The 1967 Farrer Memorial Oration

MAN LAND AND FOOD

E. J. UNDERWOOD

1967 Farrer Medallist

I AM DEEPLY CONSCIOUS of the honour conferred upon me by the award of the Farrer Memorial Medal and of the responsibility entailed in delivering the 1967 Farrer Memorial Oration. This responsibility is increased by an examination of the titles of the orations given by my distinguished predecessors since it was first decided to honour the great William Farrer thirty years ago. Indeed this examination enhances the difficulty of choosing a topic that is new and challenging and, at the same time, within the modest bounds set by my own competence and experience.

In seeking a suitable topic my first thoughts naturally turned to the subject of trace elements in plant and animal nutrition, since studies within this field have been a major pre-occupation of mine for most of my working life. Furthermore, this topic provides an opportunity to pay tribute to some of the most outstanding contributions yet made by Australian scientists and to describe some of the remarkable increases in productivity which have occurred over huge areas in this country and in other parts of the world as a result of Australian discoveries in relation to trace element deficiencies, imbalances, and toxicities in crops and stock. These discoveries have been among the most scientifically stimulating and economically rewarding in the whole field of biology.

My second thoughts on a suitable topic were concerned with the Australian wheat industry which owes so much to William Farrer's pioneering work and which has made such progress over the last two decades. This story deserves to be told and where better, you may ask, than in a Farrer Memorial Oration. However, I felt that there were others more competent than I to undertake this task, despite the fact that I was privileged to play some part in the initiation of the Wheat Industry Research Act and have been proud to represent all Australian Universities on the Wheat Industry Research Council since its inception ten years ago. During these ten years large sums of money have been allocated for research into virtually all aspects of the wheat industry. Whole new projects have

Professor E. J. Underwood, C.B.E., F.A.A., F.A.I.A.S., received the Farrer Memorial Medal for 1967, and gave the Farrer Memorial Oration, at the University of Melbourne on January 17th, during the 39th ANZAAS Congress.

Professor Underwood graduated B.Sc.Agr. (First Class Honours) from the University of Western Australia in 1928, and gained a Ph.D. from Cambridge in 1931.

Since 1946 he has been Director of the Institute of Agriculture, Dean of the Faculty of Agriculture and Hackett Professor of Agriculture at the University of Western Australia.

Professor Underwood was a pioneer worker in the field of trace elements, and wrote the first major text on the subject —"Trace Elements in Human and Animal Nutrition".

He was an original member of a research team investigating the serious problem of sheep infertility on subterranean clover pastures. This work led to definition of the nature and cause of the problem; to practical measures of reducing incidence of the disease in the field; and to discovery of a series of new plant oestrogens (the isoflavones).

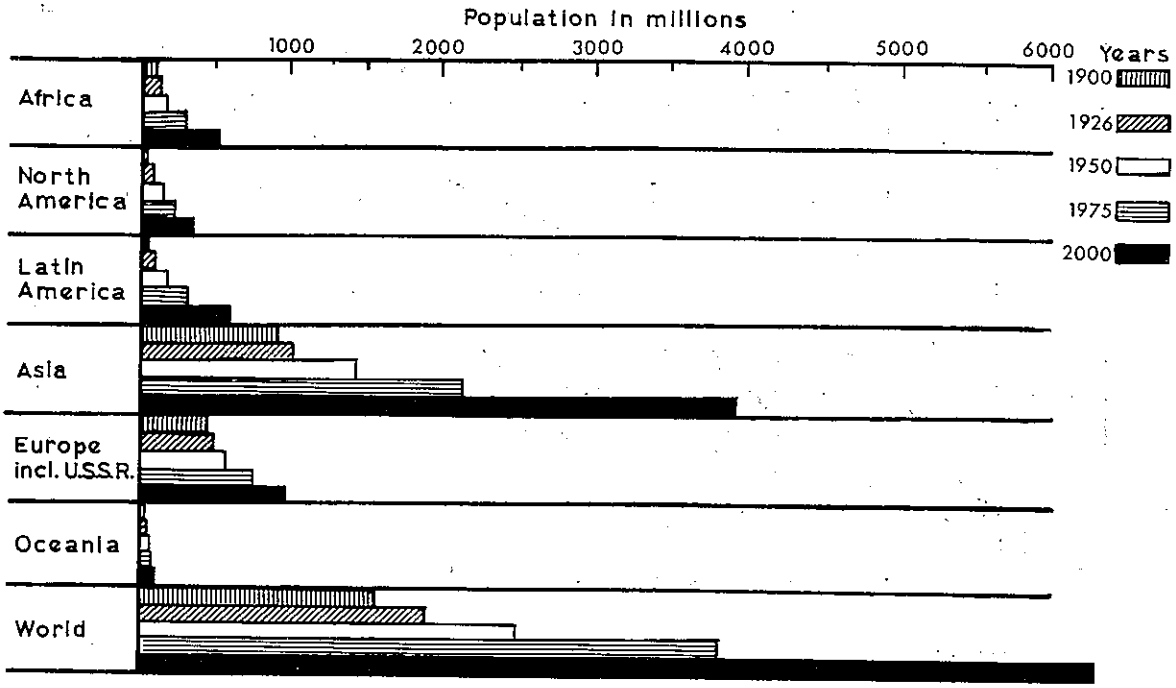
Professor Underwood was a prime mover in the initiation of the voluntary wheat levy scheme in Western Australia, and the Commonwealth Wheat Research Act in 1957.

