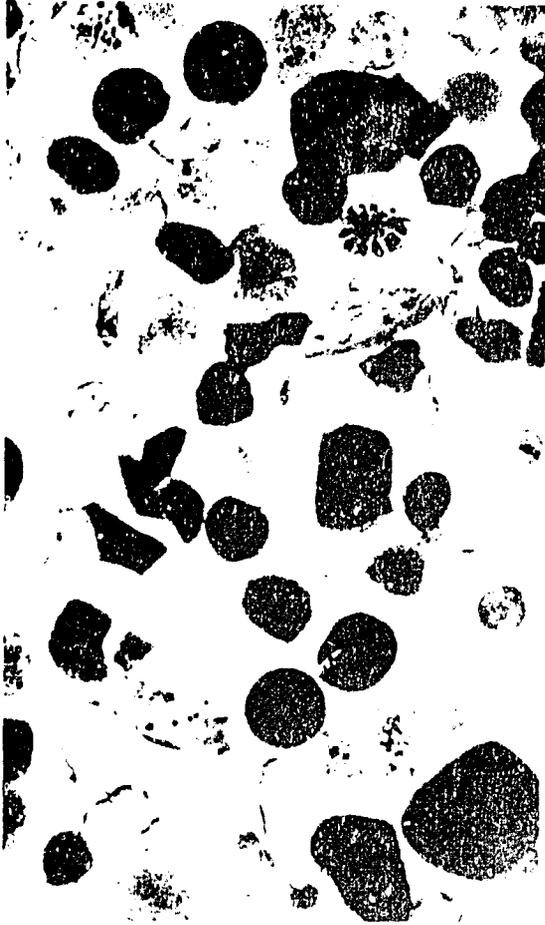
Using SCU will save the farmer labor, as well. In the past, fertilizer had to be applied frequently during the rice-growing season, a particularly arduous task because the paddies were flooded. Naturally, a large supply of fertilizer had to be kept on hand by the farmer. With SCU, he can apply the fertilizer once—at the beginning of the season—and will need only 60 percent as much storage space as previously.

SCU was tested under a variety of conditions—from carefully managed, irrigated rice paddies to rain-fed paddies subjected to intermittent flooding. The most impressive returns came from the rain-fed fields. Tests on sugar cane in Hawaii showed that 250 pounds of SCU produced crops that would require 500 pounds of standard urea. Other crops that would appear to benefit from SCU (besides rice and sugar cane) are plantains, African yams, and cassava—all of which have long growing seasons and require nitrogen at intervals.

In Peru, SCU increased experimental rice yields while lowering the amount of nitrogen fertilizer needed for optimum yields. Despite the higher cost of the treated fertilizer, the overall return of using SCU versus untreated urea was a 17 percent net increase.

An additional benefit of sulphur-coated urea, besides its slow dissolution rate and superior storage qualities, comes from the sulphur coating itself. Some tropical soils are becoming deficient in sulphur, an essential plant nutrient. AID-sponsored studies of Latin American soils, for example, show that repeated burning of fields in Brazil has seriously depleted the amount of sulphur in the soil.

A number of countries have shown interest in manufacturing SCU, among them Mexico, Taiwan, India, and Iran. The only known commercial production to date is in England.



Rock phosphate, found extensively around the world, is potentially an inexpensive source of the plant nutrient phosphorus. However the reaction of crops to rock phosphates has been unpredictable. Scientists of the Tennessee Valley Authority developed a test



that will predict with accuracy if a particular deposit is useful for agriculture. If the impurities that impede the phosphate's action are part of the crystal structure (right), they cannot be utilized by the plants.

Cooperation was established with an advisory committee of experienced rice researchers, some of whom tested the fertilizers in their own programs in various parts of the world. Included were representatives of IRRI, CIAT, the University of Hokkaido, the All-India Crop Improvement Program, The Thailand Ministry of Agriculture, and U.S. universities.

TVA is also investigating superior methods for using another plant nutrient, phosphorus. For a long time it has been known that rock phosphate is an inexpensive source of phosphorus for crops. But the reaction of crops to rock phosphates is unpredictable—some-

times it works, sometimes not—and no one knew why.

TVA investigators determined that the value of rock phosphate depends upon whether calcium carbonate is an integral part of the chemical compound or whether it is merely adhering to the rock phosphate. The researchers developed a test that reveals the relationship of the calcium carbonate content to a sample of rock phosphate. Now producers of fertilizers can predict with accuracy if a particular deposit of rock phosphate is in a form useful for agricultural purposes. This knowledge will make more quality fertilizer available at low cost.

Livestock

In those developing countries where livestock provide food, pests or parasites often destroy them or diminish the amount of meat or milk produced.

AID is engaged in research to increase the productivity of these animals. Our emphasis is on grazing animals because cattle can produce protein in the form of milk and meat on land that is unsuitable for growing crops for human consumption. Many of these lands lack rainfall; others suffer from flooding, inaccessible terrain, infertile soils. They offer little possibility for producing grains, but because of the vast areas involved can make an important contribution in the production of animal protein, and to a lesser extent in providing draft power where there are nearby crop lands.



Vampire bats cause loss of blood, death and disease to thousands of cattle in Latin America, resulting in losses estimated at \$250 million a year.

Bats, Rats and Noxious Birds

Vampire bats, those repulsive creatures of horror movies, are a very real menace to farmers in Latin America. They transmit rabies by biting cattle, causing a loss of an estimated \$250 million a year. Sometimes they also bite humans. Rodents and noxious birds, while less dangerous to humans and animals, take a heavy toll of food supplies and fiber worldwide.

A research breakthrough has been made on control of vampire bats, without endangering the interesting but troublesome creatures as a species. The technique has no adverse effect on the more useful bats that eat destructive insects.

In 1967 AID-supported research was begun by the Fish and Wildlife Service of the U.S. Department of the Interior to control the vertebrate pests that affect agriculture in less developed countries. Field research stations were set up at Los Banos, Philippines, for rat control; at Palo Alto, Mexico, for vampire bat control, and at Palmira, Colombia, for bird control.

The vampire bat, striking under cloak of total darkness, was found to be a clever adversary.

The species of vampire bat doing the damage in Latin America is *Desmodus rotundus*. The surname comes from his bloated appearance after supping on blood, his sole diet. Even if the bat does not transmit rabies, he can wreak havoc. Cattle that survive a bat's bite may suffer loss of blood, malnutrition, myiasis (a disease caused by maggots); this results in less meat and milk and animals are more prone to other infections. Bats may also be a feral carrier of the Venezuelan equine encephalomyelitis virus that killed thousands of horses in Mexico, Central America and the United States in 1969-71.

After studying the habits of the vampire bat and the way in which his body functions, researchers came up with two methods of control. Both methods employ a blood anticoagulant, ordinarily used for human heart patients, that is ingeniously geared to the peculiar, specialized physical makeup and behavior of the 3-inch, 1-ounce flying mammal.



The U.S. Fish and Wildlife Service, under an agreement with AID, has developed ecologically sound methods of destroying the predators. Here a captured vampire bat is equipped with a device to send a radio signal. Through the use of equipment such as this the investigators studied the habits of the bats and thus were able to devise the means to destroy them.

In one method, the anticoagulant is injected into the rumen of cattle, one of their four stomach compartments. It is then absorbed into the cow's blood stream. The bat bites, laps the blood, and the anticoagulant enters the bat's digestive system. Because he consumes such an enormous amount of blood, virtually his own weight every 24 hours, and since blood, the bat's sole source of food, contains no vitamin K necessary for blood clotting, he cannot tolerate the anticoagulant. It prevents clotting of the bat's blood, and he dies of internal hemorrhaging within a few days. The anticoagulant does not harm the cattle, however, disappearing within approximately four days with no residue.

The other method is based on the bat's predilection for preening and cleaning itself and other bats. Fine nets are set up near corralled or tethered cattle. When the bats have been caught in these nets, men wearing protective garments smear the bats' back with anti-coagulant mixed with petroleum jelly. Then they are released to return to their domiciles—usually caves, mineshafts or wells—where they contaminate the entire vampire bat colony. One such treatment of a few bats usually serves to eliminate a bat colony within two weeks. Control by this method reduced vampire bat bites on nearby cattle by 95 to 100 percent.

These methods are far more effective than vaccinating cattle or attempting to shelter them in bat-proof enclosures. Because the workers have discovered what they were seeking, the research phase of the bat sub-project will be terminated at the end of 1974.

The sub-project on rats combined field experimentation in rodent control in the Philippines with basic research in Denver, Colorado, focused on locating points of attack in the physiological, reproductive or social-psychological systems of the rats. Rats, like noxious birds, may tend to reproduce faster if their herds or flocks are reduced in size. Their hydra-like characteristic makes control programs based on killing rats ineffective.

The project began by considering use of a chemical compound that would sterilize male rats—similar to the model used to control the Mexican screw-worm in the United States and tsetse flies in West Africa. Studies of rats' sex lives revealed that even if only 10 percent of the normal male rat population remained unsterilized, the breeding habits of the females are so aggressive that the massive sterilization would have virtually no effect on the number of pregnant female rats.

Approaches being tested include drugs that would produce such social-psychological stress in the rats that they would become inhibited about sex, or developing sexual attractants that would lure large numbers of rats to destruction. A similar psychological approach is used for noxious birds—minute quantities of a special bait cause a few birds to issue distress signals that drive the birds away from their feed.

Different methods of control are needed for those birds that migrate and those that remain in one region. Knowledge gained in studying control measures for one species of bird is valid for other species. For this reason, the research on all these vertebrate pests is supported by an interdisciplinary research unit. As more is learned of vertebrate pests' peculiarities and life-styles, scientists are better able to devise methods of eliminating their hazardous and destructive practices.

Tsetse Fly Control

Over four million square miles of potentially productive land in Africa—an area larger than the United States—is infested by 23 known varieties of tsetse fly. These insects carry disease-causing trypanosomes which, when transmitted to mammals, parasitize the blood and produce sleeping sickness in man and a fatal disease known as nagana in cattle. Eradication efforts based on clearing and burning brush or applying insecticides are expensive and only partially successful. Drugs against animal infection are available, but a massive inoculation program is impractical. Because of the size of the problem, AID contracted with the U.S. Department of Agriculture to develop methods to control or eradicate the tsetse fly.

After pre-testing several known methods the research team decided to concentrate on sterile-male techniques as the most promising method of control. The chemosterilant used for sterilization appears to be a non-persistent chemical which will have little or no effect on the environment. Encouraging results have been obtained.

The technique is based on knowledge of the mating habits of the tsetse fly. The female mates only once and deposits fullgrown maggots, not eggs. At the height of the mating season, sterilized males are released to mingle with the wild population (whose density can be measured) with a ratio of approximately three sterilized males to each wild male. For the next 18 months quantities of sterilized males are released at 2-month intervals until the ratio favors sterilized males by 15-1. When they predominate to this extent, extermination of the species in that area is assured.

The researchers also succeeded in rearing the tsetse fly in captivity, which previously was difficult to do. Of course, large quantities of flies are required for sterilization and release to control wide areas of infestation. Now, productive self-sustaining colonies of tsetse fly can be reared in cages housed in temperature-humidity controlled rooms. As an alternative to rearing flies, researchers are experimenting with various attractants which would lure the flies to chemosterilants placed in fly-infested areas.

Some 30 articles about the research have been published in scientific journals. The researchers worked closely with African colleagues, explaining methodology and discussing research findings. FAO, UNDP, WHO, and regional offices of three European countries have been kept informed of the planning of the project, and they are apprised periodically of progress.

The sterile male control technique has proved highly successful in isolated test sites. After 15 months, the tsetse fly population has been reduced by 94 to 99 percent. In these tests the technique was also more economical than spraying, clearing brush, or destroying game.

The research should have significant impact on the economic welfare of LDCs. For example, in Africa there is land where humans can neither live nor work because of the infestation of tsetse flies; on this grazing land some 120 million head of cattle could be raised. Meat production per year is estimated at \$800 million minimum; milk and hide production would add an additional \$400 million.



The tiny tsetse fly has rendered some four million square miles of potentially productive land in Africa an agricultural wasteland. The fly causes sleeping sickness in humans and the fatal nagana in livestock. AID has sponsored a project with the U.S. Department of Agriculture to eradicate the tsetse fly by breeding sterile males and releasing them to mate fruitlessly with the monogamous tsetse females. The sterile flies bred in captivity must be marked before they are released among the wild populations, so scientists can evaluate the effectiveness of the technique.

Hemoprotzoal Diseases in Livestock

Livestock, particularly cattle, are prey to a group of diseases of the blood stream (hemoprotzoal diseases), transmitted by ticks and other biting insects. These diseases, which occur in all tropical areas of the world, are particularly severe in Latin America, where they have been responsible for 50 percent of animal losses in some areas.

In June 1968, AID contracted with Texas A&M University for research to determine the causes of these diseases and to develop preventive and immunization methods. Preliminary surveys indicated that altitude and climate play a decisive role in the incidence of the disease. No cases of chronic infection are found above 5,000 feet of elevation. Below about 1,000 feet in tropical areas, infection with two or more of these diseases is so rapid that preventive steps must be taken within the first few months of an animal's life to be effective. A variety of insects were studied to determine which ones were carriers of different hemoprotzoal diseases. Some vaccines have been tested that show promise of significantly reducing livestock losses from two diseases. A study of the use of an integrated control program for blood, internal and external parasites on the North Coast of Colombia has demonstrated reduced production losses and increased net monetary returns.

Research teams have had some success in obtaining immunity by injecting live virulent organisms into calves and moderating the effects of live parasites by treatment with antibiotics. Certain drugs appear to be specific for particular organisms, so different drugs must be used to prevent different varieties of bloodstream diseases. Protection lasts for up to 112 days in some of the procedures used.

The technique of infecting the animal with a low-virulence live strain of organism is called preimmunization. The live organisms produce antibodies on a continuing basis that protect the cattle, even though they become carriers of a low-grade strain of the disease. A single injection of vaccine would not provide the same number of antibodies, nor the same degree of lasting protection.

Control of ticks and other insect vectors has also been tested as a supplementary measure and appears promising. On the basis of early results a three-pronged attack on these diseases seems possible: vaccination, curative treatment, and control of ticks.

The importance of preimmunization is widely recognized by U.S. cattlemen interested in exporting cattle. Death losses as high as 70-80 percent are common in adult animals shipped from the U.S. to some infected areas. Even though a keen demand is present for U.S. breeding stock, buyers and importers are reluctant to import U.S. cattle into infected areas. Preimmunization and vaccination techniques perfected through this research project should overcome this problem and permit increases in U.S. exports.



One of the main obstacles to efficient cattle production in the low altitude areas of the tropics is a group of diseases of the blood stream (hemoprotzoal diseases). Texas A&M University has had some success in obtaining immunity by injecting live organisms into calves and then moderating the effects of the parasites by treatment with antibiotics.

Survey and Analysis of Cattle Feeding Systems and Nutrition in Tropics

For livestock to thrive, they must have nutritious food as well as be protected from diseases. Animal production has been chronically low in the tropics because of lack of food or because of the low nutritive values of feeds and forages.

To determine the nutritive value of livestock feeds, fodder, and agricultural by-products in Latin American tropics, the University of Florida, sponsored by AID, began a research project in April, 1969. Working with some 200 agricultural specialists from Latin American universities, ministries of agriculture, and private industries, researchers gathered existing information on the nutritive value of a variety of livestock feeds as hay, grain, silage, and forage, grown or used in the areas. During the first stages of the project a record system was devised, translated into Spanish and Portuguese, and used in nutrition laboratories to describe and record chemical and bibliographical data on feeds.

Project personnel visited 27 countries in Latin America and the Caribbean to explain the project to other researchers. In June, 1972, the first edition of "Latin American Tables of Feed Composition" was published, summarizing over 6,000 completed source forms from participating countries. The tables will be valuable to feed manufacturers, research specialists, farmers and others who formulate livestock and poultry rations in Latin America. The tables will be beneficial for increasing animal production efficiency through improved nutrition. Furthermore, the feed tables have aided greatly in identifying and describing feed-stuffs for which data was seriously limited or lacking.

Project personnel developed estimating procedures to gauge the nutritional value of specific feeds from certain areas not reported. The technique appears to be highly reliable as a temporary measure, pending more rigorous analysis of the feeds. The project is also seeking to apply standard international names to the feeds and to identify the ecological conditions needed for their production, so that farmers can choose better feeds for specific conditions.

Agricultural Economics

The goal of AID research in agricultural economics is to obtain a broader understanding of the agricultural sector in less developed countries. The research consists of investigations of the structure and relationships within the agricultural sector of such elements as: trade, market factors (including land, capital, and labor), impacts of technological change (with emphasis upon income and employment), and public investment, and of the interrelationships with other sectors of the LDC economies.

These studies are developed by U.S. and LDC economists working together. The joint objective is to find answers to country problems, to meet policy and operational needs for information. These activities also strengthen the analytic capability of LDC institutions and provide training for their personnel.

Governments must make plans and reach decisions concerning the agricultural sector. This task is complicated by rapidly changing technology, shifting social conditions, the growth and migratory tendencies of the population. Governments must consider whether certain forms of taxation or import restraints provide incentives to farmers or whether they stifle technological innovation. What will be the effects of government pricing policies, of allocations of investment and research resources? Do government policies make available the necessary knowledge to the farmer?

Developing countries are particularly eager to stimulate agricultural production — often a key to improving the quality of life in their nation. But these governments frequently do not have the trained experts and sophisticated institutions necessary to perform the complex tasks of economic analysis and planning.

Through its research in agricultural economics, AID attempts to assist developing nations in the process of charting alternative routes to agricultural development, indicating the obstacles that may be encountered. It is up to the nation's policy makers to choose which goals they want to reach. The research informs them of probable effects of the various measures they may take.

Agricultural policy is based on what has happened in the past and projections of what is likely to occur in the future if certain courses of action are taken. AID research is designed to develop and teach the most modern analytical techniques that can be used in this process.

Agricultural Decision Models

One method of tackling complex agricultural economic problems on a broad scale is through construction of mathematical models, operated by computers in such a way that variable agricultural and economic "inputs" produce alternative "outputs", or results. For example, in agricultural production, such factors as the quantity and quality of seeds, fertilizer and water used to grow crops are variables that must be considered in their relationship to weather, rainfall and soils. Variations in these inputs will directly affect the outcomes of crop production, price levels and export earnings.

To learn if decision models would be a practical approach to selecting optimum policies for developing countries that desire further agricultural development at a reasonable cost, AID in 1969 established a research project with Michigan State University. A model was developed to use empirical data from Nigeria in initial tests. Under a further contract in 1971, MSU is testing, applying and further developing the model under field conditions.

The model is being tested in Korea, as well as in Nigeria. Another goal of the research is to learn if parts of the model are useful in other countries.

MSU has described the challenge: "A reason frequently given for using a systems approach in attacking problems of development is the complexity of the problems under investigation. Development problems generally involve attempts to attain a relatively large number of objectives with relatively few means. While modern society is usually taken as the ultimate in complexity, the growth of a relatively less-developed economic system is also complex. Interactions within and among traditional, transitional, and the modern economic sectors must be considered."

In Nigeria the simulation exercise was preceded by an in-depth analysis of the total agricultural production and market systems. This sector analysis was in turn dependent upon the availability of a substantial body of technical data and studies of production and marketing. As the Korean model was built, analysis of various parts of the agricultural system proceeded simultaneously. This process was aided by the fact that some parts -- modules -- of the models were adaptable from Nigeria to Korea with only minor modifications. Even where substantial adaptation was required or new modules were introduced, the experience gained in constructing the Nigerian model was put to good use in Korea.

The model has been used to predict the consequences of adhering to Korea's 5-year plan, assuming similar plans each succeeding five years, through 1990. It has also been used to estimate the effects of plan modifications contemplated by Korean policymakers. A third set of predictions was based on policies designed to open the Korean economy to world trade in agricultural products (the model forecast great benefits to food consumers at significant costs to food producers). Further predictions were modeled to search for ways to reduce producers' costs.

The model has also been expanded to produce more detailed information about food supply, food demand, the grain marketing system, the livestock sector and ties with non-agricultural sectors of the economy.

The project has made two other important contributions. A computer software collection has been started that can be used worldwide for agricultural modeling. A training program has been designed, which includes 10 months' non-degree training for economists and others working on the model and a 2- to 4-week training course for program administrators.

Training personnel in the country that plans to use the model is a critical part of the work. The variables will change in years to come. Although the model points out possible paths, a wrong decision can be serious. The people using the model must be aware of the consequences of not keeping it current or of not fully understanding the results of a policy decision.

In Nigeria the policy and programming activities are proceeding under the direction of a committee established by the Nigerian government, comprised of both government and academic staff. In Korea, the local support has been organized primarily within the Agricultural Economics Research Institute in the Ministry of Agriculture as well as with staff participation from other Korean agencies.

A second goal of such research is the publication of findings and techniques that will enable others to carry on the work. Some 20 professional papers growing out of the MSU project have been published.

Capital Formation and Technological Innovation

This study, conducted by Ohio State University, focuses on the collection and analysis of farm data which has been assembled on a large enough scale to support broad generalizations and generate some ideas of the effects of Brazilian agricultural policy over the past two decades. Four attributes of the policy are relevant: wheat prices supported at nearly twice the world level; restricted quotas on meat exports; limited attention to research in agricultural technology and negatively priced capital (because of low interest rates that do not reflect depreciation of currency).

The study shows that increased capital is accumulating in agriculture in one area of the country in which wheat acreage is expanding rapidly. However, much of this capital is in the form of machinery, and whether there is a net capital formation has not been established. Wheat production is expanding rapidly under the stimulus of high product prices and low capital prices. Most of the increase in production is explained by an increase in acreage. Some of this increase comes from adding to size of individual farms, either by renting or buying.

Larger farmers are expanding more rapidly than small ones. In fact some smaller ones are getting out of production. This expansion of larger operations is a function of scale and financial power and not of efficiency. Because of the higher costs of small loans and the low interest rates, a disproportionate share of the credit goes to larger operators. The income distribution situation is becoming steadily more distorted.

An analysis of data for one region of the country shows that labor productivity, income distribution, and foreign exchange balance would all be significantly improved if meat prices were allowed to go up to the world market level and wheat prices were allowed to fall to world levels.

Except by implication the research results do not include an estimate or analysis of agriculture's contribution to general economic growth of the country. The implications are that not only is agriculture not contributing capital for general growth, but that also agriculture may be using up capital directly because low interest rates to farmers may be attracting capital into farm supply industries to support the inefficient wheat industry.

Under the project, data has been collected through 2,000 detailed farm interviews, 258 interviews with distributors of farm supplies, and 500 sociological interviews. The analysis is based on these data, plus the data from 954 interviews conducted in 1965 under an earlier contract, all in Brazil. Farm level data have been organized into nine regions. An organizational scheme has been used which allows for dividing regional data into 16 cells, formed by a cross-classification system involving four farm size groupings and four farm type groupings.

Primary recommendations for progress arising from the study were: to strengthen Brazil's agricultural education at the high school and university level; to increase agricultural research capabilities of universities and other institutions; and to develop technological competence in the field of agriculture within the country.

The study affirmed the validity of shifting policy emphasis of the Brazilian government onto agricultural production and away from artificial pricing policies; it further convinced leaders of the importance of seeking new and improved agricultural technology.

Five Brazilian universities, the Central Bank and the Ministry of Agriculture have all been involved in the study along with five U.S. universities. Results are disseminated broadly through research notes in English and Portuguese.

Impact of Technology on Employment and Income

To learn the economic impact of new agricultural technology, AID contracted with Cornell University to study its effect in India. Economists studied farms of varying sizes and learned that although the new technology greatly increased national income, it aggravated a tendency toward unequal distribution of income -- most of the added income went to the larger landowner, but incomes of the large majority of farmers increased little or not at all. Such income disparity creates social, political, and economic tensions that a government must consider in developing its economic policies.

There is also the question of incentive. If greater production produces no benefit for the smaller farmer, he will not go to the extra trouble required and the country's overall growth rate will be slowed.

The Cornell study seeks to learn what the actual effect of new technology has been and to develop recommendations for economic policies that will accelerate production. The objectives are to create a broadened base of rural employment opportunities and greater participation of rural people in income growth. The studies are being conducted in India with a view toward their application in a number of Asian countries.

The method employed in the project, after surveying actual conditions, is construction of a mathematical computerized model which will predict the results of alternative policies, using the more productive grains and seeds along with the material required to nourish them as the basis of the projections. The model will assess the impact of various policies on the food market and on the labor market. Preliminary findings indicate that when a low-income country like India makes major efforts to commercialize food production increases, the small farmer and lower income population must be given a stake in increasing production if a nation wishes to accelerate its economic growth rate.

The findings indicate that increasing the small farmer's income can have rewarding indirect effects on the total economy. With more income, people buy and eat more. To meet this demand, domestic production is stimulated. This has a "snowball" effect on increasing net aggregate national income, which in turn causes increased demand for other products and creates employment.

Agricultural Diversification and Trade

Although a majority of AID-supported research projects focus on helping developing countries cope with fundamental problems of nourishment and health, often under conditions that are almost primitive, some projects go beyond that point. These are designed to help countries that are already progressing in development to gain momentum and travel further down the path toward modernization.

Recent technological breakthroughs and additional improvements in farm practices have made possible a substantial increase in food grain production in a number of countries. In many of the more advanced LDCs, agricultural officials must now choose among policies and programs to arrive at the best adjustment to changes in production techniques, supplies, domestic and international demand — all of which affect farm prices and costs. They are under pressure from consumers and from other governmental decision makers.

Even though these officials have sufficient political motivation to choose the optimum economic policies, they often lack adequate information upon which to base their choices. As a result, there may be delays in making critical decisions for a nation's agricultural development — or a failure to make any decision at all.

AID is supporting two research projects where American researchers are collaborating with host country colleagues to make rigorous, objective analyses appraising the consequences of alternative uses of research, agricultural and financial resources. They are jointly designing planning tools that computerize agricultural and economic statistics. These offer policymakers realistic agricultural production and marketing alternatives at farm, regional, national and international levels. They take into account the effect of changes in production techniques, supply and price upon new patterns of crop and livestock production.

North Carolina State University is working with agencies and individuals in Mexico, Guatemala, El Salvador, and Honduras on issues of markets and trade. The Economic Research Service of the U.S. Department of Agriculture cooperates with agricultural agencies in the Philippines. In issues of trade and new types of crops that might be produced economically.

The jointly conceived project in Latin America will examine the costs, returns, bottlenecks, and effects of various scientific and technical innovations as they relate to export opportunities for selected crops in domestic and external markets. The information will identify the Latin American regions best able to compete (or what changes would be necessary to make them competitive) and will provide a guide for both public and private investment decisions — particularly where bottlenecks or high costs are expected.

If the participating countries can expand exports of selected crops they will benefit by creating jobs, obtaining necessary foreign exchange, and improving income distribution. At the same time, worldwide grocery shoppers would get a broader range and greater quantity of winter vegetables at lower prices.

The project seeks to learn which vegetables in which countries show the greatest promise for export promotion. Researchers also will analyze the best ways to achieve the goals — for example, whether major emphasis should be placed upon increased farm-level productivity, institutional development, market export management, or market access and contacts.



The development of new agricultural technology has increased food production and national income in India. However, the income has not been broadly distributed; large landowners have benefited greatly, small farmers much less. Economists from Cornell University

have analyzed patterns of income distribution and employment to suggest guidelines for economic policy in light of agricultural advances. Findings indicate that growth rates are sustained best when the small farmer has a stake in increased prosperity.

A sophisticated study of agricultural diversification in the Philippines is being carried out largely by personnel from the Bureau of Agricultural Economics, Manila, and the University of the Philippines, Los Banos, some of whom have been trained by AID in economics and agriculture. Information is being collected from farms on farm production, farm incomes, changes in income and employment brought about by new technology, and interregional competition. When the information is gathered, the Secretary of Agriculture and other Philippine decisionmakers will be provided with analysis of the probable consequences of growing different crops. For example, if, as expected, high-yield rice varieties increase production beyond self-sufficiency, the information provided by this project will indicate the type of changes from rice into other crops that will best maintain farm income and employment. The findings will be delivered in a form that can be adapted as production and marketing conditions change. Trade prospects and directions for diversification will be identified, so the studies will take into account not only economic circumstances within the Philippines but the relationships to markets and production in other countries.

Generating Employment in African Agriculture

Rising unemployment is a major social, political and economic problem in most West and Central African countries.

Under an AID contract, researchers from Michigan State University are working closely with scholars from a number of African universities to examine how trade, wage, fiscal and pricing policies affect the expansion of production and employment in major import and export crops. The research is being conducted in Nigeria and Sierra Leone, but researchers from Ghana, Malawi, Ethiopia (and possibly other African countries) will participate.

Researchers will study the way farms actually operate in tropical Africa. How could more workers be used to produce more marketable goods? What rural activities besides farming might produce more jobs? What policies could the governments set that would increase employment and benefit the country as a whole?

Migration and other aspects of labor supply are also being studied. From this project will come a network of African scholars linked with each other and with others around the world specializing in employment research. International conferences and workshops are planned. African economists and agricultural economists will be trained, given practical experience working on a critical problem.

Michigan State, the AID contractor, plays a major consulting role, but each country study is the responsibility of an institution in that country. The design, both in concept and methodology, was worked out by economists from MSU, Sierra Leone, and Nigeria, so that the two country efforts will add up to one study. Ethiopian economists have kept current with the study and may join in the research.

Because the research focuses on a problem of high priority to African governments, because much of it is being conducted by Africans, and because it increases the capabilities of African institutions, it is anticipated that the results will be sought and used by these governments.



HEALTH

Good health is a cornerstone of a country's development. Providing health services means going well beyond reducing the death rate or enabling people to survive starvation. It means permitting man to make the maximum physical and psychological adjustment to his internal and external environment, consistent with available resources.

Health services are an essential complement to other AID activities. A person debilitated by disease cannot get the maximum yield from the land he cultivates, no matter how advanced the agricultural techniques he employs. An individual will not derive maximum benefit from eating nutritious food if intestinal infections prevent him from converting it fully to the body's uses. Health may provide an incentive for parents to practice family planning; if they have some assurance their children will survive and become healthy producers, they may feel less compelled to have so many children to help them with their work.

Developing countries are faced with different health problems than are the more developed nations. Many are located in the tropics and are plagued by diseases unique to that climate. Delivery of existing health services is far less adequate in the LDCs than in countries with modern transportation and communications facilities. On the average, less than 10 percent of the population of developing countries have convenient access to adequate health services.

Health planning on a national scale is hindered because health officials often have insufficient data to determine the dimensions of the problem. Most countries have launched no programs to eliminate environmental pollution; water, soil, and food are often contaminated with human body wastes, causing a high incidence of intestinal diseases that could be prevented.

AID seeks to provide the missing ingredients in the health programs of developing countries. Research projects are designed to identify what is missing and pinpoint the optimum methods of curing malign conditions affecting large numbers of people. AID concentrates on areas that such organizations as WHO, UNICEF, and PAHO cannot handle adequately themselves, cooperating

with such groups and supplementing their work. AID research often results in findings that can be used by these organizations or by the governments of the LDCs for planning new programs or enhancing existing programs.

Through a combination of research and technical assistance programs in health, AID focuses on control of important communicable diseases in developing countries, improved health planning, adequate delivery of health services, and providing a healthy environment. The agency takes an integrated approach towards preventing disease on a comprehensive basis rather than a categorical approach of attempting to eradicate single diseases. Emphasis is placed on preventing disease instead of simply curing it once it has spread. Delivery services are planned, combining such traditional providers of medical service as healers and midwives with the findings of Western medicine. Until a sufficient number of health professionals can be trained, reliance is placed on para-medical personnel.

Research in health planning shows developing countries the most effective ways of approaching their national problems. For example, before making a survey of the causes of infant mortality, some countries had no conception of the extent to which malnutrition contributed to the deaths of children under five by leaving them defenseless before such ordinarily harmless diseases as measles.

During the past 20 years, developing countries have produced a greatly increased number of trained national health leaders. They have established more institutions. Research provides them with the tools they need to improve the quality of life in their countries.

Malaria Eradication

Malaria is one of man's most ancient and most stubborn enemies. Hippocrates noted various forms of the fever in the fifth century B.C.; he attributed the disease to drinking stagnant marsh water. Less than a century ago did scientists discover that malaria is caused by a one-celled parasite injected into a person's bloodstream by the *Anopheles* mosquito.

Throughout the world there are probably more cases of malaria than of any other infection. As many as 2 billion people live under conditions conducive to malaria; in many tropical countries, malaria is a major hindrance to development. Even when the disease is not fatal, it saps the vitality of its victims, making an already difficult struggle for survival even harder. Malaria is prevalent in less developed countries throughout Central and South America, North and Central Africa, and in the Middle and Far East.

No completely satisfactory method of eradicating the disease in all countries has been found. Some techniques that seemed promising because of their success over a short period of time have become less effective when, for example, mosquitoes have developed resistance to certain pesticides.

AID, working with the World Health Organization and other groups, continues to participate in eradication programs, including worldwide research to develop new and improved technologies for preventing transmission of malaria parasites and specific regional projects tailored to the climate and the type of mosquito transmitting the infection.

AID has also embarked on a research project that could provide a significant supplement to eradication programs. A vaccine for the prevention of malaria is being sought. None has ever been developed for a parasitic disease, and many doctors question whether such a vaccine can be developed. AID has supported the research because the magnitude of a breakthrough in this scientific area would be so great that the risks seem justifiable.

Vaccines have been successful in protecting against diseases caused by bacteria or viruses ranging from cholera to yellow fever. But malaria is a parasitic disease caused by a tiny protoplasmic unicellular animal called a plasmodium. This creature invades mature red blood cells that contain hemoglobin. It eventually destroys them, causing chills and fever and acute anemia in the victim; capillaries carrying blood to the brain may be blocked, resulting in death.

It has been found that a person who has had malaria does not develop solid immunity to further attacks for at least 10 years. This finding has increased the skepticism of those who believe vaccination against malaria may never prove effective. The AID research, however, is based on the participating scientists' conviction that the failure to develop immunity after natural infection could be overcome artificially if due consideration is given to stimulating immunity to stages or products of the plasmodia which are normally present in the human body for only a short time.



The search for a malaria vaccine is an arduous task requiring work on a miniscule scale. If the work is successful it will be the first vaccine developed for a parasitic disease such as malaria. Here a scientist working on the AID project at the University of New Mexico dissects the salivary glands of an *Anopheles* mosquito which has fed on an animal infected with malaria. The glands will be prepared for antigen injections or used to infect other test animals.

Worldwide Research

Research scientists have not been marking time while seeking to discover ways to prevent malaria; they have concentrated on improving the methods of controlling the spread of the disease. For almost 20 years, AID and its predecessor agencies have supported the work of the Technical Development Laboratories (TDL) of the Center for Disease Control, run by the U.S. Public Health Service in Atlanta, Georgia. Here a continuous quest has been carried out for the most efficient and practical ways of preventing transmission and freeing regions of malaria.

TDL has been instrumental in developing and testing new insecticides, in evaluating their efficiency and finding the ways they can be used most effectively. This task has been complicated by the fact that some 200 different species of anopheline mosquitoes exist. They do not all have the same reaction to specific pesticides.

Although DDT was first synthesized in 1874, its use against mosquitoes was not demonstrated in the United States until the 1940s. DDT revolutionized the attack on malaria because it provided an economical substance which would remain effective if sprayed on surfaces about every six months. TDL developed new test methods and specifications to be used in the surveillance of stored DDT powders. Between 1955 and 1971, some 824 million pounds of DDT powder were bought under specifications drafted by TDL. The Laboratories redesigned and set new standards for packaging DDT powder that made handling and storage more efficient with 25 percent reduction in shipping costs and less chance that the insecticide would be damaged in transit.

Because some species of *Anopheles* seemed to develop resistance to DDT, TDL has conducted extensive investigations to find other insecticides, along with chemicals that will destroy mosquitoes' larvae and eggs, that might be used as alternatives to DDT. More than 800 such experimental compounds have been evaluated in the laboratory and in the field to find those that would kill the most mosquitoes at a reasonable cost.

Among the alternative insecticides tested by this research are malathion and dichlorvos (DDVP). Extensive research on the chemistry, analytical methodology, and formulation of malathion resulted in a sound base for developing specifications for purchasing, storing and using the chemical to control mosquitoes. The World Health Organization (WHO) approved malathion as a substitute for DDT. So eminent has been TDL's work in the field that WHO designated it a center for the evaluation and testing of new insecticides.

The work has not only resulted in better chemicals, but also in better ways to apply them. Through experimentation, TDL developed improved types of sprayer and nozzle equipment that are widely used throughout the world. The nozzles cost little more to produce and require less insecticide to provide effective protection inside houses. The spraying equipment provides a more uniform spray over a broad area; its parts last longer than those of sprayers formerly used.

TDL has experimented with rendering male mosquitoes sterile through use of chemosterilants. This technique has proved successful in controlling tsetse flies under another AID research project. Two substances show promise of being effective in sterilizing male mosquitoes. Encouraging results have also been obtained from studies which evaluate the action of certain hormones on larvae development.

Another method (which has met with limited success) attempts to breed and foster natural predators of the mosquito. Fungal, nematode, and protozoan parasites that infect anopheline larvae have been isolated and studied with a view to encouraging their growth in areas where vectors are prevalent.

In addition to publishing reports on significant findings, TDL has consulted with individual countries requesting assistance on chemical testing, mosquito rearing, equipment testing, mosquito resistance, and local insecticide formulation procedures. Providing such solutions to immediate problems has led frequently to training nationals to deal with similar problems in the future. The project has assisted LDCs in finding both long-range and short-term solutions to malaria eradication problems.

AID has sponsored research into the malaria control problems peculiar to Central America by establishing a research station there (CAMRS) that is one of the few of its kind in the world. Although what is learned at CAMRS may well be applicable in other world regions (including the United States), the station was founded in 1968 in San Salvador to investigate the causes of antimalarial program failures at specific locations in Central America and to find practical methods of overcoming these failures. The host country, El Salvador, provided facilities and buildings, and many situations for field trials. Studies have been conducted in Nicaragua, Honduras, Costa Rica, Guatemala, Panama, and Brazil as well.

Central America has been the site of some of the most troublesome problems in eradicating malaria. CAMRS is trying to learn what ecological factors present obstacles to methods that have been effective elsewhere. Its scientists collect and isolate different parasitic strains of disease organisms that the mosquitoes transmit to man. These have been sent to the CDC laboratories of the U.S. Public Health Service where the organisms' life-patterns are studied along with their sensitivity or resistance to the commonly used anti-malaria drugs.

Traditional and innovative means of mosquito control are evaluated at CAMRS. Some adaptations and improvements of classic methods have been developed, and techniques involving chemosterilants, mosquito diseases and predators and hormonal larvicides are being evaluated experimentally. Particular emphasis has been placed by the scientists of CAMRS on combining multiple measures in a single onslaught, or using them in logical succession.

To assure that this work will not proceed in a vacuum, CAMRS conducts studies of the attitudes of the population the program is designed to aid. They evaluate the response of the people in the region to see what types of programs are most effective and to develop educational techniques to encourage the population to accept the programs and cooperate in making them successful. Some improvements in antimalaria methods that are developed at CAMRS are used by the governments of the Central American countries. The station's activities are coordinated

with WHO programs and those of the Pan American Health Organization.

Thailand is a country where it appeared malaria was well under control. The technique of residual house-spraying started in 1951 had led to countrywide coverage by 1965, with a resultant decrease in malaria cases from 3.6 million to 70,330. The progress slowed, and in 1968 there was an increase in the number of cases. This turned into a trend; more than 100,000 cases were reported in 1970. Why?

The answer to this question is important not only to the people of Thailand and that country's eradication effort, but also to other LDCs where similar conditions exist. So under a contract with AID, the Center for Disease Control of the Public Health Service began research from September 1967 to June 1972 at the Thailand Malaria Operations Research Unit (TMORU).

Among the reasons for the persistent transmission TMORU identified: possible changes in habits of known malaria-carrying mosquitoes; increasing refusal of occupants to allow their houses to be sprayed; growth of strains of malaria parasites that had become resistant to chloroquine, the principal drug used to cure the disease; and the movements of rural populations.

The primary vector of malaria in Thailand, TMORU confirmed, is the *Anopheles balabacensis*. TMORU found a high incidence of falciparum malaria that is resistant to chloroquine. Surveys in six areas of Thailand showed resistance rates from 63 percent to 94 percent. After experimenting with a number of alternative drugs, the researchers recommended the use of sulphur-methoxine-pyrimethamine as the standard treatment for falciparum malaria in Thailand. This standard was adopted by the Thai government. Findings with significance for the worldwide malaria eradication program are disseminated by WHO and other international, regional, and national programs.

The Quest for a Malaria Vaccine

AID undertook a contract with Dr. Paul H. Silverman of the University of New Mexico (when he was at the University of Illinois in 1966) to develop a vaccine for malaria. It was acknowledged to be "long-shot research." Now there is definite evidence that immunity can be produced with killed vaccines. There are still some difficult problems remaining to be solved, but they are largely of a technological nature rather than those requiring the need to establish new principles of science.

The cause of malaria is well known: The Anopheline mosquito bites a person and injects sporozites, the infective form of the protozoa, into his blood. The number of sporozites any mosquito may inject is highly variable but never enough of the little parasites are planted in any one person to cause an immune reaction. Furthermore the sporozite does not linger in the blood stream long enough to induce immunity. In less than an hour, it has entered the tissue of the liver, where it is no longer available to the body's immune system.

The secret lies in taking sporozites that have been weakened by ultra violet or X-ray or killed by freeze-thawing or careful dehydration and introducing them into the bloodstream in a state in which they cannot be transformed into the stage that invades the liver. Dr. Silverman explains: "We have here in malaria immunity a situation which contrasts sharply with the experience of microbial immunologists. It appears that it is possible to induce a better immunity to malaria by artificial means than that which normally occurs as a result of exposure to natural infection."

The work done so far indicates that the ideal malaria vaccine should contain material (antigens) from both the infective and the blood stages of the parasite. As one can imagine, extracting these minute materials is painstaking work. So far the technical ability to produce the required antigens in adequate quantities is lacking, and there has been a shortage of resources and facilities to test antigens adequately in monkeys and men.

Dr. Silverman described the task involved "Preparing adequate amounts of sporozite antigen involves the laborious and difficult

maintenance of *Anopheles* mosquitoes, infecting them by feeding on animals whose blood contains gametocytes (infective cells), storing the infected mosquitoes in a healthy condition until oocysts (the developing stages of malaria in the mosquito midgut) and sporozites have developed, then manually dissecting out the infected mosquitoes' salivary glands and preparing them for antigen injections or using them for the infection of mammals."

The variety of culture factors to be tested is enormous. Many types of physio-chemical incubation conditions need to be examined to find the optimal environment for the parasite to replicate and metamorphose through its various life-cycle stages. Once the parasite can be made available under laboratory conditions, testing facilities for primates are necessary. The most effective method of immunizing must be determined as well as the post-vaccination effects. How much vaccine will be required? What is the best kind? What kind of adjuvants (substances that enhance antigenic activity) should be mixed with the antigens? These are some of the questions that must be answered.