He has received numerous awards and honours, both at home and abroad, in recognition of his knowledge of modern agriculture and his administrative abilities.

been started and old ones have been stimulated to greater achievements in the Universities, State Departments of Agriculture, and CSIRO.

Some of these researches have had immediate and successful application to the more secure and more efficient production of wheat from the land. In other words, they have achieved the very same objective which Farrer set for himself in his early efforts to cope with the problems of drought and disease by the breeding of new and improved varieties of wheat. In addition, the Wheat Industry Research Funds have been used to sponsor a number of more fundamental studies with no immediate practical relevance to the Australian wheat industry. Much of this type of research is so recondite, so sophisticated in the techniques employed, so dependent upon concurrent advances in the basic sciences that it would have bewildered Farrer. I am, nevertheless, convinced that he would have given such work his full support. We must remember that Farrer's methods were considered to be highly impractical and were even the subject of derision by most of the practical men of his time. Great changes in attitudes have taken place since then but there is an increasing tendency to argue, with all the industry research funds, that such funds can best be spent on applied research of obvious usefulness and immediate applicability. This tendency should be resisted vigorously if the storehouse of knowledge is to be continuously replenished and if those really original and unexpected ideas and techniques, upon which all progress ultimately depends, are to continue to appear.

These brief reflections bring me at last to my chosen topic, "Man, Land and Food". This title was finally selected because it gives me the opportunity to compare and contrast the impact of science and technology upon agricultural development and food production in technically developed countries like Australia and the USA and in the technically underdeveloped regions of the world. It also enables me to draw upon my own experiences in Asia, Africa, and Latin America, while serving with the Food and Agriculture Organization of the United Nations.



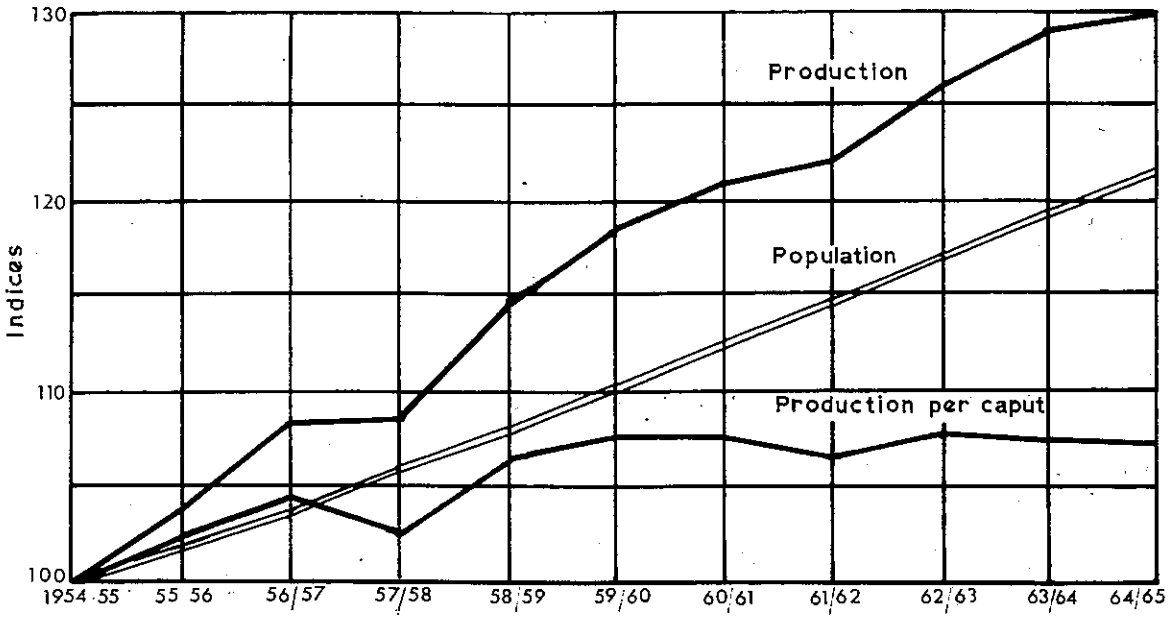
Growth in populations by continents 1900-2000, with projects based on medium assumptions (U.N. Populations Studies No. 28). Adapted from The Population Explosion C.W. Park, Heinemann Educational Books, 1965.