If this research succeeds, the world's most epidemic disease might be reduced to a negligible level. Significant resources now used for malaria suppression and treatment would be freed for other uses. Finally, success of this research would open up possibilities for the immunization control of other major parasitic diseases, which so far are not subject to immunization procedures.

Serological Diagnosis of Malaria

At best it will be several years before a vaccine is forthcoming to prevent malaria. In the meantime, worldwide eradication efforts continue.

The eradication process relies basically on two steps: spraying every home and building in infested areas to kill the mosquito that has fed on a human; and after malaria incidence is at a low level, identifying and curing every malaria victim, who otherwise is a source of infection for the entire community. Both tasks are essential.

Positive detection of malaria has depended on microscopic blood examination, which is time-consuming. A more rapid and accurate detection procedure is needed. The serological (blood serum) diagnostic technique that is being researched by PHS's Center for Disease Control, under an AID contract, is a promising approach. This is a chemical procedure that is easier to conduct and less costly than microscopic blood examination. In serologic diagnosis, the blood sample is tested by chemical and physical reactions that are readily produced and easily observed

Diagnostic techniques employing malaria serology were known in principle before the project began, but they had not been developed for field use to meet the large scale case findings and investigational needs of malaria programs. Key problems remained to be solved.

Research focused on two tests, the Indirect Hemagglutination (IHA) and Indirect Fluorescent Antibody (IFA). With both tests, the primary challenge was to perfect a stabilized antigen and standardize the method. Antigens are chemical substances in the infecting organism (in this case the plasmodia) which are responsible for the antibody reaction in the victim.

In perfecting the IHA test, scientists prepared plasmodium parasites maintained in rhesus monkeys, that react with antibodies to human plasmodium species. They also developed a standard method of collecting finger-prick blood specimens on filter paper. A major drawback of this test is that it produces positive results even though the subject may have been infected long before and the disease is now dormant. The test



If a malaria victim is not identified and cured, he remains a source of infection for the entire community. This Peace Corps volunteer who works with a malaria spraying team in Thailand is taking blood samples to see if malaria is present in the village. Under an AID

contract, the U.S. Public Health Service has developed an accurate chemical blood serum diagnostic procedure that will identify malaria more quickly and at less cost than the microscopic blood examinations used in the past.

has a wide range of applications in malaria programs. It can be employed to measure how much malaria exists in an area, and to determine whether malaria is being transmitted or not by testing two specimens taken some months apart from a relatively small number of persons. The test can be used to detect seasonal changes in transmission of the disease. It can serve to warn of reintroduction of malaria into an area that had been considered free of the disease. The test can be especially useful in areas where the regular malaria surveillance network is limited, and it can be used as a screening mechanism to detect potential carriers of malaria parasites in blood donor programs.

Under the contract, the laboratory developed a new and vastly improved technique to detect the presence of malaria in humans using the IFA test. Previously this test had been time-consuming and not always accurate. Antigens were washed free from red blood cells and the donor's antibodies and a thick smear specimen prepared. This test technique was found to work consistently and was able to detect the presence of different species of malaria accurately. In developing the technique, the scientists learned more about the nature of malaria.

Many laboratories have now adopted the thick smear antigen for use in the IFA test for malaria. The serologic methods are used in the United States to detect donors of malaria-infected blood. Since malaria can be transmitted by using infected needles, this test has also been applied in drug-abuse control programs. Using the IFA test in Brazil, it was determined in just three days that the Mato Grosso area, thought to be highly malarious, had a low incidence of the disease, and a costly spraying program was discontinued.

Safe Water Supplies

Sometimes health research can benefit an enormous number of people in the LDCs even if it does not address itself directly to medicine. Pure drinking water, which almost everyone takes for granted in our country, is in short supply in much of the world. Polluted water can produce tragic results.

Perhaps as many as a billion people living in developing countries are without adequate supplies of safe water. Contaminated water exposes them to a variety of intestinal diseases that annually affect about 500 million people, killing as many as 10 million of them. About half of that number are children.

The rural population of less developed countries usually depends upon wells and ground water supplies for their drinking water. These water sources can become contaminated easily if the water is obtained by direct dipping or by a rope and bucket. This problem can be overcome easily by using a hand pump over the well. But not just any hand pump would do the job. In fact, AID recognized that no hand pump in existence is satisfactory under the rugged conditions prevailing in most LDCs.

Battelle Memorial Institute, Columbus, Ohio, took on the task of designing a pump that would be so rugged it could stand up under almost continuous use (as much as 18 hours per day in some parts of the world). Because repair facilities are rare where the pump would be used and maintenance virtually nil, the pump was to have few parts and few points of wear. And although the materials that went into the pump had to be extremely durable, they also had to be inexpensive. It was important that the pump could be manufactured in the countries where it would be used and made available to poor communities at a price they could afford (preferably no more than the equivalent of ten dollars).

Battelle designed a pump that is simple and rugged, with a minimum number of moving parts and few elements, such as nuts, bolts, or threaded fasteners. The design incorporated inexpensive and corrosion-resistant cylinders and plastic pipe or black steel with epoxy coating. The pump can be manufactured in small foundries using few power tools.

To gauge international interest in the pump, AID and Battelle issued a news release in June, 1969, describing the development and soliciting inquiries. Within a year, 66 responses were received from 20 countries.

The next step was to test the pump under field conditions to learn what unanticipated problems would arise in a small rural community. Under another AID contract, initiated in June, 1971, Battelle began a 2-year field test of the design to learn what modifications of the pump experience would dictate.

Each pump will be inspected by local personnel four times a year. Reports on the pump's condition and performance will be sent to the researchers for evaluation. Should any pump break down, it will be sent back for a detailed evaluation of what went wrong. All test pumps will be evaluated at the end of the test period in any case.

Tests have begun as planned in Thailand and Nigeria. Through a fortuitous circumstance, Bangla Desh officials learned of the pump at a time when they faced a severe water supply problem. They requested permission to have three firms there manufacture some 160,000 pumps. (A third country had been sought for the test, but plans had not included such massive production). With support from UNICEF, the three Bangla Desh manufacturers are proceeding and the researchers will have an opportunity to compare their products and draw some conclusions about the practicability of mass manufacture of the design by LDC companies.

Adaptations of the design to fit local circumstances are encouraged. For example, the pumps in Thailand sit higher off the ground than those in Nigeria, because it is customary to carry water in containers on the head in Thailand.

It is expected that the pump may be used in the United States in national parks where they would be heavily used during the tourist season, or on Indian reservations which are generally in remote areas without access to municipal water supplies.

Another AID research project sought to find the most efficient and economical ways of designing community water supplies for developing countries. The project, conducted by the University of North Carolina, deter-

mined the amount of water consumed by households in small communities as related to environmental, social and economic variables and to forecast water demand over a period of time. San Carlos University in Guatemala collaborated in the study.

The methodology that this project has developed can be of great benefit to AID and other assistance agencies in planning better ways to improve sanitation and provide potable water supplies in many LDCs. The University of North Carolina believes that the cost of previous AID sanitary engineering projects in Brazil and Thailand would have been less if these findings relative to optimal design and scale of construction had been available at that time and had been used.



This rugged community water pump in Bangladesh is used virtually round-the-clock by the villagers. It was designed by the Battelle Institute to be made locally in LDCs, using inexpensive black pipe made corrosion resistant with an epoxy coating, and a minimum of parts vulnerable to breakdown. Battelle pumps are also being tested in Thailand, where minor modifications have been made to meet local conditions.

Study of Malabsorption

The person suffering from malabsorption is unable to utilize the full value of food because of poor absorption of nutrients across the lining of the intestine and into the bloodstream to be converted into body tissue or energy.

The normal human intestine is lined with regular, finger-like obstructions called villi. This lining can become misshaped and blunted by bacteria and viruses. Then it fails to absorb the carbohydrates, proteins and fats in food, that are normally converted for the body's uses.

Under a contract with AID, the U.S. Public Health Service attempted to measure the amount of nutrient loss resulting from malabsorption. Research was based on the hypothesis that malabsorption is a significant source of malnutrition among some people in the LDCs and that this condition has a detrimental effect on the health of individuals, as well as placing a serious burden on the food supply.

Chemical tests exist which can be useful in estimating the importance of malabsorption in poor nutrition but applying these tests in community studies is not without difficulties.

The primary test for measuring malabsorption is to compare the quantity of a particular substance that an individual ingests against the amount he excretes.

Studies were conducted under the contract in Iran, India, and Puerto Rico. Absorption of nitrogen (as a measure of protein), fat, and xylose (an easily detectable crystalline sugar) were tested. Some of the study sites reported poor nitrogen absorption. Fat absorption was found to be low in the Indian test group. Xylose malabsorption and poor absorption of vitamin B12 were observed in Puerto Rico, where about half the rural population showed abnormal intestinal function.

In the course of the study, a discovery was made that may be beneficial to several developing countries. In 13 villages of the Shiraz region of Iran, it was found that the villagers had been depleted of such mineral elements as zinc and calcium, even though their diets contained an abundance of these minerals. Key to the problem is thought to be that their food staple, whole wheat, contains an excess of the cereal constituent called phytate, which is normally removed in the milling process. Experiments suggest that the phytate in the villagers' bread had an adverse effect on zinc and calcium absorption, depriving the people eating the unleavened whole wheat bread of these minerals. As a consequence, rickets and other bone diseases were prevalent in the area, along with retardation of growth and sexual development and iron deficiency anemia—all suspected to be the result of high phytate intake. It was learned that the situation can be rectified by using more refined flour in preparing the unleavened bread the villagers favor; by leavening the bread dough, or by fortifying the wheat flour with added minerals.

Aside from the findings in Iran, however, the project's results did not confirm unequivocally that the relationship between malabsorption, malnutrition, and health in the areas is a serious problem bearing on food supply.

Inter-American Investigation Of Child Mortality

Certain health problems are so overwhelming in some parts of the world that it is difficult to get a handle on how to begin to solve them. The appalling mortality rate of infants and children up to five years old—which amounts to half the death rate in some developing countries—is such a problem. The countries are well aware of the overall statistics, but they seldom have adequate specific health data upon which to base an allocation of resources.

To what degree is malnutrition responsible for these deaths, or infectious diseases? What is the interrelationship? What social, environmental, and economic conditions conspire to cause this excessive number of deaths? To answer these questions in Latin America, where the problem is particularly severe, the Pan American Health Organization (PAHO), under an AID research contract, began a comprehensive survey and data collection program in June, 1966.

PAHO worked with personnel and institutions in the eight countries being studied, so the techniques could be learned and continued by local health officials after the project ended. So that the research might benefit both medical education and health programs, all of the projects except one were developed in schools of medicine and public health in collaboration with those responsible for delivery of health services.

Fourteen teams composed of a leader (the principal collaborator), at least two local physicians, two public health nurses or social workers, and a secretarial staff gathered information in the eight countries about each death of a child under five. Facts about the illness leading to death (including details of the birth, breast feeding, weaning, foods added to the diet and medical attention received), history of pregnancy and prenatal care for the mother, demographics of the parents and other members of the household, and housing conditions, were collected. Reports included hospital or clinic records and interviews with physicians when the child had been given medical attention. In addition interviewers visited the home to obtain as many facts as possible about the fatal illness.

Field investigation also included probability samples—visits to homes at random to compare the health and circumstances of surviving children in comparable situations. This technique was new to most of the areas where the program was conducted and provided valuable experience for local teams.

The findings of the study have convinced some of the countries participating to redirect their health programs. For example, the early discovery that many children in Recife and La Paz, Brazil, were dying of measles led to massive vaccination of all children 8 months to 3 years old. Various national programs are planned or underway in several countries of the region. The importance of improving the quality and handling of clinical records as well as reporting of births and deaths was demonstrated to Latin American health officials. The level of pediatric pathology has also improved substantially since the project began.

One of the study's most important findings is the seriousness of nutritional deficiency in the countries surveyed and the high proportion of deaths in childhood in which nutritional deficiencies were a contributing cause. In four projects using data for the age group 6 months through 6 years, investigators found nutritional deficiency to be the underlying cause in 10 percent of the deaths, a contributory cause in 31 percent, and a consequence of the underlying cause in 15 percent. A total of 56 percent of the deceased children had severe nutritional deficiency.

The lasting significance of the inter-American investigation project lies not in the specific findings (although they did lead to immediate action to solve short-range health problems) but in demonstrating the value of this methodology to health officials in participating countries.

For many years the main tool in malaria eradication has been the pesticide DDT. It has many desirable features: it costs about 18 cents per pound because it is simple to manufacture and can be produced on a large scale; it is relatively non-toxic to animals and humans, and it is persistent, remaining effective for about 20 weeks after spraying.

Scientists are aware of the drawback of DDT's persistence, which prolongs its life in living tissues and makes it an objectionable environment pollutant. DDT is not biodegradable; traces of the toxic chemical remain in the systems of insects, fish, and animals exposed to it. For example, in Lake Michigan scientists have found that the water contains .000001 parts of DDT per million, yet fish taken from the lake contain 10 parts per million and herring gulls that eat these fish retain 100 parts per million. The concentration of DDT in humans in India is estimated at about 20 times that of people in the United States. In short, DDT can contaminate the food chain.

Another drawback to DDT is that some strains of mosquito, particularly in Central America, have developed resistance to the pesticide. This was a primary reason for the search for alternatives to DDT conducted by the U.S. Public Health Service under the AID-sponsored worldwide malaria eradication project.

Because DDT is widely used to kill insects other than *Anopheles* mosquitoes, a number of ecology-conscious organizations have been searching for alternatives to the pesticide which would be biodegradable. Among them was the Rockefeller Foundation, which supported research in four U.S. universities, one of them the University of Illinois. Heading the Illinois project was Dr. R. L. Metcalf, who pursued the approach of trying to learn why DDT does not break down and thus cumulates through the food chain. He and his staff sought analogues to DDT—substances that were similar, but with differences in their chemical composition that would correct DDT's shortcomings. They found that two extra atoms of chlorine in the DDT molecule was the factor that made it nonbiodegradable.

AID made a grant to the project, because with additional funds, the research could be

directed to the specific malaria-DDT relationship of special interest to the Agency's health program. If DDT analogues were to be useful in malaria eradication programs in LDCs, they would have to be tested for specific properties.

With AID support, huts and ponds were constructed on Illinois property for tests to determine the analogues' effectiveness against mosquitoes, the length of time they would remain effective inside huts, their toxicity to animals and to fish (the degree to which they would concentrate within the food chain) and how biodegradable they would be.

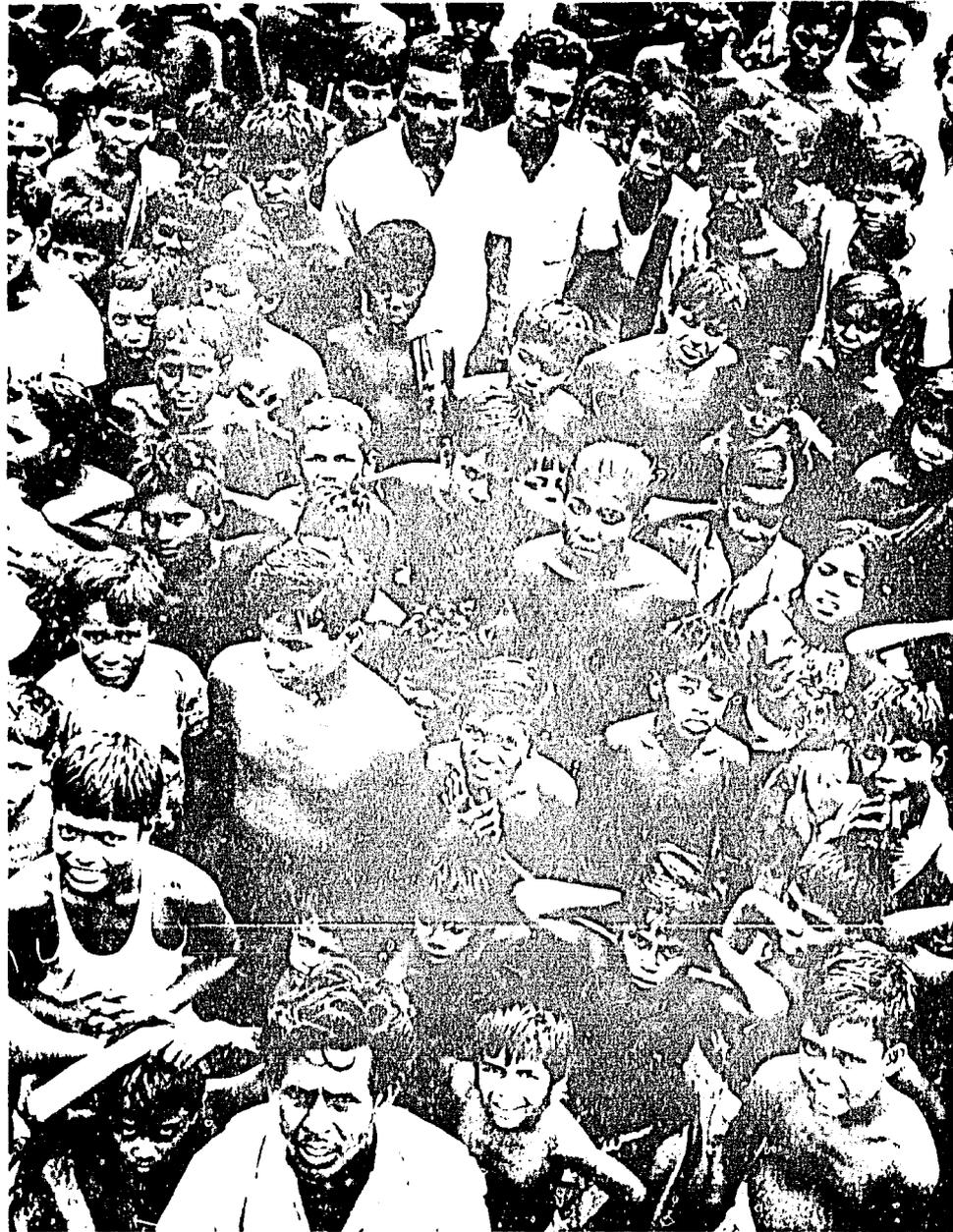
Minute quantities of some 30 analogues were tested. Some killed insects effectively, others did not. The process of culling the most promising analogues continued. Under the AID project, the production of leading analogues was cut from some 30 steps to two steps during six months. Several were produced in larger quantities. The process may be further refined and—from a cost standpoint—the analogue should be roughly equivalent to DDT.

The Illinois scientists developed a series of biodegradable analogues that incorporate chemical groups in the basic molecule which can be converted by enzymes in living tissues into water-soluble degradation products. Animals quickly eliminate these products instead of storing them in fat (as they do DDT). The chemicals still kill insects, however, because insects are not able to degrade them nearly as efficiently as vertebrates can.

The best analogues do not appear to concentrate in the food chain; virtually all are broken down in a matter of hours. Consequently, the analogues are much less toxic to fish.

Certain mosquitoes that have developed resistance to DDT were found to be vulnerable to the analogues. The chemical reason for this was discovered—enzymes in the mosquitoes were able to break down DDT molecules, but they could not cope with the different chemical construction of the analogues. Because there are so many analogue possibilities, if mosquitoes should build resistance to any one of them, a slight chemical change could be made without destroying the insecticide's potency.

POPULATION



POPULATION

The possible effects of the world's population growing at the present rate have been discussed by responsible scientists in distinguished journals. Their sober speculations sound like a mixture of horror stories and science fiction. If population were to continue to double at its current rate of approximately three times a century, there would be 30 billion people on earth in 100 years. Long before that time, it is believed, the competition for the earth's resources would lead to global catastrophe.

The apocalyptic potential of population growth was noted as long ago as 1798, when Malthus put forth his gloomy theories of the effects of unbridled human multiplication. Only recently, has the urgency of such warnings galvanized the leaders of developing countries to adopt policies of family planning as a necessary prelude to achieving national goals.

The dynamics of population growth shape every aspect of development policy: health, nutrition, agriculture, education, economics. Family planning can make important contribution to maternal and child health care which is an essential part of a sound national health program. Nations do not benefit from sound agricultural practices and high yielding seeds if population increases outpace the increased food supply.

Like all AID research, that in the field of population is aimed at solving specific problems of developing countries. Methods that are effective in countries where parents are well educated about the need for and techniques of family planning may not be transferable to LDCs where parents are not highly motivated. Research seeks easy methods that will be acceptable and effective within the sociological and cultural environment of these countries.

AID research in population focuses on the general areas of behavioral sciences and biological sciences. Numerous LDCs do not have full-scale censuses or complete vital registration systems; they can only guess at the true dimensions of their population problem. AID sponsors descriptive demographic research to fill this initial need. Similarly these countries need to know much more about population dynamics: the factors affecting population growth and distribution within a given society and the effects of population characteristics and changes on the society. Once these vital background data have been compiled, a country is prepared to launch a family planning program. To design the best program, population planners must be able to answer such questions as:

What factors influence parents to have the number of children they do?

What are the most effective methods of educating people to the need for family planning and encouraging them to accept birth control techniques?

What personnel are needed to spread the program and how should they be trained?

What evaluation criteria are needed to insure that the program is having the desired impact?

Operational research seeking improvements in the actual conduct of family planning programs is carried out to answer these questions. Biomedical research is carried out to develop safe, effective and convenient means of contraception. Great advances have been made in recent years in the biological and medical areas of family planning. Scientists are hopeful that further breakthroughs are imminent. AID-sponsored work progresses on methods of contraception that would require less constant vigilance on the part of the user, that would be reliable and inexpensive, as well as free of undesirable side effects.

The following sections provide a brief description of some of the projects in the four areas of research activity—descriptive demography, analysis of population dynamics, family planning program operations research, and development of improved means of fertility control.

Descriptive Demography

The first step in approaching a problem as enormous as world population growth is to define the problem itself. AID is supporting an international effort to assure that subsequent programs are grounded in the reality of statistics: a 5-year World Fertility Survey began in 1972 under the auspices of the International Statistical Institute, The Hague, Netherlands.

Many developing countries are hard pressed financially and in terms of trained personnel to collect basic census and information; they need help in collecting data upon which to base population planning policy. The World Fertility Survey seeks to assist between 50 and 60 countries throughout the world in carrying out nationally representative, internationally comparable sample surveys of human fertility in observance of the U.N. World Population Year, 1974.

In addition to gathering information on the age of a woman and her husband, birth history and survival of all children, pregnancy history and marital history, investigators will explore fertility regulation practices, breast feeding, attitudes about family size (including desire for more children), and such social and economic factors affecting fertility as: educational attainment, literacy, occupation and employment status of husband, family structure and other cultural characteristics.

The basic goal of the World Fertility Survey is to provide uniform scientific information that will permit each participating country to describe and interpret the fertility of its population. Improved data in this area will assist national efforts in economic, social and health planning for development as well as giving guidance for designing family planning programs.

The International Statistical Institute is a scientific organization with an elected membership of eminent statisticians from countries throughout the world. During the WFS, the organization will collaborate with the International Union for the Scientific Study of Population and the United Nations. A professional staff for the project will run a center in London where the work of national staffs in participating countries will be assembled.

Other projects include one carried out by the University of Wisconsin to study the relationship between internal migration within a developing country, urbanization, fertility and economic development. Investigators are analyzing the community preferences of migrants and determining the differential fertility rates and earning capacities before and after migration and between migrants and non-migrants.

Research is building upon data collected several years ago in several Colombian communities and a national sample of large farms in Chile. Researchers hope to learn from this study how development policies affect migrants, their earning capacity and their fertility—information that will be valuable in national planning.

Population Dynamics Research

Population dynamics research involves study of the factors affecting population growth and distribution within a given society and the effects of population characteristics and changes on the society. Much more knowledge of these is needed as an aid to less developed countries in discovering the best means for coping with population problems.

A sociological study on family planning attitudes and practices was conducted for AID by Harvard University between June of 1969 and September of 1972. Investigators tested the validity of the conventional wisdom that families in areas of high infant mortality have more children to assure surviving heirs and helpers and that parents in some societies prefer sons to daughters and are likely to continue having children until they produce a son.

Extensive testing was conducted in two townships in Taiwan—one with a high level of infant mortality, the other with a low level. Individual experience of child loss suggest that higher levels of infant and child mortality do give rise to higher fertility. Parents who had lost one or more children among the first two or three births tended to have higher subsequent fertility than those whose early births all survived. But the families were ultimately larger where all offspring survived. On the average, subsequent fertility compensated for about 60 to 70 percent of the original child loss. The difference in family size between the low-mortality township and the high-mortality township was negligible.

An attitudinal preference for sons was shown to have a small but consistent relationship with fertility behavior and attitudes (at least in Taiwan). In cases where all early births survived, researchers found that the number of subsequent births was smaller if at least one of the early births was male. Part of the reason may lie in the tradition in Taiwan of parents paying more money for the marriage of a son than of a daughter. Therefore, although it is important to families to have at least one surviving son, there is good reason to avoid having too many sons. Other studies (notably one in India) have produced contrary findings, which indicates that son-preference may be a complex cultural and social phenomenon that varies from country to country.

In 1972, the Rand Corporation completed a 2-year study for AID to explore the differences in fertility among individuals and among social and economic groups in developing countries—to learn what affects parents' decisions on the number of children they will have. Among other questions, the study examined the relationships between parental decisions to produce offspring and the prevailing rate of child mortality and the relationship to female education. The purpose of the study was to provide a basis for countries to better define alternative family planning program strategies, indicate their potential comparative advantages and test the cost effectiveness of actual operations.

Other projects include an epidemiological study carried out by John Hopkins University in Taiwan seeking information on pregnancy loss and how this relates to health, fertility levels, and other factors.

Operational Research

Research is needed to determine the best ways of educating or motivating people to use available family planning services. To what degree does acceptance of programs depend upon the communications ability of clinic personnel or field workers? How much do side effects of certain contraceptives discourage people from using them?

The answer to these questions may differ in countries with significant cultural variances and where a variety of family planning education and health delivery systems exist.

The most successful national family planning programs have benefited from an integration of research and evaluation activities with active programs of disseminating advice and equipment. Field programs provide researchers with valuable information about what kinds of people are accepting family planning methods, which methods they employ, and whether they continue to use them. Operational research programs serve to identify and study problems and give important clues about what modifications may be necessary to improve acceptance of family planning methods. There are several means of trying to reach the population—through mass media, door-to-door visits by field workers, or appeals by community leaders, for example. The effectiveness of various approaches are being evaluated in different LDCs.

Operational research includes research on the best methods of education and recruitment of acceptors, development of optimal staffing patterns, improved training methods for program workers, and evaluation of the impact of the program.

From fiscal 1965 to fiscal 1972, AID has provided \$17 million for over 60 technical assistance and operational research projects in 18 countries in Africa, Asia, and Latin America to meet these needs.

Pilot studies on the use of various fertility control methods, development of improved service statistics systems, and testing of mobile clinics and other delivery systems have been carried out in India, Pakistan, Turkey, the Philippines, and other Asian, Caribbean, and Latin American countries.

A major objective of family planning programs is getting the information to women who need it at a time when they are most likely to be receptive. In any population there is a large group of women who become pregnant again shortly after bearing a child or after a pregnancy termination. Characteristically, it has been found, these highly fertile women are young, in the lower economic levels, have little or no education, and have little motivation toward family planning. But the time they are most receptive to family planning information is usually immediately after delivery of a child.

AID supported a research project developed by the Population Council from 1967 through 1971 to explore the opportunities for extension of family planning by attaching the services to maternal postpartum care and treatment in large public hospitals. The concept was tested in 111 hospitals in 12 countries: Nigeria, Thailand, Indonesia, Venezuela, Honduras, Ghana, Hong Kong, Iran, Philippines, Mexico, Colombia, and Turkey. Studies indicated that maternal and child health centers, as well as hospitals, can provide family planning information and services effectively. Successful experience with immediate postpartum insertion of IUDs and the administration of oral contraceptive pills before the patient leaves the hospital has substantially increased the number of women accepting fertility control programs. In the majority of institutions, between 10 and 20 percent of women there for delivery of pregnancy termination became direct acceptors, and in some cases as many as half became active in family planning.

The program collected and computerized data from all research sites on each woman's age, living children, sons, education, contraceptive and abortion experience, noting the outcome of postpartum visits and the degree of acceptance of fertility control measures. These data are available to AID and other family planning programs.

In some countries where the research was conducted, government officials were sufficiently impressed that they extended the postpartum program to many or most maternity hospitals as a major component of national family planning programs. Among these countries are Colombia, Venezuela, India and Thailand.



Women who have just had babies at a hospital sign up to receive oral contraceptives and other family planning services. Research carried out by the Population Council has shown that the post-partum period

finds mothers most receptive to family planning. The concept was tested in 111 hospitals in 12 countries.

What motivates families to make use of the family planning services available in a developing country? This was the primary question investigators from Bowman Gray School of Medicine (of Wake Forest University) attempted to answer in an AID project conducted in Costa Rica from 1969 through 1972. Extensive interviews were conducted in six Costa Rican communities served by family planning clinics. The interview schedule, consisting of pretested demographic, psychological and sociological items, was administered to 1,652 females comprising a stratified random quota sample.

Findings included recommendations to arouse greater interest in fertility control, the means favored by the women interviewed (and why they rejected other meth-

ods, including exploration of whether the reasons were purely subjective or related to actual side effects of certain contraceptives), what improvements in clinic procedures are necessary to interest the optimum number of women, where women get their information about family planning, and why women who had been clinic patients dropped out.

Survey data and reports have been translated into Spanish and published in a 173-page report, distributed by the Costa Rica Family Planning Program. Costa Rican scientists, doctors, and family planning experts were active in the project from its inception and are continuing evaluation with other funding since the termination of the AID phase of the program.

Improved Means of Fertility Control

Since AID began assistance programs for family planning in 1965, the Agency has supported only programs that are voluntary and which seek to make it possible for individuals and families to regulate their fertility in keeping with their personal desires. Any research on fertility control technology sponsored by AID seeks methods consistent with the exercise of individual choice.

In the United States during the past decade, increasing numbers of families have improved control of fertility through acceptance of oral contraceptives and intrauterine devices (IUDs). Persons seeking advice and assistance in family planning have ready access to physicians and clinics. As a result, many Americans have accepted family planning methods, and national fertility surveys document increased use of fertility control in all strata of society.

In the less developed countries where health care systems are weak and the people who could benefit from family planning are often poorly educated, fertility control techniques are needed that are especially adapted to the local conditions of these countries and less dependent upon sophisticated delivery systems.

Experience indicates that in LDCs, as in more developed countries, those official family planning programs or private channels that offer a wide variety of techniques are more successful than those relying on only a few methods. Different methods appeal to different women. Oral contraceptive users are younger, on the whole, than those who prefer IUDs, and a still older group tends to choose sterilization.

In addition, cultural differences seriously limit acceptance of certain methods, such as those requiring vaginal examinations, or those causing side effects of vaginal bleeding. Increased bleeding can be a serious problem for IUD users already anemic from parasitic infestations who lack sanitary supplies and facilities; and decreased lactation among users of oral contraceptives may compromise infant nutrition in some settings.

Any new means of fertility control must be acceptable both to individuals and to society; furthermore, they must be adequately safe, demographically effective, and practical for use in family planning programs in terms of administrative ease and reasonable cost. AID research is attempting to develop a variety of means of fertility control which are suited to conditions in LDCs.

New Methods of Fertility Control

Simpler, more effective, safe to the user—these are the results researchers strive for in developing new contraceptive methods. If a woman could take a pill once during the month, the method might be simpler to use, probably cheaper, and overall, more effective, than the present contraceptive pill, which requires daily use during exposure periods.

AID has supported research in three projects that share the goal of discovering a once-a-month contraceptive. From May, 1969 through May, 1972, AID contributed to an extensive program by the National Institutes of Health, which involved 28 contracts with university and other research organizations. Other projects studying the ways that hormone-producing structures work and what can be altered to affect fertility have been supported by AID at the Worcester Foundation for Experimental Biology, and at the Population Council.

The corpus luteum that forms in the ovary shortly after ovulation (release of the egg) produces a sex hormone, progesterone, which is required for pregnancy. If methods can be found to interfere with the function of the corpus luteum, the way will be open to develop a once-a-month contraceptive.

Under another AID contract, the Population Council (and seven subcontractors) are also studying methods to interfere with the corpus luteum process—without endangering the health of the woman using the method. Scientists are seeking a safe way to inhibit the production of progesterone by the corpus luteum, or to prevent the progesterone from performing its function.

Releasing Factor Studies

The reason that the corpus luteum excretes progesterone hormones is because the brain has given it a signal to do so. Releasing factors are chemical "messengers" that link the hypothalamus of the brain with the anterior pituitary gland, directing the gland to produce hormones involved in conception.

The Salk Institute for Biological Studies is attempting to develop a new oral contraceptive that would be effective if taken only once a month. This method would eliminate most of the side effects of the present oral contraceptive. The research is concerned with determining the chemical structure of releasing factors, particularly the luteinizing hormone releasing factor (LRF) that ultimately controls endocrine processes necessary to pregnancy. Once scientists have learned the chemical makeup of LRF, they will concentrate on synthesizing chemicals that interfere with LRF activity and prevent conception.

Prostaglandins

Prostaglandins show promise of a breakthrough in contraceptive technology particularly suited to the needs of AID-assisted programs in developing countries.

Since fiscal 1968, AID has initiated prostaglandin studies which have included research on new means of measurement, new approaches to prostaglandin synthesis, studies of formulation and delivery methodology, compound screening, studies of the effects of prostaglandins on mammalian and primate reproductive physiology, human clinical trials, and a prostaglandins information service.

This work has been carried out at 18 different institutions, either funded directly or through a program coordinated by the Worcester Foundation for Experimental Biology. They have included Harvard, Makerere University (Uganda), The Royal Veterinary College (Sweden), Oxford, Yale, and the Universities of North Carolina, Johns Hopkins, George Washington University, University of Wisconsin, and Washington University (St. Louis).

Although further testing and development is necessary, these compounds and their analogues appear to be very promising as a means of regulating fertility. However, use is still hampered by side effects and some therapeutic failures. It is hoped that new prostaglandin analogues and improved delivery systems can overcome these problems.

Research to Improve Currently Available Methods

Safety of Contraceptive Steroids

Oral contraceptives—The Pill—are favored by more women in developing countries than any other single form of fertility control. Certain steroid hormones are the active agents in these contraceptives (and in other experimental methods using injection and implantation techniques). Although the effectiveness and acceptability of contraceptive steroids has been proved, minor side effects have been reported and questions of unreported hazards have been raised. For example, women suffering from disease or malnutrition in a developing country might experience different subjective side effects than the relatively healthy American women tested.

Under an AID contract, scientists of the Southwest Foundation for Research and Education are conducting clinical studies of the metabolism of the estrogenic component of contraceptive pills on women from various ethnic backgrounds. Tests are run on various brands of commercially available pills to learn whether slightly different components produce different subjective side effects—such as nervousness, depression or weight gain.

If studies reveal that women with health or nutrition problems suffer adverse reactions to the pills, supplements of vitamins or folic acid, for example, might be added to the compounds that would negate these effects while still maintaining the contraceptive effectiveness of the pills.

Developing and Testing IUDs

Intrauterine devices rank just behind oral contraceptives as the most important fertility control methods now used in family planning programs in most countries. However, high rates of removal caused by side effects, spontaneous expulsion, and the incidence of accidental pregnancy limit the effectiveness of IUDs in current use.

Since 1970 the Battelle Memorial Institute has been analyzing the physical characteristics of IUDs—their size, shape and texture—and studying side effects that have been reported with the different devices, such as pain, bleeding, and inadvertent expulsion. Battelle seeks to develop an improved IUD with minimum side effects through experimenting with new materials and designs using bioengineering analysis. The research employs an empirical approach to improving devices and providing needed ancillary instruments, inserters and packaging for LDC users.

Battelle is concentrating on measuring the wide range of geometric and mechanical possibilities—and comparing their clinical performance. Both inert and biochemically active materials are being tested to discover new materials and devices and to measure their suitability in a number of ways, including animal testing. Most IUDs depend upon their shape and texture to perform their function; some scientists have found that added elements like copper and other metallic ions, make IUDs more effective. Battelle is also investigating the advantages of medicated IUDs.

The researchers are interested in assuring the acceptability of IUDs in developing countries as well as their effectiveness and safety. Battelle makes findings and methods known to other workers in this field, and collaborates with other contributors and organizations by exchanging information and providing technical material through newspaper releases, seminars and lectures, and publications.

Surgical and Engineering Research

Under a separate contract Battelle has been asked by AID to develop improved and simplified methods of female sterilization and reversible male sterilization and means of fertility control that would be suitable for use in developing countries (where elaborate medical facilities are seldom available to the bulk of the population).

Battelle has come up with devices that would not require skilled medical personnel, nor general anesthesia and intra-abdominal operations for female sterilization. One method is to occlude (block) the woman's Fallopian tubes with tissue adhesives, which can be applied through the vagina without an abdominal operation.

Although male sterilization, through vasectomy, is available in several LDCs, many men are reluctant to accept the operation because it is irreversible. Vasectomy is an operation that disrupts the vas deferens

(sperm duct) by cutting and tying so that sperm cannot travel from the testes. Battelle has developed experimental plastic valve devices that accomplish the same purpose as the tying, but can be removed if the man later desires to have children. Experiments are being performed on guinea pigs and small goats.

Related studies on reversible sterilization are being carried out by the University of North Carolina with AID support. Experiments are being conducted with a special plastic and steel clip with a loading mechanism that would occlude Fallopian tubes with greater safety than current techniques and yet could be removed.

Instruments have been designed to insert the female clip through a laparoscope (which would eliminate the need for hospitalization). Several prototypes of this equipment were manufactured for research purposes and are being used in clinical trials.



A U.S.-trained LDC surgeon performs a laparoscopic tubal ligation requested by a 36-year-old mother of seven. This technique of female sterilization normally requires ten minutes on the operating table with

discharge from the hospital the same day and is based on procedures developed by the University of North Carolina under an AID research contract

Combined VD Prophylactic Contraceptive

Aside from the obvious practical benefits of a vaginal foam contraceptive that would also kill venereal disease germs, this form of fertility control would be politically acceptable in many countries where family planning programs are best combined with health and preventative medicine.

A combined prophylactic/contraceptive could introduce family planning into regular venereal disease control and other public health programs at a minimum expenditure of professional manpower and with a high probability that the substance will be accepted and used. Such an agent would be particularly useful for women where clinical methods of contraception and treatment facilities are not available.

The University of Pittsburgh is working to develop improved intravaginal agents with spermicides to kill sperm and with drug components effective in preventing transmission of a broad range of genital tract infections. Tests for effectiveness and safety have been conducted with rabbits; field tests for humans are planned at both U.S. and LDC sites.

Simplified Techniques of Fertility Control

In 1972 AID supported a Johns Hopkins University research program to find ways of simplifying fertility control techniques used in LDCs. As an integral part of this program, obstetricians and gynecologists occupying key roles in family planning programs in developing countries are offered a short-term training course in the most up-to-date techniques.

The training program, conducted in a model clinic setting, instructs physicians from developing countries in the most advanced techniques of sterilization, contraception, pregnancy termination, and family planning clinic management.

Grants for Research on Fertility Regulation

Under the administration of the University of Minnesota, AID provides a series of small grants for finding new and improved methods of fertility control. A scientific advisory committee of experts selects, screens and reviews projects costing less than \$50,000 each to be carried out by U.S. and overseas institutions. Preference is given workers in LDCs.

Although the program was started recently, several novel and promising ideas are being pursued. Among them: effectiveness of a hydro-fluoro-carbon compound that traps spermatozoa when applied intravaginally; and evaluation of Indonesian herbs believed to control fertility, to learn if the folk remedies are medically sound; the effects of adding sperm enzyme inhibitors to vaginal foams and jellies. Another project will study improved IUDs.

Under this program, some 20 projects may be funded with the purpose of encouraging and broadening the pool of population research talent in the U.S. and in developing countries.

International Fertility Research Program

A major program supported by AID to extend the availability of a clinical network for field trials is the International Fertility Research Program, which was begun in mid-1971, based at the University of North Carolina. To determine the safety and effectiveness of new fertility control methods for use in developing countries, the IFRP evaluates field trials on new IUDs, sterilization techniques, pharmacologic means of contraception, and other means of fertility control, in a variety of cultural settings.

Such practical trials shorten the time in which undesirable effects or health risks can be eliminated. They also demonstrate the favorable characteristics of new methods.

IFRP has designed standardized study forms that permit side-by-side comparison of data collected on various methods of systemic contraception, menstrual regulation, pregnancy termination and sterilization. For example, different types of IUDs or steroid pills can be compared using the same criteria under similar conditions in the same country. Program managers collect and evaluate these data from an internationally established network of experienced clinicians conducting collaborative field trials.

Under the program, special studies are initiated to develop new methods to the level where clinical trials can be conducted. Another important objective of the program is to train LDC investigators in the use of new methods.

A similar program with particular emphasis on IUDs was previously conducted by the Family Planning Evaluation Center established within the Pathfinder Fund. The Center analyzed performance characteristics of IUDs from data gathered in more than 100 clinics in 40 developing countries. By studying uniform records through centralized data processing, researchers have been able to determine which performance patterns relate to the IUD users and which to the clinics where the devices are inserted. For example, the important category of removals because of bleeding or pain has been shown to be closely related to the supportive nature of individual clinics providing contraceptive service, and the effectiveness of devices is strongly influenced by cultural and social attitudes. When advice is given by sympathetic and competent personnel in a clinic setting that the clients find comfortable, results are frequently far superior to those obtained through distributing the same devices in different locations.

Dissemination of Information

As the amount of funds devoted to research on fertility control technology and the number of investigators and laboratories increases, rapid and effective communication of results and work in process becomes more important. To meet this need, a new program for information interchange has been established with AID support at the Biological Sciences Communication Project of George Washington University.

The Population Information Program is providing a series of organized and indexed publications containing references, abstracts, and analysis for each of the important means of fertility control, including steroidal contraception, IUDs, and sterilization.

NUTRITION



NUTRITION

Malnutrition and associated infection causes more deaths and destroys the health of more young children in the LDCs than any other single disease. Yet health policies frequently emphasize treatment and rehabilitation rather than prevention. Developing countries generally have few public health facilities and a limited number of clinics and hospitals. As a result these facilities are available only to a fraction of the population and are relatively expensive per patient. As part of a strategy to bring needed services to a wider portion of LDC populations, AID is exploring the feasibility of assisting several countries to establish multi-purpose integrated delivery systems that would attack problems of nutrition, health and family planning. More food per capita and more nutritious foods are both basic requirements for reducing malnutrition. Many resources are being devoted to producing more food, but greater emphasis is needed on the severe problem of low food quality, particularly protein deficiencies in the diets of the poor.

AID's research is concentrating on how this goal can be achieved at a realistic cost; a concern also reflected to an increasing degree in the programs of the international agricultural research centers.

Because improved nutrition may not be part of an LDC government's national plan, the responsibility for pursuing nutritional policies often gets shunted about from one department to another. For example, a minister of agriculture might feel that malnutrition was a health problem that did not concern his agency. Although health officials could indeed help him identify the nature and extent of nutritional problems, the agriculture decision maker could have great impact on low-cost protein availability through nutrition-oriented agricultural policies; a pricing policy that would reward the farmer for growing high-lysine corn or beans, peas and lentils would have widespread effect on improving the diets of the rural poor.