The world food problem

Expressed in the simplest terms the world food problem can be stated like this: The underdeveloped world is losing the capacity to feed itself—it is losing the race between production and reproduction. Out of a total world population of some 3.2 thousand million, no less than 2.2 thousand million cannot provide enough food to meet their increasing needs and the position is deteriorating rapidly.

Let us look first at the statistical evidence for this statement. According to studies made by FAO, per capita food output in Asia, excluding Communist China, has dropped 4 per cent in the last five years, while in Latin America food output per person has declined each year since 1958, falling 5 per cent in the last five years. This situation is reflected even more strikingly in the changed trading position of the underdeveloped world. Before World War II the less-developed regions of Asia, Africa, and Latin America were not *exporters* of grains, the principal food crops. Together they exported 11 million tons of wheat, rice, corn, and other food grains per year to the developed world. By the end of the war those regions had not only lost their grain surplus, they had become *importers* of these commodities. Furthermore, their dependence on the developed world is increasing. From 1948 to 1952 four million tons of grain per year moved from the technically advanced to the technically underdeveloped regions; during the late 1950's this flow increased to 13 to 15 million tons per year; and by this year net grain imports by the developing countries are estimated to reach a level of 25 million tons or about 1,000 million bushels annually. A substantial part of their population increase is being sustained by food shipped from the developed world, mainly North America and to a lesser extent Australia.

Such contributions cannot possibly provide a permanent solution to the world food problem, although they are likely for some



Comparison of the global growth of agricultural, fishery and forest production with the growth of population
(After FAO, State of Food and Agriculture, 1965).

years to make valuable, indeed vital, contributions as an emergency measure. Calculations made recently by Lester Brown, the noted international agricultural economist, show that by 1980, that is, in only 13 years time, the increase in grain consumption required to meet the expected increase in population of the underdeveloped countries would raise grain requirements by an amount approaching that of the current total output of the whole of North America, Western Europe, and Australasia combined. I will emphasize this. Even if such a fantastic increase in production were possible in so short a time; even if the developing countries could afford to pay for it; even if the necessary shipping, handling, and distributing facilities were to be provided from some unknown beneficent source, the situation would still be untenable. It would be unstable and disruptive, if not explosive. The difference between the haves and the have-nots would become accentuated and whole peoples would lose their hope and their self-respect. The answer to the world food problem does not lie in increasing still further the productivity of the rich, industrialized nations, however necessary this may be—it lies in increasing the per capita food production of the underdeveloped countries and in reducing their rate of population increase. There is no other way. The food-producing potential of the land must be developed to the full, not merely in this country, not merely in North America and Western Europe but in *all* countries if man is not to succumb to his own fecundity.

I am very conscious of the fact that all this has been said before, many times before, and that it can become tedious with repetition. Despite this I am saying it again because it is an issue which vitally affects the future of all of us. Most of us know this in our hearts but, because of its complexity and its magnitude, we tend to dismiss the world food problem from our minds and to concentrate on questions which seem more immediate and more obvious and more amenable to solution. We cannot afford to do this any longer.

Characteristics of the developing countries

Development has been defined as "the unfolding of the potentialities of people to produce goods and services through the use of resources". If we accept this definition,

all countries, including Australia, must be regarded as developing. In practice the term "underdeveloped", or its more acceptable euphemism, "developing", is usually confined to those parts of Asia, Africa, and Latin America where the level of production of goods and services through the use of resources is far below that of the technically developed countries of North America, Western Europe, and Australasia. The extent to which this lag occurs and the social and political structures of the various developing countries vary widely from one region to another but there are many common and characteristic features that can be recognized.