Integration between nutrition programs and educational programs furthers the aims of both. A wide variety of projects are in operation to teach mothers the desirability of choosing certain foods for the family diet, how to prepare or serve specific foods to maintain their nutritional value, and the

causes and prevention of malnutrition. In several developing countries, mass media campaigns explain in a simple manner what available foods will help to build healthy young bodies. Numerous educational techniques have been employed; research is needed to gauge which are the most effective in bringing about change. Such knowledge is necessary to permit sound planning of the educational component of nutrition programs. AID has initiated an evaluation of nutrition education programs designed to provide some of the answers.

The relationship between nutrition and family planning programs is more subtle. Better spacing of children leads to smaller families, more favorable food availability and better maternal health, and these result in better nutrition. In many LDCs, delivery systems for food distribution extend into areas that are not reached by health or family planning centers. Family planning programs are frequently rejected by the populations of developing countries. However, some evidence exists that mothers who see their children visibly improved through a nutrition program will place greater confidence and faith in the program that has provided the nutritional benefits and will become more receptive to family planning.

Governments of developing countries are quick to recognize the need for such tangible resources as, say, steel. So they are willing to commit funds on a priority basis to the building of a steel mill. But they may not see so readily the economic benefits of improving nutrition. AID research projects provide tools for government planners to identify the gaps in their current nutritional programs, so they can set policies which will contribute to the health and strength of their citizens.

Research also points to new directions to be explored—innovative approaches that may overcome persistent problems at a reasonable cost.

Through an irony of nature, the foods that are most nutritious are also the most expensive. Meat, fish, eggs, and dairy products are rich in high quality protein, the complex substance made up of a combination of amino acids that are essential for health and growth. But these foods are practically unavailable to many people.

In the developing countries of Africa, Asia, and Latin America, about one-fifth of the population is undernourished—they do not receive enough food of any kind and subsist on far fewer calories than they should. But a larger proportion, at least 60 percent, is malnourished, not receiving balanced nutrition from what food is available.

A large percentage of the malnourished are children who need more protein than adults. Extreme lack of protein can result in such serious diseases as kwashiorkor which stunts the child's physical growth and may hinder his mental development. Scientists have learned that growth and health are affected not only by the amount of protein an individual eats, but also by the quality of that protein. The standard diet in many LDCs contains protein that is deficient in one or more of the essential amino acids.

Protein malnutrition has been increasing in recent years. With the rapid population growth in LDCs and the need to produce sufficient calories, some cropland appears to have been shifted from pulses to the new higher yielding cereals.

The approach AID takes in agriculture, of breeding plants with inherently better nutritional properties, is particularly beneficial in countries where large portions of the population subsist on crops they grow themselves. In more urbanized societies nutritional fortification is more effective. Supplements are added to the food after harvesting and before marketing, effectively improving the nutrition of masses of people.

Improved food technology, which falls within the province of nutrition, can also improve a country's economic development. Food processing, more modern marketing techniques, better storage and preservation of food, create employment opportunities, reduce waste and spoilage, and generate greater income.

Rice Fortification

More people eat rice than any other single food—and to many of them in LDCs it is their primary source of food. Yet rice is not high in protein, and the protein it does contain is deficient in two essential amino acids—lysine and threonine. The shortcomings of rice have particularly deleterious effects on children, pregnant women and nursing mothers.

Under an AID contract, Harvard University is conducting studies to learn the effect of fortifying rice with a synthetic rice-like grain containing amino acids and vitamins and minerals.

These field studies are designed to determine if fortified rice will physically benefit substantial numbers of children and whether an effective delivery system can be designed to provide fortified rice to communities where rice is the basic food staple.

Tests are being conducted in Thailand where the residents of some 25 villages are cooperating. Even if the villagers grow and eat their own rice, it is their custom to take it to the village mill for processing. The miller is supplied with a metering device that will add one percent of nutritive supplement to the weight of the rice he husks and polishes (he is paid a modest subsidy by the project for the service).

Five experimental groups of villages are being studied. Children in one group attend day care centers in villages where the rice is supplemented with vitamins and the amino acids lysine and threonine. A second group also attend day care centers in villages where rice is fortified only with vitamins and minerals. A third (control) group is tested at day care centers, but the village rice contains only placebos. Two other groups do not attend day care centers—one group's rice is fully fortified, the other's contains placebos. The day care centers were constructed with AID support as an incentive for villagers to participate and as a convenient location for measuring the children's growth and asking whether they were eating the rice, whether they had been ill, etc. (The day care centers AID built to reward village participation proved so popular that the Thai government decided to build hundreds more.)

Although all villagers get fortified rice, only the children are examined for nutritional effects. Every 15 days blood tests are taken from the participating children, weight is measured along with the circumference of head, arms and wrists; periodic X-rays of hands and wrists are taken.

The tests were preceded by a survey of the marketing and distribution of rice in Thailand to determine the best method for reaching a representative sample of the population. Information collected in this survey may be useful for feeding trials in future research.

It will take some 18 months to determine whether the children who received amino acid supplementation benefited more than those who got only vitamins, or substantially more than children who received no supplements. Even if the fortification produces healthier children, problems may be encountered in implementation, primarily because of increased cost. Some kind of government subsidy may be required.

Because of the added vitamin, riboflavin, included in the nutrition pellet in the Thailand trials, rice became yellow when cooked, instead of white. Researchers feared that might diminish acceptance, but the color change has been found to present little problem. Sometimes the pellet remains hard after cooking, however; when that happens, it has been found that Thai villagers simply pick the hard granules out of the rice and do not eat them. A softer granule has been substituted.

Since the project began, Thailand has taken steps to establish national policy on nutrition. When the project findings have been compiled, a conference of representatives from rice-eating countries will convene to discuss remaining problems.

Improvement of Other Cereal-Based Foods

Under an AID contract completed in 1971, Johns Hopkins University and the British-American Hospital in Lima, Peru sought to establish the amount of lysine that must be added to wheat flours to make them effective sources of protein for infants. Researchers also studied whether wheat proteins, with lysine added but without additional protein supplements, can be used to satisfy the protein requirements of infants, including some who have been rehabilitated from serious diseases caused by malnutrition (such as kwashiorkor).

Data obtained from these clinically controlled experiments showed that lysine-enriched white wheat flour, as a sole source of protein, will support normal growth in convalescing malnourished infants over an extended period of time.

The findings of the project are being used to guide wheat fortification programs, particularly in emergency feeding situations such as occurred in Africa and Asia. Action programs to improve wheat protein utilization by adding lysine to wheat flour are under way in India, the Philippines, and Tunisia. The Pillsbury Company is also test marketing lysine-fortified flour in the United States.

Another AID-supported project tackles a problem familiar to American parents who fed their children cod-liver oil in fruit juice: how to make nutrients palatable.

Kansas State University in 1967 began to explore ways to fortify wheat-based products such as bread, couscous (Morocco) and chapatis (India & Pakistan) while retaining their flavor and texture so they would be acceptable to consumers—and available at a price consumers could afford. The fortifi-cants to be added were such low cost supplements as soy, chickpea, or broadbean flours, which improve nutritional value.

Surveys and studies, combined with laboratory work resulted in a major breakthrough by the KSU research team. They found that addition of a dough conditioner, sodium stearoyl-2-lactylate, allows the incorporation of significant levels of protein concentrates without disturbing the taste, texture or appearance of the bread. This chemical is commercially available and has been approved by the U.S. Food and Drug Administration as a food additive. The mixture has been distributed by AID's Food for Peace Program and has proved so popular that in the first year consumption has grown to millions of pounds.

Using this conditioner, bread with 12 percent soy flour has been produced that is practically indistinguishable from non-supplemented white bread in color, loaf volume, texture and overall acceptability. In tests, this bread as compared to non-supplemented bread has produced a significant improvement in the growth of small animals. The technique also works for wheat-based foods other than bread.

India and the Philippines will be using about 40 million pounds of soy-fortified flour this year and some 20 additional countries have requested samples. Commercial bakeries and food companies from the U.S. and other countries have consulted with KSU to develop ways of marketing the new technology.

The researchers and their associates have published 33 papers in U.S. and international scientific, technical, and commercial journals and bulletins; some of these papers were presented during 13 national and international technical meetings. In addition to explaining the chemistry and techniques to overseas visitors to their laboratories, KSU researchers have given extensive training to food technologists from India, Colombia, and Guatemala.

The discovery shows decided promise for incorporation of a variety of nutritious substances—cottonseed or sunflower seed, for example—into many wheat-based foods, without destroying their appeal to the consumer.



Wheat-based foods like bread, couscous and chapatis (being made above) provide the basic nutrition for millions of people. Unless such foods are enriched, their nutritional value is relatively low. But researchers learned that adding fortified flours from soy or chickpea often changed the taste and texture of the wheat products. Many people would not eat them. Food technologists from Kansas State University have discovered a dough conditioner that, when added to the flour, permitted the addition of nutrients without disturbing the taste or texture.



Millers in Guatemalan villages have cooperated in an AID project to determine the feasibility of enriching the "masa" from which tortillas are made. Villagers bring lime-soaked maize to be milled, if they desire fortification, the miller adds the required proportion of vitamin and protein supplement. The resulting tortillas are twice as good in terms of utilizable protein as unfortified tortillas. The research project is carried out by the Institute for Nutrition for Central America and Panama (INCAP).

Corn Fortification

Related research on corn, another diet staple, is being carried on in a Guatemalan Indian village under an AID contract with the Institute of Nutrition for Central America and Panama (INCAP). It is designed to evaluate the nutritional effect on children and mothers of fortifying corn during the milling process with lysine, soy (which supplies the needed amino acid tryptophan), and vitamins. Researchers want to learn if such a fortification program at the village level is practical in terms of cost and management. They also hope to discover the effect of the fortification on the incidence of disease in children and on intestinal infections.

The work is being done in cooperation with village leaders at the test site. Crucial to the project's purposes is determining whether the proposed fortification program can be carried out at the village level without substantial outside aid or technical assistance.

The local miller is supplied with fortified soy mixture. When a woman brings her maize to be milled, the miller inquires if she wants the maize fortified. If the answer is yes, he weighs the maize and adds the required proportion of fortification mixture during the milling operation. Tortillas prepared from this fortified maize have a protein content of about 12 percent, compared to 8 percent in the ordinary tortilla. In terms of utilizable protein, the fortified tortilla is about twice as good.

After 13 weeks of trials, 40 percent of the mothers in the community were participating (the program was promoted particularly for its value to pregnant and nursing mothers and pre-school children). The response was considered remarkably high for a tradition-bound community. What biological effect the program will have on the target population of the village, and the cost of carrying out such programs on a large scale, are still to be determined.

Infant Foods

An AID-funded project was initiated in 1967 in Chile to develop a low-cost high-protein food suitable for infants and pre-school children. Under the leadership of Dr. C. O. Chichester, then at the University of California, a team of Chilean doctors, chemists, marketing specialists, and food technologists searched for two specific kinds of nutritious processed foods—one type for weaned infants, another for youngsters eating solid adult-type foods.

They developed a mixture of wheat with various oilseed meals and fish protein concentrate that can be heat processed to produce an acceptable food in one step. Some of the products are nutritionally suitable substitutes for milk in the diets of children, and they cost less than milk. Chile is one of a number of countries where cow's milk is in short supply and therefore expensive. The processed foods were clinically tested by the metabolic unit of the University of Chile to make sure that field tests of acceptability to children could be safely conducted.

Other advantages of the low-cost food are: it has a long shelf life, and it is easy to transport. The government made plans to produce several of the products tested and to incorporate one or more into the national school and pre-school feeding programs. Chile has a nationally announced goal in nutrition. These foods, designed by Chileans, are expected to contribute toward meeting that goal. The experience gained through this project, it is believed, should lead to broad application in other developing countries faced with shortage of cow's milk for children.

Using Coconut Protein

Coconuts are grown in many tropical countries. But they are harvested in a manner that destroys much of their nutritive value. The traditional way of preparing coconuts for food is to husk and split them in the fields and leave them out in the sun to dry into copra—coconut meat plus oil. Sometimes simple hot-air dryers are used to hasten the process. These primitive techniques result in vast waste of the coconut's valuable nutrients; proteins are spoiled beyond recovery. Most coconut growers in developing countries are primarily interested in coconut oil, anyway; the food potential is secondary to them.

Texas A&M, with AID support, has developed a process for recovering the protein of coconuts for human use in ways that would be practical in LDCs. Although the most desirable place to work on such a processing method would be in some developing country where coconuts grow, the university has outstanding facilities for developing oil-seed technology plus experienced investigators interested in the problem. After preliminary laboratory work, the research team may move to an LDC location for further testing.

The research team is enthusiastic about its progress. It has developed and tested on a laboratory scale a new process for handling coconuts that appears to offer major advantages over the traditional methods, not only for the preparation of human-grade protein in the form of a milk substitute, but also for the production of coconut oil. This breakthrough in processing may be particularly timely: The U.S. Food and Drug Administration has raised serious questions about the quality and safety of coconut products being imported into the U.S., which could adversely affect coconut growers overseas if they did not meet more stringent standards.

The Texas A&M team developed an aqueous process of extracting the oil from fresh coconuts. Previously, it had been believed that solvents were needed, that water alone could not extract the oil and protein substances in a way that would permit separation. A pilot plant has been designed for performing the process, which would have several advantages for LDCs. The plant could handle small quantities economically; there would be no danger of explosions (as when solvents are used). Because fresh coconuts are used, the oil is of a better grade than that derived from copra. The protein derived from the coconut has nutritional characteristics similar to those of non-fat dried milk. It can also be used directly as a beverage. The project's next step will be to sponsor a demonstration of the commercial viability of such a plant in a coconut-producing country.

Scientists from the Philippines and Thailand were recruited to join the Texas A&M research team. Nine scientific papers based on the research have been presented at meetings of professional groups such as The Third International Congress of Food Science and Technology, the Institute of Food Technology, the American Association of Cereal Chemists, the American Chemical Society, and the Chemical Society of the Philippines.

Effects of Proteins and Calories Upon Humans

Nutrition is a developing science. Many questions remain to be answered. Basic knowledge about the amount and quality of food that people need for health and growth has been gained largely through recording the effect on small animals—because their life and growth span is much shorter, results can be gained in a briefer time period. But specific research is needed to learn the effects of nutritive intake on people under the stress conditions that prevail in LDCs, where there often is not enough food, or where the food available is of low nutritional quality. Research seeks to learn whether the requirements proposed for specific population groups will be sufficient under existing life conditions. In addition, it is important to determine if specific nutritional fortification programs (such as amino acid supplementation) that scientists find successful in animal experiments are transferable to humans.

For example, it has long been observed in animals that there is competition among the metabolic mechanisms for scarce nutrients. The body will use proteins from tissue for energy when caloric reserves are depleted and energy requirements are greater than caloric intake. Calorie-restricted diets are prevalent in some developing countries. AID is supporting a research project conducted by the Massachusetts Institute of Technology to determine how critical protein-calorie relationships are in humans.

The project will simulate the type of diet common in LDCs in a controlled environment (at MIT) to answer two questions:

How well can protein be utilized by the human body when calorie intake is sub-optimal?

How well can a protein supplement to a wheat-based diet be utilized when presented with or between meals?

Tests were conducted with healthy, young, male adult volunteers. Results indicated that persons fed basically wheat diets, whether with restricted calorie intake or with adequate calories, did not utilize protein as well as persons fed more balanced diets. Lysine corrected the deficiency when given with adequate calories, and the amino acid produced a small increase in protein utilization by those people fed an inadequate calorie wheat diet.

Other results indicated that the time the protein supplement is taken, whether with meals or between meals, is not critical. Spacing of eating proteins and carbohydrates was found insignificant. But the information substantiates the thesis that the quality of protein is important in nutrition, with or without adequate caloric intake. The experiments, originally limited to wheat, will be continued with other cereals and legumes deficient in specific essential amino acids. Findings could well form the basis for widespread AID food fortification policies and the selection of food grains for human consumption.

Clinical Evaluation—New Protein Sources

Another AID-supported project takes up the problem of what dramatic steps can be taken to improve the conditions of those who are suffering the effects of a nutritionally poor diet. Obviously, these people will not through some stroke of magic have access to meat, milk, eggs, and fish. But some available sources of protein have not been used to improve their overall nutrition.

Feeding tests with animals point the way to potential human foods that may be beneficial. Human tests are still necessary.

The British-American Hospital in Lima, Peru, is testing the effects of some non-traditional sources of protein (which could be made available at low cost) for infants being rehabilitated from severe protein and calorie malnutrition. The protein sources fed these children as supplements to cereal grains include cotton seed, soybeans, and peanuts. Evaluation of their effects on humans is a *critical preliminary to any large scale program of distributing such food supplements.*

The children entering into the feeding experiments are in the course of recovery from diseases associated with malnourishment, and appropriate safeguards are maintained to assure the experiments will not be harmful to them. The protein quality of the experimental food mixtures is being compared with the quality of cow's milk. The products are fed as the only source of protein for periods ranging from 4 to 12 months.

Studies showed that certain soy products, cottonseed protein, fish protein concentrates—balanced mixtures of these materials with cereals—can be comparable in effectiveness to cow's milk under such circumstances. The project has also demonstrated procedures and limits for determining and evaluating the protein quality of unconventional foods. Results of the studies have already been used by AID in the Food For Peace Program and by UNICEF in planning emergency feeding programs. Experimental results have also been made available to the private food and drug industry and have stimulated development of new, inexpensive high-protein foods.

Maternal Nutrition and Pregnancy

Another group of people who have special nutritional needs are pregnant and nursing mothers. For many years it was taken for granted that the mother's diet would not affect the growth, behavior, and overall health of the infant she was carrying. However, in recent years, studies have suggested that there may be a relationship between the mother's diet and the infant's health. Laboratory animal studies have shown that the diet of the pregnant animal influences the size of the offspring at birth, as well as its health and vigor during early life.

AID signed a contract in 1971 with Johns Hopkins University to determine if diets supplemented with nutrients provided to human mothers during pregnancy and lactation would have a measurable effect on their children. Tests were planned for measuring birth weights, growth rate, neuromotor development and susceptibility to infectious diseases. The project continues work begun in Taiwan under an earlier program in 1967 that was jointly funded by the U.S. Navy, Johns Hopkins, and the Rockefeller Foundation. Research is being conducted under cooperative arrangements with Taiwan government officials and scientists.

By its design, this project will not reveal results for another year—the children have to be examined over a period of time and compared with children of mothers who did not have special diets during the critical periods of pregnancy and nursing. These findings could have profound results on feeding programs by demonstrating to government officials the importance of prenatal feeding programs.

Malnutrition and Work Capacity

So far the projects discussed have been directed toward improving the nutrition, and thus the general wellbeing, of individuals. But few planners are swayed to institute potentially expensive programs purely on humanitarian grounds. If a link can be proved between the state of an individual's nutrition and the amount of productive work he is able to do, then by extension a relationship is established between the nutritional status of workers in general and the productivity of a nation. Such a demonstration could elevate the position given nutrition in the economic priorities established by the governments of developing countries.

Under an AID contract, the Medical College of Wisconsin is conducting tests to confirm the relationship between proper nourishment and work capacity. Research on the physical work capacity of malnourished human adults is not new, but previous projects were limited to subjects with experimentally induced malnutrition. The wide differences between the effects of induced malnutrition and chronic malnutrition indicate that they must be considered and treated separately; experience gained through experiments with induced malnourishment may have no applicability to dealing with those who have been malnourished for most of their lives.

Cooperating with the Universidad del Valle in Cali, Colombia, the research team has conducted physiological experiments with workers in a nearby sugar cane plantation and mill. Workers have been classified according to their states of relative nutritional health. Researchers examine and measure the subjects' work capacity in relation to their nutritional status, as well as comparing their output with their work capacity. Such variables as the effect of protein depletion over an extended period of time on the amount of work an individual does are measured.

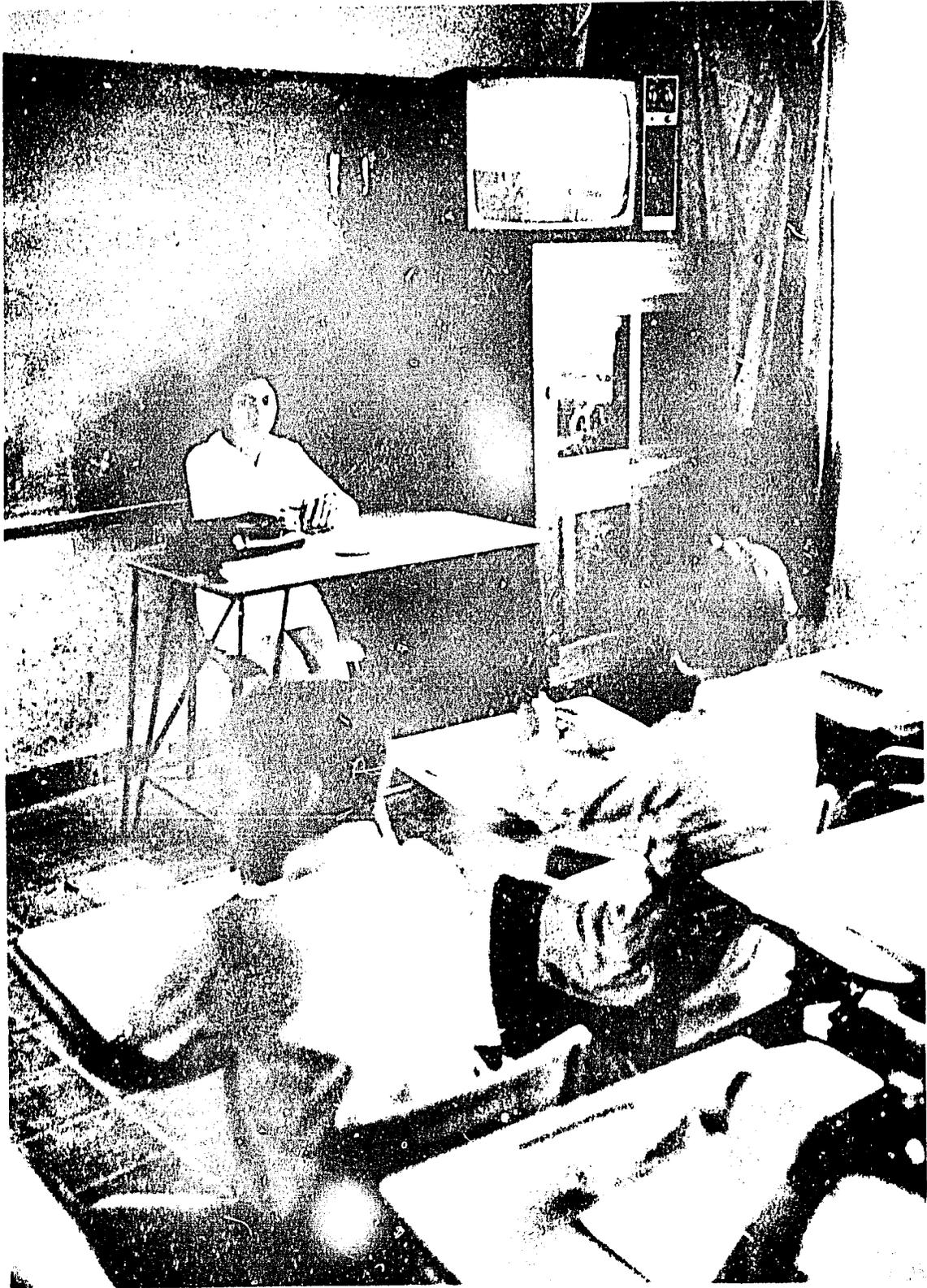


This sugar cane cutter is also working for science. The contraption he wears measures his protein depletion and reveals other biological changes. The study conducted by the Medical College of Wisconsin is designed to determine the relationship between proper nourishment and work capacity and to measure how debilitating chronic malnutrition is to laborers.

Research conducted under this project tends to confirm what has been suspected for some time, but the findings undergird theories of the economic importance of nutrition on productivity. Work capacity is substantially reduced in undernourished individuals. The worse his nutritional condition is, the more his work capacity is diminished.

As nutrition improves, the capacity of an individual to do physical work grows—even if he has been living under sedentary hospital conditions during the period when protein was being replenished in his system. It was also found that poor nutrition affects a person's maximum work capacity, but that he may perform much less demanding physical work as well as a better-nourished person. The study emphasizes the need for good nutrition if a person is to realize his full labor potential.

EDUCATION



EDUCATION

Developing countries place education high among their national priorities. The commitment of LDC governments is reflected in the relatively high portion of gross national product devoted to educational programs, an allocation that has expanded significantly in recent years.

Education does not lend itself to dramatic research breakthroughs of the kind sometimes achieved in the so-called "hard sciences," but research can produce findings about education of great social importance. Education is affected by a variety of cultural and political forces beyond the control of educators. Through experimentation, case studies and analytical evaluation of the results, researchers learn which educational approaches work best in different contexts.

AID views education as a vital instrument in improving the quality of life for people in developing countries. The Agency's approach in its program of research has been to focus on major educational development needs. Seeking results that can be applied quickly to real problems, AID supports research conducted in developing countries and encourages collaboration between U.S. and LDC scholars.

To give cohesiveness to its research and other innovative programs—instead of diffusing resources on disassociated projects—AID has determined to concentrate on a few carefully selected problem areas. These are non-formal education, educational technology, and education economics and analysis. In each area, AID has commissioned research "mapping" surveys of what is known, what is useful, and what should (and potentially can) be learned.

While these blueprints for research were being drawn, AID made grants to U.S. universities to develop resources for carrying out projects directed to key problems: to Florida State and Stanford Universities in educational technology, and to the University of California at Berkeley to study the financing, costs and efficiency of education and training programs.

Although leaders in developing countries have succeeded in building better traditional educational systems for far larger numbers of their people than ever had access to

education before, they realize that important requirements are unmet. For example, they see the need to expand educational opportunities. In most developing countries, there are many people who have never been to school and significant percentages of their youth cannot be accommodated in existing formal educational facilities. One way to meet this need is through non-formal means of education.

Experience in both developed and developing countries has shown that non-formal education can be much more than an inferior substitute for academic instruction. It can reach large numbers of people where they live and work, introducing them to knowledge and skills without removing them from their normal environment. Non-formal education should be established in a systematic way and coordinated with a country's formal education so that a national learning system results. Of course, the problem of delivering non-formal education is more complex—and the solution will be closely tied to developments in the area of educational technology. Non-formal education research is expected to take the form of evaluation of experiments, studies of full-scale trials conducted by LDC institutions and supported by U.S. universities under contract to AID for development of this area.

Another need—a continuing one—is to find ways to improve the effectiveness of learning, whether in formal school systems or through non-formal education arrangements. Research in educational technology is directed to this need.

Educational technology is defined as a systematic way of designing, carrying out, and evaluating the total process of learning and communication. It encompasses human teachers and teaching tools—television, films, radio, computers, and more traditional means such as textbooks and visual aids.

As educational technology is brought to bear on existing learning systems, it can be used to stimulate reform and renovation, as it has for example in El Salvador and South Korea. A growing number of countries are making firm, long-term commitments to educational technology as a major instrument of development. The experience of these countries will be helpful in establishing a knowledge base upon which other LDCs can build.

Another area where research can contribute to more efficient educational systems is through improved analysis of the sector, leading to clear diagnosis of deficiencies and better planning. Such research includes investigation of new funding sources and less costly ways of providing education.

Although LDCs have been increasing their investment in education, the disparity between educational needs and resources continues to widen. The basic problem is by no means one of resources alone. Too often funds are wasted on archaic systems with subject matter and methods of instruction which contribute little to social and economic development.

The role of efficiency is often overlooked in considering educational finance—the less efficient a system is, the more funds must be raised for any given level of operation. As a first step toward developing a program (which includes research) for guiding LDCs in financing education in an efficient manner, AID commissioned a report from Harvard University to provide decisionmakers with a clear idea of the known methods for financing education, and for reducing costs, together with an evaluation of their advantages and disadvantages.

When the surveys of the state of current knowledge in these key problem areas have been completed and analyzed, AID will concentrate research projects on the areas where further development of new data are needed. Two recent projects described below are not necessarily representative of the future directions of AID research in education, although they contain elements of the principles behind continuing efforts in this sector. The overriding criterion for judging future research possibilities is: the probability that the research will facilitate changes in education that make it significantly better, cheaper, or available to a wider number of people in LDCs within a reasonable period of time.

Effectiveness and Cost Efficiency Of Instructional Technologies

Many developing countries have concentrated on establishing a system of instructional television in schools and have ignored the potential of less complex and expensive technologies, such as radio accompanied by printed and illustrative material. Relatively few countries have explored ways to use television to extend education beyond classrooms.

Under an AID contract, Stanford University's Institute of Communications Research examined the experience of developing countries with broadcast and supplementary material for instructional purposes. Investigators considered how such media mixes can be managed more efficiently and applied more selectively to produce concrete educational improvements for both in-school and out-of-school populations at acceptable costs.

The researchers conducted case studies of three uses of media for education, which they characterized as "platforms of knowledge" for future policy and research:

— The intensive use of classroom television as an agent of comprehensive educational reform, illustrated by major projects in American Samoa, El Salvador, and Niger.

— The use of radio and television combined with correspondence study to extend education beyond the school, the so called "open school" pattern represented by many differing projects around the world.

— Applications of radio (sometimes augmented by visual aids) for different kinds of instruction, other than the "open school," in developing regions of the world.

Particular study was given Mexico's system of secondary education through television to supervised groups in villages that have no secondary schools. Researchers gathered comparative data from the televised education system and the traditional Mexican secondary system on student ability and achievement, student and teacher attitudes, teacher observations, costs, and dropout and retention rates.

A pilot project to use radio in primary schools in Mexico was also studied. This instructional system is designed to transform rural 3-year schools into complete 6-year primaries. Teachers assume responsibility for more than one grade, and the radio lessons are keyed closely to centrally prepared student workbooks.

The Stanford project is expected to advance the state of knowledge about the comparative costs and effectiveness—and the overall educational effects—of systems using different instructional technologies that vary in cost and administrative complexity. Findings should provide guidance to LDC educational policy makers on optimal mixes of media and human instruction within their budgets.

Beginning Science Curricula For English-Speaking Africa

Educational Development Center, Inc., a leader in creating new science curricula (along with improved teaching methods and materials) in the United States, was commissioned by AID to assist 10 English-speaking African countries in developing and testing a new approach for primary school science instruction.

The new curriculum emphasizes scientific inquiry and thinking, as opposed to rote learning of scientific facts. The content focuses on subject matter related to such major problems of developing countries as sanitation, nutrition and health. It also is designed to provide a solid base for further scientific and technological education for students who go forward to secondary and higher levels.

While the project had prominent research aspects, it also had strong operational emphasis from its inception, in 1965. As materials and teaching techniques were developed, participating African countries were encouraged to incorporate them in their primary school systems.

In general, African primary students had no science in their curriculum. As part of the project, scientific development centers were established near the schools, including displays of live and mounted animals, and other natural objects. Primitive scientific instruments were produced at low cost, such as a crude microscope made of a stick and a piece of glass, which sold for 14 cents.

Conferences and workshops were conducted for African teachers and educators and a number of U.S. representatives. Curricula were adopted by seven countries; materials were tailored to the particular environment, topography and animal and plant life of each country. In some countries the environment was similar enough to permit adoption of almost identical curricula. Additionally, teacher guidebooks were developed in teacher training colleges, in-service workshops and by individual classroom instructors.

Since 1970, when the essential research was completed, the project has been continued through technical assistance funds. Reports and materials from the project have been widely disseminated in the U.S. as well. They have helped educators in many disciplines who are interested in introducing the problem-solving method of science instruction.

SCIENCE AND TECHNOLOGY

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SCIENCE AND TECHNOLOGY

Many developing countries are recognizing the important role of science and technology in achieving their national goals. As a group, LDCs have increased their financial support for research and development efforts to the point that it now exceeds 0.2 percent of their gross national product. Almost every Latin American country and more than half the developing countries of Africa and Asia have national science planning bodies or scientific research coordinating committees. Many of them are directly linked to economic planning agencies. But they lack experience in how to develop policies that will expand their science and technology capabilities efficiently—and at the same time make good use of their existing capabilities. Even when science and technology resources are relatively plentiful, there are invariably major problems in bringing them to bear on priority development concerns.

The eminence of the United States in advancing the frontiers of science and technology is widely acknowledged. AID research has contributed to strengthening the scientific and technological components of programs in health, agriculture, nutrition, population and education. Some of the needs of developing countries lie beyond the scope of these programs, or involve several disciplines; and AID is prepared to consider these problems, too.

AID has also collaborated with international agencies, such as the UN Development Program, helping to fill gaps in scientific or technological research.

In changing their traditional methods, the developing countries often turn to "off-the-shelf" technologies, even those which are unsuited to their economic and social conditions. Thus, important development opportunities are sometimes foregone because countries are unable to devise their own technology or to adapt one from foreign sources that best suits their situations. Some of these technologies from advanced countries come with built-in mechanisms or time elements that hinder modification or adaptation. Some situations require innovation, not simply adaptation.

Among the consequences of choosing inappropriate technologies have been wasting scarce capital, particularly foreign exchange, increased unemployment, a lack of incentive to develop their own industrial skills at the rate required, and over-accelerated urbanization.

AID can make a substantial contribution to developing countries in overcoming these problems by strengthening institutions and training local personnel so they will be aware of the alternatives which exist to meet their specific needs. Although selection of technologies is largely a matter for private entrepreneurs, LDC technological institutions can exert a benign influence through their effect on government economic policies, by making possible through technical and managerial solutions the opening of new exports and local industry. Generally, AID sponsors collaboration between U.S. and LDC technological institutions that work with local private industry, as well as government industry.

Such institutions would include governmental bodies for formulating national science and technology policies, determining priorities and implementing decisions in this field; universities, which can orient science and engineering courses to particular national development needs; and industrial service institutions, which can choose the technologies most suitable to the country's economic and cultural circumstances. Particular attention is paid to stimulating commercially viable small-scale industry, which tends to use more labor and less capital per unit of output.

AID has sponsored a number of workshops and seminars where LDC engineers, scientists and government administrators are informed of recent developments of potential interest to them and discuss the organization and costs required to apply them. Through a contract with AID, the National Academy of Sciences gives program direction, suggests research possibilities and guides new initiatives of particular benefit to developing countries through the initial stages of these meetings and cooperative studies. The Academy also conducts bilateral workshops on science and technology priorities, and on the coupling of science with development and manpower.

Three other areas where U.S. science and technology expertise can undergird LDC efforts are natural resource development, reduction of public investment costs and improvement of housing construction.

Many developing countries have neglected or wasted assets by failing to assess and manage the vast wealth of indigenous natural resources. More than 70 percent of the world's timber is in the tropics, for example; recent oil discoveries in Nigeria, Indonesia, and the Middle East illustrate the unrealized energy potential of the developing countries. There is no geological reason why a disproportionate share of the world's major metallic ore bodies should continue to be found only in the more developed countries of the world. LDCs can capitalize more effectively on their natural resources base only if rapid and inexpensive techniques for identifying and appraising natural resources can be made available. Also needed are improved techniques for managing natural resource developments, including integrated land use planning, conservation of renewable resources, and pollution abatement and control.

Because developing countries, like the rest of the world, are experiencing a trend toward greater urbanization, they are obliged to invest heavily in public works, housing, transportation, communications and energy development. Even a modest technological contribution to reducing short- and long-term costs can have a significant impact on the national budget for these activities. One area where guidance can enable developing countries to realize savings is in the reduction of foreign exchange costs by greater use of indigenous materials. Increasing job opportunities may be opened up in the manufacturing of the materials required and in construction activities.

National savings brought about by a selective reduction of the costs of economic infrastructure could release public revenues to be applied for other development needs. AID concentrates on those activities that relate directly to the quality of life for the mass of the population, such as water and sewage for low-income areas, low-income housing and rural development.

Research can play a key role in utilizing science and technology to advance economic and social development. Because technologies that suit developed countries are often not easily transferred to LDCs, specialized research is often necessary in the context of prevailing situations; for example, labor costs may be low but there may be a shortage of skilled manpower.

Two of the first AID science and technology research projects are described below. They are not totally representative of what is expected to be the major focus of the research program in this area when it reaches maturity. Examples of other areas of investigation that are contemplated include: practical methods for detecting mineral deposits in tropical areas, and research on the development of binders for indigenous materials to provide low-cost roofing in tropical areas. Both projects have potentially far-reaching impact.

Design, Siting and Construction

Typhoons, hurricanes and earthquakes take a devastating toll in developing countries; losses of thousands of lives and tens of million of dollars occur each year. Much of this loss is from structural failure of housing and other buildings, or from poor siting. AID contracted with the U.S. National Bureau of Standards to make preliminary studies and formulate recommendations to alleviate this severe problem through improved design, construction, and siting.

In carrying out the study, NBS researchers took into account economic and social conditions prevailing in developing countries, the availability of technology to effect recommended changes, and the overall practicality of suggestions. They sought to identify the cultural and socio-economic constraints and to examine the structural alternatives to existing dwellings with a view towards greater resistance to severe windstorms and earthquakes.

The report compiled by the NBS researchers discusses the structural performance of buildings typical of developing countries under earthquake and windstorm conditions. Suggestions for improvements to mitigate effects of these phenomena on buildings are presented on a systematic basis, classified according to whether the cause of the destruction is related to the structural configuration or aerodynamic features of the building or to its foundations, walls, frames, upper floors, or roofs.

It was found that considerable improvement of the earthquake or windstorm resistance of structures widely used in LDCs may be achieved by relatively simple measures. These include, for example, horizontal bracing of certain types of roofs over adobe masonry houses, rational distribution of openings in shear walls, provision of adequate walls or frames to withstand concentrated seismic load action, reinforcement of critical areas susceptible to being overstressed, and strengthening of connections at critical joints. For typhoon-resistant construction in such countries as the Philippines, special studies on the distribution of extreme wind speeds and in the aerodynamics of full scale buildings and of reduced-scale models are required.

The NBS study also presents recommendations on the siting of buildings to reduce the destructive effects of earthquakes and windstorms. Traditional and industrialized methods of housing construction are described, and the current state of construction technology in LDCs is examined. Suggestions for upgrading these methods specifically for protection against high wind and earthquake forces are included.

The study suggests that much of the devastation from natural disasters could be avoided if countries would establish and enforce appropriate building codes and regulations to prevent unsafe design and construction. For example, most of the developing countries affected by earthquakes do not have building codes that include provisions for earthquake resistant design or construction. However, building codes should not restrict technological innovation.



Devastation like this can be prevented or minimized. Under an AID contract, the U.S. National Bureau of Standards has studied housing construction and siting in developing countries afflicted by typhoons, hurricanes and earthquakes. The Bureau found that the collapse of this house in Peru during the 1970 earth-

quake was due to the absence of sound horizontal tie-beams, a weakness that can be corrected with inexpensive materials. The Bureau has made general recommendations on siting of buildings, construction designs using local materials and inspection methods to detect the danger of severe damage.

New developments in building materials offer the people of LDCs the opportunity to construct safer houses at a price they can afford. For example, new processes to stabilize adobe, which can be produced in vast quantities at low prices, make it superior to many other materials in structural, architectural, thermal, and acoustical properties. It can even be made to look better than ordinary adobe, which was rejected by many householders in Peru and Turkey as "less noble" than bricks. Deterioration of bamboo used as reinforcing rods in adobe walls can be prevented by specific chemical preservatives, which can be manufactured in developing countries. Much progress has been made in the United States and Europe in designing sturdy prefabricated houses; these techniques could be adapted to LDCs.

The research report points out that new construction methods using common materials such as jute fiber, reinforced concrete with vegetative or plastic components, and lightweight structural sandwich systems now

being used in the United States, could also be produced for low-cost housing in developing countries. Improved production methods and equipment could result in lower costs and better quality of these materials. National research institutions can play a significant role in developing technical improvements that will mitigate earthquake and windstorm effects.

The NBS study recommends institutional action that governments can take at various levels, and discusses the role of the private sector and international groups. Priorities to be emphasized by governments would depend upon the specific needs of the developing country.

One of the major recommendations of the study is being implemented in a new 3-year research project by the National Bureau of Standards entitled, "Design Criteria and Methodology for Construction of Lower Cost Housing to Resist Typhoons and Hurricanes"

Mosquito Genetic Control

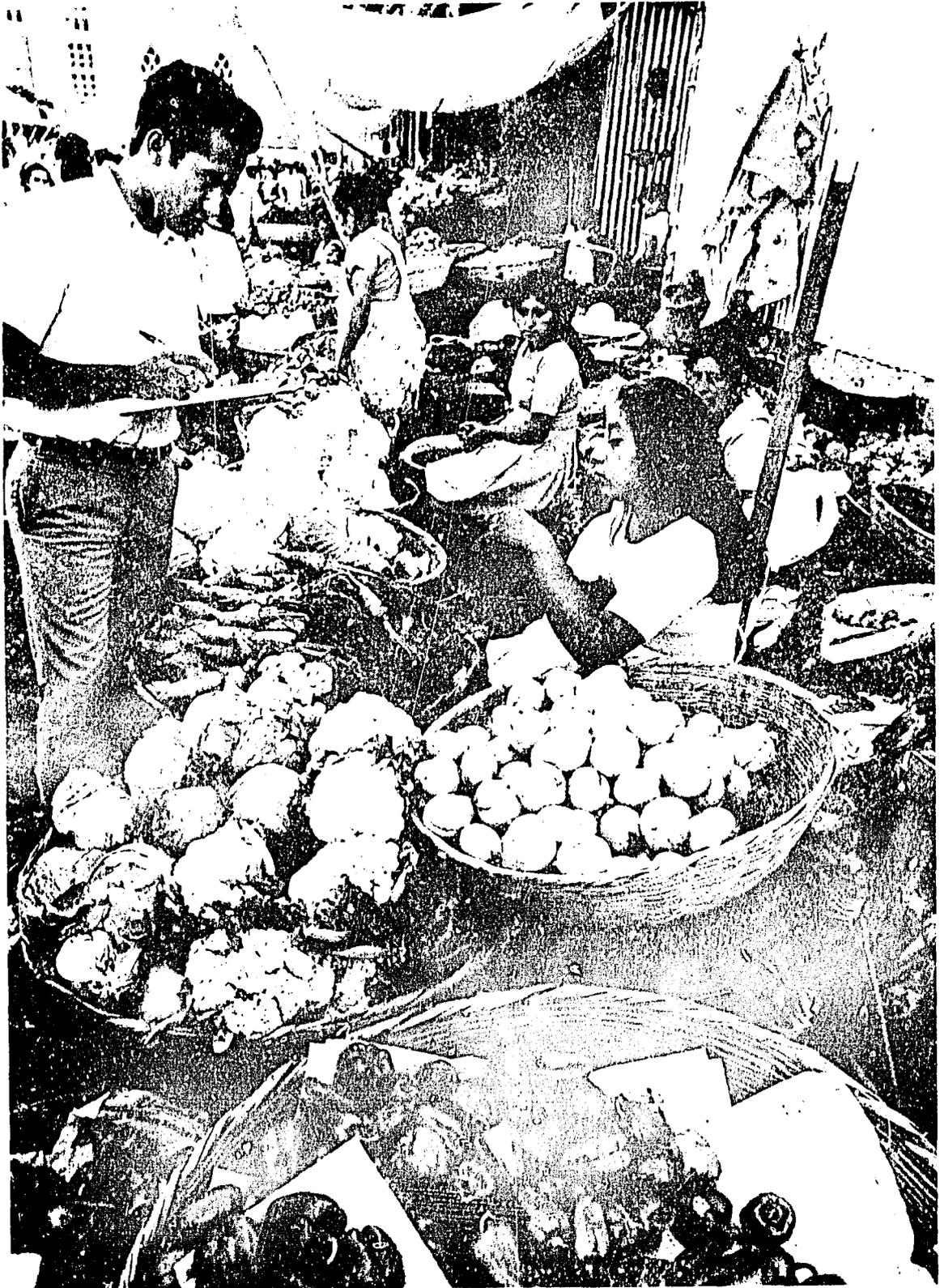
Mosquitoes are carriers (vectors) of a wide variety of debilitating and fatal diseases in many developing countries of the world. Among these diseases are malaria, yellow fever, dengue (breakbone fever), filariasis and hemorrhagic fever.

Health authorities have traditionally concentrated on impeding the transmission of mosquito-borne diseases through use of chemical insecticides. However, these are proving to be an inadequate tool—both technically and ecologically—for effectively controlling these disease vectors. Not only is it plainly impractical to spray every vector breeding ground and habitat with chemicals, but some insects are developing resistance to many of the most common insecticides. In addition, the environmental hazards associated with the use of chemical agents such as DDT have been well publicized over the last few years. As a result there is worldwide interest in non-chemical methods of insect control, including the possibility of breeding insects with genetic weakness which would interfere with the reproductive cycles of their offspring.

Under an AID contract, scientists from the University of Notre Dame's Vector Biology Laboratory, in cooperation with colleagues at several East African institutions, have begun a program of research, field testing and evaluation in Kenya to determine whether genetic control of mosquitoes is technically and economically feasible. Work is being done on the *Aedes aegypti* mosquito, whose genetic, physiological and bionomic characteristics are already well known to the Notre Dame scientists. In 1967, they discovered that this species is monogamous (which gives greater control in breeding experiments). Since this particular research project began in 1971, the investigators have demonstrated that *Aedes* which reside in native villages do not appear to mix with jungle-breeding *Aedes*, a critical finding in terms of the design of any control program. Although it had long been known that *Aedes aegypti* is a vector of yellow fever, dengue, and hemorrhagic fever, the Notre Dame team has recently discovered that it is also a carrier of filariasis (which causes elephantiasis, a major disease in East Africa).

The project was conceived and designed as a model for biological control of mosquitoes. Specifically, the scientists are attempting to cripple the mosquitoes genetically by introducing partial sterility through chromosome translocations—a method developed at Notre Dame by which a latent, lethal and self-perpetuating "Achilles' heel" is bred through successive generations of this mosquito.

At the field testing site in Kenya, the native *Aedes* are studied along with laboratory-raised mosquitos to determine the ecology of the natural populations, with emphasis on population dynamics and reproductive biology. Particular attention is given to the solution of certain technical problems which have constrained past biological control techniques—mass production and release of altered mosquitoes that remain competitive within the natural populations. At the same time, genetics of East African populations are studied in the laboratory to discover which among several currently available transformation mechanisms afford the most effective, least expensive means of control.



DEVELOPMENT ECONOMICS

Economists concentrate on the most effective means of allocating resources to produce goods and services that contribute to human welfare. They are concerned with learning how to increase the growth and expansion of resources, how to harness improved machines, technologies and trained manpower to achieve economic goals. Rapid economic and social changes have been taking place in recent years—changes that affect the structure of each country and the people who live there.

Research is needed that can describe an economy, how it works, and that will serve as the basis for predictions. Food supply, population growth rate, health and educational levels, and international trade performance are frequently factors in the equation in addition to unemployment rates, labor supply, land use statistics, productivity rates and capital resources.

Economic research provides tools for social policy. It can reveal, for example, how and why goods and services are distributed among classes of people and among the sectors of an economy. On the basis of this knowledge, economists can predict that certain industrial policies may lead to smaller increases in employment than could be attained with alternative policies—even though those who do work will enjoy higher incomes.

Developing countries confront complex problems when they seek to convert national income growth into improved welfare for the mass of their citizens. Population growth in many countries continues at rates only slightly less than the rise in national income, so that even though the income pool is widening, the number of claimants on the pool is growing almost as rapidly. Many developing countries have been disturbed by persistent and sometimes increasing inequalities in income distribution and the widespread unemployment that has often accompanied national income growth.

AID supports collaborative research between American and LDC economists that analyzes existing economic structures in developing countries, revealing to policymakers and planners of those countries alternative courses of action—with an indication of the probable consequences of following each path.

Resources Allocation and Development Policy Studies

Since 1962, members of the Center for International Affairs at Harvard have acted as advisors to 10 of the 50 new nations that have emerged since the late 1940's. The Center has provided expert advisors to LDCs requesting assistance; the advisory groups were funded by non-AID sources.

AID began a research project with the Center in 1967 that has forged linkages between the Agency's foreign assistance efforts, the LDCs' requests for advice on policy and planning problems, and the accumulated research and advisory capabilities of the Center.

Through the Center's efforts AID and the developing countries have been provided a common background of research against which policy dialogue can take place.

Research by Center personnel in Colombia was incorporated into decisions by the nation's leaders on tax reform and foreign trade policies, as well as on an altered allocation of educational expenditures. A comprehensive and innovative approach to transportation costs and benefits was developed by the Center and used in several Colombian transportation investment decisions—a project that AID was being asked to finance.

Studies the Center conducted for Ghana analyzed the effects of economic policies under the Nkrumah government prior to 1966 compared with those of successor governments which moved the economy toward greater reliance on the market mechanism. Economists concluded that Ghana had done better under policies that reflected levels of supply and demand than under the Nkrumah policies of direct controls and allocations. The controls contained several imperfections that had serious economic effects. Through the Center's efforts, AID and the Although the report was prepared for the government of Ghana, it contains implications that import controls may be an inefficient, high-cost instrument of economic policy for other African countries, too.

Planning models constructed by the Center have been used for economic planning on a nationwide basis in Pakistan and Korea. One of the computerized models is being used by Korea to assess its investment plans for steel and petrochemicals.

The Center has produced comparative studies of the economic systems of Taiwan, Greece, Korea, Turkey, Jamaica, Honduras, Guyana, Japan and Thailand to analyze the effects of new financial institutions and policies upon their economies.

Under the AID contract, the Center has achieved an integration of field experience and analytical work that contributes to an approach to development policy heavily grounded in practical experience. During 1972, the research produced 15 economic development reports, 10 journal articles and three books. The approach to development policy, and specific research findings, have been the basis for discussions with AID and other donor agency officials, special seminars for U.S. officials at Harvard, and have contributed to enhanced graduate training of U.S. and LDC students.

A developing country's economic and social plans, combined with the policy decisions to carry them out, have far-reaching effects on the rates of growth and the welfare of the people of the country. The work of the Center has focused on collaborative work with experts in the developing countries to provide factual information and an institutional base from which AID and the LDCs can develop economic and social plans and policies that promote the goals of growth and human welfare. The impact of the research will depend largely upon the extent to which the governments of developing countries choose to employ the new economic perspective provided by the Center's experts.

Unemployment Problems Of Developing Countries

The creation of productive jobs for people in LDCs is an essential part of economic development. The number of jobless in LDCs is usually high, and many people work in jobs that add little to the nation's total output. In the name of economic development, LDCs often pursue policies that encourage jobs for machines, not for men and women. Foreign assistance to these LDCs may inadvertently encourage a program of development that gives too little attention to job creation as a part of the process of increasing national productivity.

Production technologies of the developed world have evolved in response to conditions of labor shortage and abundance of capital. These are not the conditions that prevail in developing countries. Consequently, different technologies and alternative processes of creating jobs are needed to increase workers' productivity and stimulate national output in LDCs. Development is frequently hampered by an inadequate understanding of the problems, which makes it more difficult for leaders to determine what policies they should pursue.

Under an AID-financed research contract, members of the Economic Growth Center at Yale University are working with scholars and government officials in Colombia, Korea, Taiwan, Pakistan, Brazil, India, Chile, Kenya, Ghana and Zaire to seek a better understanding of the policies and programs that will best increase production and employment simultaneously. The Yale work provides AID and the LDCs with a better picture of the problem and the options open to the LDCs, taking unique situations into account. Fifteen studies are being written on various aspects of the problem; ten studies in individual countries, and five sectoral or cross-country studies related to employment in agriculture, education, industry-services labor absorption, choice of technology and transfer of technology. A final study analyzes and synthesizes the methodologies and results of the component studies to indicate policy alternatives for AID and LDCs in dealing with unemployment problems.

The kind of findings the Yale work develops—and their usefulness—is illustrated by a single-country study. In Colombia, the economists found that small farms tend to use capital, land and labor more efficiently than large farms, the reverse of some orthodox economic understanding. These findings suggest that the government of Colombia can best increase its agricultural output, and also widely distribute these gains among its people, by appropriate measures to encourage small farmer activity. The latest Agrarian Reform Decree in Colombia reflects the substance of this research.

The Colombia and Zaire studies also suggest that officially measured unemployment figures may be misleading in some urban areas, reflecting a large number of relatively skilled and affluent people who are unwilling to accept jobs in lower paid or lower status categories. To the extent that this kind of situation prevails, the unemployment problem especially in urban areas takes on a different dimension than ordinarily assumed and should not be equated with the poverty problem. The solution may lie in tailoring policies for the "underemployed," instead of exclusively for those with no jobs at all.

Several studies indicate that new nations may benefit from policies and periods of trade restriction that only gradually change toward freer trade and more liberal policies. During the early phase of development, when an LDC encourages agriculture for export and uses trade restrictions to encourage home production of consumer imports, the system sacrifices employment opportunities in favor of the rapid development of domestic industrial capacity. In later stages of development, when a wider range of exports is encouraged by moving to more realistic exchange rates and other measures, this conflict need not exist. The studies suggest that new entrepreneurs develop management skills during periods of subsidization and trade protection. Export-oriented policies then force them to become more innovative in combining labor and machines in production processes to take advantage of the relative scarcity or abundance of those factors to increase output with favorable effects on employment.

Another part of the overall study indicates that the "green revolution" in India—the introduction of new agricultural technology—has apparently increased the demand for labor rather than displaced it. The full impact of new farming technology on the relationship between employment and productivity is not clear. But economists believe that greater understanding of these relationships is essential if the benefits of agricultural change are to be shared equitably. Findings of the Yale research have been widely disseminated among AID and other development agencies, LDCs, and the academic community. AID is formulating guidance to direct more attention to the employment opportunities that alternative kinds of foreign assistance may encourage.

Foreign Exchange Controls

Government control over the use of foreign exchange by its citizens is a policy tool commonly used by LDCs. What happens to a nation's economy, particularly the rate of savings, investment allocations, research and development financing, and commerce, when foreign exchange controls are adopted or removed is not fully understood by economists. The National Bureau of Economic Research, New York, under an AID-financed research contract, has engaged scholars to prepare analytical case studies in 10 LDCs (Brazil, Chile, Colombia, Egypt, Ghana, India, Israel, Philippines, Turkey, Korea) of the impact of exchange control liberalization on the process of economic development. Four of these studies are being conducted or co-authored by scholars from the countries they examine. Some degree of collaboration with LDC scholars was involved in all studies. These book length studies have been substantially completed, and several should be available during 1973.

The research has three objectives: to develop a common analytical framework for studying exchange control liberalization; within that framework to examine the impact of exchange liberalization in individual countries, and to identify economic principles that appear to apply generally to most of the countries studied. A summary paper will contain the research findings.

Each of the countries studied has undergone significant shifts in its exchange control program in the past. Some have increased restrictions, and some have reduced them. Because the common methodology was developed and applied to each country study, policy recommendations on the management of foreign exchange can be formulated which will not only be of direct use to policymakers in the countries studied, but will have broad applications in developing countries in general.

The research gives insight into the adequacy of analytical tools in estimating the impact of economic growth on different foreign trade policies. Also, the research is clarifying the different results LDCs attain when they move toward more liberal trade policies and the reasons for these differences. However, there is clear evidence that factors outside the control of the countries which have tried to liberalize their foreign trade have had significant effects on the success of these efforts.

Income Distribution

During the past decade many developing countries have made substantial gains in production and economic growth. However, evidence mounts that large groups of people have not shared proportionately in the benefits of this economic growth. In fact, some economists argue that increased equality in the distribution of income is incompatible with rapid economic growth objectives.

But a process by which the rich get richer and the poor get poorer is not the goal of developing countries—or of AID. The governments of most developing countries do not seek this result because, among other things, it tends to weaken political stability and interfere with long-range national growth.

AID is supporting research by senior economists and political scientists from Rice University in collaboration with colleagues in Colombia, Malaysia and Turkey to explore the ways that the distribution of gains from development are related to the development process. A study of the problem of inequitable distribution of the fruits of economic growth involves the interaction of several disciplines: political science, sociology and economics.

Research reports will be published in local languages and will address three salient features of the growth and distribution problem: the impact that a particular distribution of development benefits has on future growth; the efficiency of government policies in influencing income distribution, and the effect of socio-political and regional groups on development policy (including the composition and outlook of such special interest groups and how they influence the distribution of benefits).

Import Substitution

Many of the nations that have emerged since World War II have encouraged the growth of domestic industries to produce consumer goods that formerly were imported. Like the United States in its early years, these countries have employed tariffs, quotas and foreign exchange restrictions to protect and foster their "infant industries." Within limits this widely accepted policy of import substitution can be an effective device to expand the industry and economic growth of developing countries. But a point arrives where such policies and practices become counterproductive.

An extended study of the impact of import substitution policies on many LDCs was conducted by Williams College, under an AID contract, from 1964 through 1972. The study demonstrated that over the long run excessive reliance on such policies created significant price distortions in the LDC economies, reduced the rate of savings in many countries, blunted the growth of export industries, and encouraged the substitution of machines for labor in countries with huge unemployment and underemployment problems. This research signals an urgent need for policy changes, to encourage export diversification in many LDCs if they are to develop a balanced economy that produces goods for export as well as producing some goods formerly imported.

The Williams research focuses on matters of great importance to AID—and to the developing countries. U.S. assistance is geared to encouraging LDCs to help themselves: to export in order to buy needed imports; to develop and mobilize savings for investment in new plant and the social services required for growth and welfare. This research has helped clarify points of agreement and conflict between LDC policies and goals.

Williams prepared 47 research papers, ranging from short memoranda to book-length studies, which have been made available to assistance agencies and the governments of developing countries as objective and unbiased information for their independent policy decisions. The findings have been released at a time when an increasing number of LDCs have formed economic planning commissions, and the countries are producing more skilled economists and administrators. Both general and specific studies on Brazil formed part of the rationale for AID program loan negotiations in 1967, for example. Another Williams study was influential in evaluating Pakistan's third 5-year plan, and an analysis of Pakistan's growth and excess capacity was used by the Pakistan Planning Commission and the AID mission there. The Board of Investments of the Philippines used effective rates of protection and shadow prices of foreign exchange based on studies that grew directly from the Williams project. Conferences between AID and local government officials have been held in South America and Africa to explore the implications of the studies for future policy and research actions by developing countries. Korea and Taiwan are further examples of countries which in the 1950's encouraged local production of import substitutes but shifted policy toward export promotion in the 1960's.

The ultimate direct influence of collaborative economic research on the basic decisions of sovereign governments abroad is difficult to appraise. The studies emphasize important considerations that a number of governments have chosen to take into account. However, decisions on trade policy by LDCs reflect complex social and economic variables. AID officials have been encouraged by the subtle shifts in trade policy among LDCs and the potential for interaction of this research with these changes.

The results of the studies have contributed to an academic consensus that import substitution policies of the LDCs should be re-evaluated. Many developing countries are taking a new look at their trade policies with a view toward liberalization. In part, at least, this may be attributed to the work undertaken by Williams College on problems associated with import substitution.

Patterns of Participation In Modernizing Societies

As underdeveloped societies begin to modernize, people find that old associations begin to fade and new ones emerge. The importance of the tribe or the clan may give way to farmer associations, urban groups or labor unions. And the governments of developing countries find that this is a challenging period as men associate in new ways in order to adjust and contribute to development and modernization, and at the same time to compete for and share in the gains from growth.

AID wants to encourage and assist technically effective development projects, but it also wants this assistance to foster wide and significant participation of men and women in the process.

There has been little research on how associations change and how participation of the little man is affected by accelerated development. AID supported a project by Harvard University to help close this knowledge gap. Many forms of social and economic participation are susceptible to influence by governmental policy and economic aid programs. Better understanding of these relationships should increase the effectiveness of assistance agencies and LDC governments in providing popular participation in achieving development objectives.

Harvard has prepared independent studies which represent a wide range of approaches, including cross-national analysis, intensive country case studies and detailed examinations of specific social sectors within specific countries. Case studies have been prepared on Pakistan, Colombia, Kenya, Turkey, the rural sector of Vietnam and Mexico City.

Unlike the majority of AID-supported research projects, which are designed to help solve a specific problem, the Harvard project is expected to contribute broadened general insights into a diversity of economic, political and social problems and to stimulate new approaches to making informed policy decisions.

Comparisons of Per Capita Income

Important foreign assistance decisions by AID, the World Bank, and other donors are based on calculations of per capita national income. These agencies have recognized that calculations and comparisons are faulty in many ways. For example, comparisons of per capita income among India, Japan, Indonesia and the United States fail to represent the real differences in standards of living. They suggest that the real difference between India and the United States, while still substantial, is closer to tenfold than twentyfold.

AID-financed research by the University of Pennsylvania, with support of the Ford Foundation and cooperation of the United Nations, has improved the techniques for estimating national income and product. A manual incorporating the findings of this research can be used by LDCs to improve the collection and interpretation of national income data. A permanent unit established within the United Nations is applying the product of this research in collecting, compiling, and publishing country data.

Effects of the Food for Peace Act

To learn more about the economic and social development impact of food aid shipments made by the U.S. AID program to LDCs under the Food for Peace Act of 1966, AID supported research by Iowa State University to analyze the major considerations involved in extending food aid to other countries over the next decade. Nine studies focused on the long-term needs and prospects for food aid under U.S. Public Law 480 programs, and analyzed planning, as well as economic and social effects, of food aid imports, on the countries receiving them. India was selected as the nation to be studied in depth.

The results of the research have been valuable to policymakers in AID and LDCs who are charged with projecting the future needs for food aid by countries, designing optimum distribution programs to diminish the adverse effects of imports on domestic production quantities and price levels to be charged for food aid shipments. The study also assesses the effects of possible "self help" conditions imposed on recipient countries. The report has been widely distributed to AID agricultural officers and to the World Bank and other donor agencies.

RESEARCH PAPERS AVAILABLE

Over the past 10 years the research projects that are briefly described in the report have produced nearly 2,000 documents. These include routine progress reports, theses, dissertations, journal articles, monographs, books, etc. A bibliography of these documents has been compiled and is being edited for final printing. This bibliography will be available to researchers throughout the world and provide access to older documents no longer in print through the National Technical Information Service of the Department of Commerce. In addition to the bibliography of research, a quarterly journal of abstracts has been initiated to announce current documents. Even though these documents will be available for purchase from NTIS on a permanent basis, we encourage researchers in the developing nations to correspond directly with the contractors currently engaged in AID-funded projects for copies of research papers.

For your institutions to be placed on the distribution list for both the research bibliography and the AID Research Abstracts, write to

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APPENDIX
Catalogue of Centrally Funded Research Projects 1971-1973

Page in Text	Title	Contractor and Principal Investigator	*Approved Duration and Funding	Research Sites and Cooperating Countries
AGRICULTURE				
<i>Improved Plants and Farming Methods</i>				
3	Improvement of Nutritional Quality of Wheat (CSD-1208)	Univ. of Nebraska Lincoln, Nebraska Dr. Paul J. Matern	6/29/66-6/30/74 \$1,543,614 to 3/31/74	Int. Maize and Wheat Improvement Center, Mexico, Worldwide Research Network
5	Inheritance and Improvement of Protein Quality and Content in Maize (CSD-2809)	Purdue University Research Foundation Lafayette, Indiana Dr. L. F. Bauman	6/30/70-6/30/75 \$809,812 to 3/31/74	Int. Maize and Wheat Improvement Center, Mexico, Brazil, Colombia, Guatemala, Nigeria, Vietnam
7	Inheritance and Improvement of Protein Quality and Content of Sorghum Vulgare (CSD-1175)	Purdue University Research Foundation Lafayette, Indiana Dr. J. D. Axtell	6/30/66-6/30/75 \$1,667,390 to 3/31/74	Worldwide Research Network
9	Improvement of Grain Legumes (Pulses) Production in Puerto Rico (PASA RA-AJ-3-00)	Agricultural Research Service U.S. Dept. of Agriculture Dr. Julio Bird	6/25/63-6/30/73 \$2,845,672 to 6/30/73	Iran, India, Worldwide Research Network
9	Preparation of a Plan for Orientation of Research on Cassava (CSD-2497)	University of Georgia Athens, Georgia Dr. C. Hendershott	6/30/69-12/1/71 \$84,366	CIAT, Colombia
11	Research on Farm Equipment Power Requirements for Production of Rice and Associated Food Crops in the Far East and South Asia (CSD 834 and CSD-2541)	IRRI Los Baños Philippines Dr. A. H. Khan	6/28/65-1/28/74 \$1,166,366 to 1/28/74	The Philippines, Pakistan, Bangladesh, India, Taiwan, Thailand, Indonesia, Korea, Sri Lanka, Malaysia
12	Control of Weeds in LDCs (CSD-1442 and AID/CM/ta-C-73-23)	Oregon State Univer Corvallis, Oregon Dr. Stanley Miller	6/30/66-3/31/76 \$1,998,272 to 3/31/74	Colombia, Ecuador, El Salvador, Panama, Honduras, Guatemala, Nicaragua, Costa Rica, Brazil
<i>Tropical Soils and Water Management</i>				
14	Determination of Research Needs of Soils of the Tropics (CSD-2505)	National Academy of Sciences Washington, D.C. Dr. Joice Torio	6/30/69-6/30/72 \$124,200	Researchers from England, Belgium, France, Nigeria contributed articles

Page in Text	Title	Contractor and Principal Investigator	*Approved Duration and Funding	Research Sites and Cooperating Countries
<i>Tropical Soils and Water Management</i>				
15	Soil Fertility Requirements to Obtain Efficient Production of Food Crops on the Extensive, Deep, Well Drained but Relatively Infertile, Acid Soils of the Humid Tropics (CSD-2490)	Cornell University Ithaca, New York Dr. Matthew Drosdoff	6/30/69-3/31/74 \$1,126,846 to 3/31/74	Brazil
15	Agronomic-Economic Research on Tropical Soils (CSD-2806)	N.C. State University Raleigh, N.C. Dr. C. B. McCants	6/30/70-6/15/75 \$748,360 to 3/31/74	Brazil, Peru, Guatemala, Honduras, Nicaragua, Costa Rica, Bolivia, Paraguay, Colombia, Venezuela, Ecuador, Panama, El Salvador
17	Water Management Research in Arid and Sub-Humid Lands —Latin America (CSD-2167)	Utah State University Logan, Utah Dr. H. B. Peterson	6/28/68-3/31/76 \$2,226,071 to 11/27/73	El Salvador, Colombia, Chile, Brazil, Ecuador, Bolivia, Guatemala, Honduras, Venezuela, Panama
17	Water Management Research in Arid and Sub-Humid Lands —Asia (CSD-2162)	Colorado State Univ. Fort Collins, Colorado Dr. W. D. Kemper	6/28/68-3/31/76 \$2,042,649 to 11/30/73	Pakistan
20	Tailoring Fertilizers for Rice (PASA RA-QA-5-69)	National Fertilizer Development Center Tenn. Valley Authority Muscle Shoals, Alabama Dr. D. McCune	7/1/68-3/31/73 \$466,500 to 3/31/73	The Philippines, India, Mexico, Colombia, Thailand, Sri Lanka, Brazil, Afghanistan, Indonesia, Kenya, Vietnam
<i>Livestock</i>				
22	Control of Vertebrate Pests (PASA RA-ID-1-69)	U.S. Dept. of Interior Denver, Colorado Dr. N. J. Kverno	4/5/67-6/30/77 \$2,790,720 to 6/30/73	Mexico, Brazil, The Philippines, Colombia
24	Research on Sterility Methods of Tsetse Fly Control (PASA RA-1-00)	Agricultural Research Service U.S. Dept. of Agric. Gainesville, Florida Dr. D. Dame	6/14/63-6/30/76 \$1,572,870 to 6/30/73	Tanzania
25	Research on Hemoprotozoal Diseases of Food-Producing Livestock in LDCs (CSD-1947)	Texas A and M Univ. College Station, Tex. Dr. Fred D. Maurer	6/30/68-6/30/76 \$1,362,731 to 3/31/74	Int. Center for Tropical Agric. Colombia, Ecuador, Peru, Guatemala
26	Survey and Analysis of Problems of Cattle Feeding Systems and Nutrition in Wet/Dry Tropics of Latin America (CSD-2498)	University of Florida Gainesville, Florida Dr. J. H. Conrad and Dr. L. R. McDowell	6/30/69-9/30/73 \$519,011 to 9/30/73	Regional Research Networks throughout Latin America and Caribbean

Page in Text	Title	Contractor and Principal Investigator	*Approved Duration and Funding	Research Sites and Cooperating Countries
<i>Agricultural Economics</i>				
26	Rural Development Analysis Agricultural Sector Planning Models (CSD-1557)	Michigan State Univ. East Lansing, Mich. Dr. Glenn L. Johnson	6/30/67-6/30/71 \$402,325	Nigeria, Korea
27	Adapting and Testing of Agriculture Simulation Model to Sector Analysis (CSD-2975)	Michigan State Univ East Lansing, Mich. Dr. Glenn L Johnson	6/21/71-6/30/74 \$685,000 to 3/31/74	Nigeria, Korea, The Philippines, Colombia, Brazil
29	Analysis of Capital Formation and Technological Innovation at the Farm Level in LDCs (CSD-2501)	Ohio State University Columbus, Ohio Dr. David H. Boyne	6/30/69-3/31/74 \$1,306,290 to 3/31/74	Brazil
30	Impact of New Technology on Rural Employment and Income (CSD-2805)	Cornell University Ithaca, New York Dr. J. W. Mellor	6/30/70-12/31/73 \$499,991 to 12/31/73	India
31	Agricultural Diversification and Trade in Latin America (CSD-3283 and CSD-3632)	N.C. State University Raleigh, N.C. Dr. R. L. Simmons	5/1/71-3/31/75 \$218,352 to 3/31/74	Mexico, Guatemala, El Salvador, Honduras
31	Agricultural Diversification and Trade in Asia (PASA RA-AJ-13-71)	Economic Research Service U.S. Dept. of Agric. Dr. L. J. Atkinson	5/1/71-3/31/74 \$172,394 to 6/30/73	The Philippines
33	Employment Generation in African Agriculture (CSD-3306 and CSD-3625)	Michigan State Univ. East Lansing, Mich. Dr. Carl K. Eicher	6/15/71-6/30/75 \$349,596 to 12/31/73	Nigeria, Sierra Leone, Ghana, Malawi, Ethiopia
HEALTH				
37	Malaria Eradication Research Worldwide Programs (PASA RA (HA)-7-00)	National Communicable Disease Center, U.S.P.H.S. (H.E.W.) Dr. George W. Pearce	1/17/62-6/30/72 \$5,064,822	Worldwide Research Network
38	Central America Malaria Research Station (PASA RA (HA)-2-67)	National Communicable Disease Center, U.S.P.H.S. (H.E.W.) Dr. G. M. Jeffery	3/1/67-6/30/72 \$2,185,219	El Salvador, Nicaragua, Honduras, Costa Rica, Panama, Brazil
38	Thailand Malaria Operation Research (PASA RA (HA)-1-70)	National Communicable Disease Center, U.S.P.H.S. (H.E.W.) Dr. William Chin	8/29/69-6/30/72 \$444,639	Thailand
39	Malaria Immunity and Vaccination (CSD-1432) succeeded by CSD-3689	University of Illinois Urbana, Illinois Dr. Paul H. Silverman	6/30/66-6/30/72 \$1,948,502	U.S. Research Project has trained personnel from Ghana, Nigeria, West Cameroons, Israel, Guatemala, Pakistan, Peru, Taiwan
	Malaria Immunity and Vaccination (CSD-3689)	Univ. of New Mexico Albuquerque, N.M. Dr. Paul H. Silverman	7/1/72-6/30/75 \$773,223 to 3/31/74	

Page in Text	Title	Contractor and Principal Investigator	*Approved Duration and Funding	Research Sites and Cooperating Countries
HEALTH				
40	Serologic Diagnosis of Malaria (PASA RA (HA)-5-68)	National Communicable Disease Center, U.S.P.H.S. (H.E.W.) Dr. Irving G. Kagan	4/1/67-12/31/72 \$403,473	Nigeria, Bangladesh, Nepal, Ethiopia, The Philippines, Brazil, El Salvador, Haiti, Indonesia, Afghanistan
41	Water Pump Application for LDCs (CSD-1434 and CSD-3305)	Battelle Mem. Inst. Columbus, Ohio D. W. Frink	6/30/66-4/30/74 \$117,690 to 4/30/74	Bangladesh, Nigeria, Thailand, Laos
42	Development of Methodology for Determination of Optimal Design Capacities of Small Water Supplies (CSD-2494)	University of North Carolina Chapel Hill, N.C. Dr. D. A. Okun	6/30/69-6/29/72 \$40,000	Guatemala
43	Measurement of Nutrient Loss Due to Malabsorption (PASA RA-HA-9-69)	U.S. Public Health Service Dept. of Health, Education and Welfare Dr. J. M. May	5/9/69-6/30/73 \$146,906 to 6/30/73	Iran, India
44	Inter-American Investigation of Mortality in Infancy and Childhood (CSD-1431)	Pan American Health Organization Washington, D.C. Dr. Ruth Puffer	6/30/66-3/31/73 \$1,175,556 to 3/31/73	Argentina, Bolivia, Brazil, Chile, Colombia, El Salvador, Jamaica, Mexico
POPULATION				
48	World Fertility Survey (CSD-3606)	International Statistical Institute The Hague, Netherlands M. G. Kendall & E. Lunenberg	6/30/72-6/30/77 \$1,043,000 to 6/30/74	Netherlands, England, Worldwide Research Network
48	A Study of Fertility Rates and Earning Capacity of Rural Migrants in Latin America (CSD-2863)	Univ. of Wisconsin Madison, Wisconsin Professors William Flinn, Eugene Havens, Marion Brown	8/25/70-6/30/74 \$400,000 to 6/30/74	Colombia, Chile
49	Determinants of Family Planning Attitudes and Practices, Phase II (CSD-2478)	Harvard University Cambridge, Mass. Dr. David M. Heer	6/30/69-9/15/72 \$120,877	Taiwan
49	Fertility Determinants—A Theoretical Inquiry (CSD-2533)	Rand Corporation Santa Monica, Calif. Dr. Paul T. Schultz	1/5/70-6/30/72 \$326,500	U.S. Research

Page in Text	Title	Contractor and Principal Investigator	*Approved Duration and Funding	Research Sites and Cooperating Countries
POPULATION				
49	The Epidemiology of Outcome of Pregnancy in Diverse Cultures in Selected Countries (CSD-2246)	Johns Hopkins Univ. Baltimore, Md. Dr. Paul Harper, Dr. L. P. Chow, Dr. John Kantner, Dr. Rowland Rider	5/1/69-7/31/72 \$224,958	Taiwan
50	Evaluation Studies of an International Postpartum Family Planning Program (CSD-1565)	Population Council New York, N.Y. Dr. Bernard Berelson and Dr. Gerald Zatuchni	6/30/67-8/31/71 \$600,000	Nigeria, Thailand, Indonesia, Ghana, Hong Kong, Iran, The Philippines, Mexico, Colombia, Venezuela, Honduras, Turkey
51	Utilization of Family Planning Services (CSD-2512)	Bowman Gray School of Medicine Wake Forest Univ. Winston-Salem, N.C. Dr. Clark Vincent, Dr. David Evans, Dr. Carl Cockrane, Dr. Clay Honey, Dr. Fleetus Gobble, Jr.	6/30/69-11/30/72 \$393,471	Costa Rica
53	Research into the Corpus Luteum Function (PASA RA (HA)-8-69)	Nat. Inst. of Health, N.I.C.H.D. Washington, D.C. Center for Population Research	5/7/69-5/6/72 \$1,562,752	U.S. Research
53	Research For Development of a Once-a-month Contraceptive Pill (CSD-2169)	Worcester Foundation for Experimental Biology Shrewsbury, Mass. Dr. Edward Klaiber	6/30/68-2/28/73 \$207,375 to 2/28/73	U.S. Research
53	Contraceptive Development: A Method to Prevent Pregnancy by Direct or Indirect Anti-Progestational Activity (CSD-2491)	Population Council New York, N.Y. Dr. Sheldon J. Segal	6/30/69-6/30/74 \$3,000,000 to 6/30/74	U.S. Research
53	Development of Inhibitors of L-H Releasing Factor as Contraceptive Agent (CSD-2785)	Salk Inst. for Biological Studies San Diego, California Dr. Roger Guillemin	6/30/70-5/31/75 \$4,448,139 to 5/31/75	U.S. Research
54	Prostaglandin and Other Contraceptive Research Development (CSD-2837)	Worcester Foundation for Experimental Biology Shrewsbury, Mass. Dr. Edward Klaiber	6/30/70-9/1/73 \$2,980,000 to 9/1/73	Sweden, England
54	Prostaglandin/Human Reproductive Research (CSD-3300)	Makerere University Kampala, Uganda M. M. Sultan Karim	6/30/71-6/30/74 \$821,538 to 6/30/74	Uganda, Singapore

Page in Text	Title	Contractor and Principal Investigator	*Approved Duration and Funding	Research Sites and Cooperating Countries
POPULATION				
54	Studies on Synthesis of Prostaglandins (CSD-2965)	Univ. of Wisconsin Madison, Wisconsin Dr. Charles Sih	6/30/71-6/30/74 \$227,725 to 6/30/74	U.S. Research
54	A Study of the Side Effects and Mechanism of Action of Prostaglandins (CSD-3160)	Washington Univ. St. Louis, Missouri Dr. Arpad I. Csapo	6/30/71-6/30/74 \$301,406 to 6/30/74	U.S. Research
54	Research on Safety of Contraceptive Steroids (CSD-2821)	Southwest Founda- tion for Research and Education San Antonio, Texas Dr. J. W. Goldzieher	6/30/70-9/30/73 \$995,426 to 9/30/73	Mexico
5				
95	Development of IUD and Controlled Release Contraceptive (CSD-2819)	Battelle Mem. Inst. Richland, Washington Robert G. Wheeler	6/30/70-6/30/75 \$1,132,230 to 6/30/75	Collaboration with physicians in India, Egypt, field test planned in LDCs
56	Surgical and Engineering Research on Means of Fertility Control (CSD-3152)	Battelle Mem. Inst. Seattle, Washington Dennis J. Prager	6/30/71-12/31/74 \$1,029,792 to 12/31/74	U.S. Research evaluation studies planned in LDCs
56	Research on Reversible Sterilization (CSD-2504)	University of North Carolina Chapel Hill, N.C. Dr. J. F. Hulka	6/27/69-6/26/72 \$213,763	Information exchange with physicians in India, Singapore, Thailand, Egypt
57	Combined VD-Prophylactic Contraceptive (CSD-2822)	Univ. of Pittsburgh Pittsburgh, Penn. Dr. John C. Cutler	6/30/70-6/30/75 \$719,284 to 6/30/75	Field trials—Jamaica, Guatemala
57	Simplified Techniques of Fertility Control (CSD-3627)	Johns Hopkins Univ. Baltimore, Maryland Theodore M. King	6/30/72-6/30/75 \$3,507,451 to 6/30/75	Clinical training for family planning personnel from LDCs
58	Program for Applied Research on Fertility Regulation (CSD-3608)	Univ. of Minnesota Minneapolis, Minn. J. J. Sciarra	5/30/72-6/30/75 \$3,349,523 to 6/30/75	Twenty studies by overseas and U.S. institutions
58	International Fertility Research Program (CSD-2979)	University of North Carolina Chapel Hill, N.C. Dr. Elton Kessel	6/30/71-6/30/74 \$4,906,000 to 6/30/74	Worldwide Research Network
59	Family Planning Research and Evaluation Center (CSD-1573)	Pathfinder Fund Boston, Mass. Alfreda Goldsmith	6/30/67-6/30/73 \$1,483,000 to 6/30/73	Worldwide Research Network of over 40 countries
NUTRITION				
62	Improvement of Rice by Fortification With Synthetic Amino Acids and Vitamins (CSD-2170 and CSD-3291)	Harvard University Cambridge, Mass. Dr. S. N. Gershoff	6/30/68-6/30/75 \$498,110 to 3/31/74	Thailand

Page in Text	Title	Contractor and Principal Investigator	*Approved Duration and Funding	Research Sites and Cooperating Countries
NUTRITION				
63	Lysine Enrichment of Wheat Flour (CSD-1805)	British-American Hospital Lima, Peru Dr. George Graham	6/20/69-6/30/71 \$132,032	Peru
63	Improvement of Nutrient Value of Cereal-Based Foods (CSD-1586)	Kansas State Univ. Manhattan, Kansas Dr. William J. Hoover	6/30/67-3/31/75 \$930,457 to 11/30/73	Training of technologists from India, Colombia, Guatemala, Pakistan, Morocco
65	Corn Fortification with Amino Acids (CSD-3357)	Inst. of Nutrition for Central America and Panama Apdo. Postal 1188 Guatemala City Dr. Leonardo J. Mata	9/15/71-9/15/76 \$278,700 to 3/31/74	Guatemala
65	Effects of Extrusion Processing Variables on Nutritional Quality of Inexpensive High Protein Food Mixtures (CSD-1587)	Univ. of California Davis, California Dr. C. O. Chichester	6/30/67-12/31/71 \$223,273	Chile
65	Development of Infant and Preschool Foods Based Upon Indigenous Protein Sources (CSD-3646, formerly CSD-1587)	Univ. of Rhode Island Kingston, R.I. Dr. C. O. Chichester	7/1/72-3/31/74 \$109,706 to 3/31/74	Chile
66	Coconut Protein Products for Use in Foods (CSD-2804)	Texas A and M Univ. College Station, Tex. Dr. Karl F. Mattel	6/15/70-3/31/74 \$501,327 to 3/31/74	The Philippines, Thailand
67	Caloric Intake and Protein Utilization (CSD-2808)	Mass. Inst. of Tech. Cambridge, Mass. Dr. N. S. Scrimshaw	6/15/70-3/30/74 \$334,932 to 3/30/74	U.S. Research
68	Clinical Evaluation of New Protein Sources to Prevent Malnutrition (CSD-1433 and CSD-2946)	British-American Hospital Lima, Peru Dr. G. C. Graham	6/27/66-6/30/76 \$466,383 to 3/31/74	Peru
68	Influence of Maternal Diet on Offspring (CSD-2944)	Johns Hopkins Univ. Baltimore, Maryland Dr. Bacon F. Chow	6/1/71-6/1/74 \$160,500 to 12/31/73	Taiwan
69	Malnutrition Effect on Work Planning (CSD-2943)	Medical College of Wisconsin Milwaukee, Wis. Dr. G. B. Spurr	6/30/71-6/30/75 \$128,797 to 3/31/74	Colombia
EDUCATION				
72	Studies of Low Cost Instructional Technology (CSD-3284)	Stanford University Stanford, California Dr. Wilbur Schram	6/15/71-12/31/72 \$239,563 to 12/31/72	Mexico

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EDUCATION				
73	Beginning Science Curricula for English-Speaking Tropical Africa (CSD-772)	Educational Development Center, Inc. Watertown, Mass. James L. Aldrich	2/17/65-6/30/71 \$2,736,962	Kenya, Tanzania, Uganda, Zambia, Nigeria, Sierra Leone, Ghana
SCIENCE AND TECHNOLOGY				
77	Design, Construction of Locally Planned Structures to Withstand Earthquakes and Storms (PASA RA/CE-9-71)	National Bureau of Standards Dept. of Commerce Washington, D.C. Dr. E. O. Pfang	5/1/71-6/30/73 \$110,570 to 6/30/73	Turkey, Peru
79	Mosquito Genetic Control (CSD-3159)	Univ. of Notre Dame South Bend, Indiana Dr. K. S. Rai	6/15/71-6/30/76 \$244,000 to 3/30/74	Kenya
DEVELOPMENT ECONOMICS				
81	Comparative Studies of Resource Allocation and Development Policy (CSD-1543)	Harvard University Cambridge, Mass. Dr. Joseph J. Stern	5/31/67-12/31/73 \$1,931,786 to 12/31/73	Ghana, India, Pakistan, Indonesia, Korea, Liberia, Nigeria, Colombia, Argentina, Taiwan, Greece, Turkey, Jamaica, Honduras, Guyana, Thailand, Japan, Malaysia, Bangladesh
82	Employment and Unemployment in the Developing Countries (CSD-2492)	Yale University New Haven, Conn. Dr. Gustav Ranis	6/30/69-6/30/74 \$993,520 to 6/30/74	Colombia, Korea, Taiwan, Pakistan, Brazil, India, Chile, Kenya, Ghana, Zaire
84	Exchange Control Liberalization and Development (CSD-2783)	Nat. Bureau of Economic Research New York, N.Y. Hal B. Lary	6/29/70-6/30/74 \$546,300 to 6/30/74	Brazil, Chile, Colombia, Egypt, Ghana, India, Israel, The Philippines, Korea, Turkey
85	Distribution of Gains, Wealth and Income from Development (CSD-3302)	Rice University Houston, Texas Dr. James W. Land	6/15/71-6/30/74 \$557,114 to 3/31/74	Malaysia, Colombia, Turkey
85	Import Substitution and Economic Policy in Economic Development (CSD-2475)	Williams College Williamstown, Mass. Dr. Paul Clark	12/31/64-9/30/72 \$356,329	Colombia, Mexico, Jamaica, Brazil, Nigeria, East African Region, Pakistan, The Philippines
86	Participation Patterns in Modernizing Societies (CSD-2502)	Harvard University Cambridge, Mass. Prof. Samuel Huntington	6/27/69-12/31/72 \$390,469	Kenya, Colombia, Pakistan, Turkey, South Vietnam, Venezuela, Mexico

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DEVELOPMENT ECONOMICS				
87	Comparison of Indian Real Per Capita Income and Currency Purchasing Power with the U.S. (CSD-2481)	Univ. of Pennsylvania Philadelphia, Penn. Prof. Irving Kravis	6/16/69-6/30/72 \$31,433	India
87	Growth and Development of Food Aid Shipments Under the Food For Peace Act of 1966 (CSD-2163)	Iowa State University Ames, Iowa Dr. Earl Heady and Dr. Leo Mayer	6/29/68-8/31/72 \$330,000	India

*In fiscal year 1973 AID obligated a total of \$8,444,300 for centrally funded research