The essential characteristics of a typical underdeveloped country or region are:

(i) a rapid rate of population increase;
(ii) widespread poverty, resulting in low levels of saving and investment and high levels of malnutrition in the vulnerable groups of the population;
(iii) a high level of unemployment or of under-employment;
(iv) low average educational standards, with varying degrees of illiteracy and ignorance of modern technology, that is, *functional* illiteracy;
(v) a socially and technically backward agriculture, with usually a high proportion of the population engaged in subsistence farming under oppressive or archaic conditions of land tenure; and
(vi) deteriorating conditions of external trade.

Two aspects of these common characteristics need to be emphasized. The first is that they vary greatly in intensity and in significance from one region and one country to another. In other words, each feature is not equally prominent in each developing country. The second and the most important aspect of these characteristics is that they are interdependent and interacting. This means that it is extremely difficult to effect significant improvement in one of the factors without effecting a concurrent improvement in the others. Or let me put it the other way round. It is not possible to tackle one single facet of the problem by itself, such as education or malnutrition or fertilizer use, and expect a consequential improvement in all the others. In fact, this approach may even exacerbate other aspects of the whole problem, as I will show later in this address. It is the combination of interacting and interdependent features that makes the problem of the developing countries so desperate and so intractable.

The demographic revolution

Despite what I have just said, there can be no reasonable doubt that the demographic revolution of the last few decades, or to use the popular phrase "population explosion", lies at the root of the problem. It can readily be calculated that an increase of 2 per cent per year doubles a population in 40 years and an increase of 3 per cent per year doubles a population in 25 years. Over the greater part of the developing world the rate of population increase is over 2.0 per cent per year and is rising. In some countries it is already close to 3 per cent per year. Population increases of this magnitude are raising obstacles to development as fast, or faster, than they are being overcome. The opportunities for improved incomes, employment, education, and nutrition are being eroded away by the annual tidal wave of new people to be fed, clothed, educated, housed, and employed.

The causes of this demographic revolution are well known. On the one hand human fertility tends to remain at a traditionally high level in the developing countries. On the other hand, mortality rates have fallen rapidly from their traditionally high level as a result of the application of advances in medical science and public health. One of the greatest tragedies and one of the greatest challenges of our time is that it is so much easier and so much cheaper to apply the findings of western medical science to poor and underdeveloped countries, so that death rates fall, than it is to apply the findings of western agricultural science to these same communities, so that food production rises. In these circumstances, modern medical science is saving lives now but it is building up more misery for all. In the words of the great Swedish

economist and sociologist, Gunnar Myrdal, "This great revolution (in death control) can be thought of as a radical lowering of the level of misery at which the cruel Malthusian checks on population increase go into operation."

Some examples of the ways in which the situation just described actually arises are worth mentioning. In Ceylon and in Mauritius, malaria has now been so effectively controlled that explosive increases in population are occurring in those islands. In India, tuberculosis, formerly a major killer in that country, is steadily being brought under control through the massive efforts of the World Health Organization and local public health authorities. In all the developing countries improvements in water supplies and domestic and public hygiene and the availability of antibiotics and vaccines are reducing infant and maternal mortality. Within the last 20 years the life expectation of a girl baby in India has been raised from 27 to 48 years. In the islands of the Caribbean, where I was working last year, the infant mortality rate has been reduced from 150–200 per 1,000 live births to 30–50 per 1,000 in little more than a decade. It is not generally realized that in Puerto Rico, for instance, the average life expectancy is now higher than it is in the continental United States.

These remarkable improvements have been brought about by the development of child care and maternity centres teaching better hygiene and nutrition and by the provision of supplies of dried skim milk from UNICEF and from US sources. By these means the incidence of protein-calorie malnutrition and gastro-enteritis in infants has been reduced, although these diseases are still a major cause of infant mortality in some areas. As a consequence of these changes arising from the application of western medical technology more mothers are surviving childbirth and living longer to have more children and more children are surviving the hazards of infancy to marry and to multiply.

It would be unthinkable, even if it were possible, for the technically advanced nations to consider withholding or reducing the benefits of their medical technology to the developing countries. These, of course, must be increased. However, we must recognize that such action will inevitably accentuate their long-term problems unless advances in other aspects of western science and technology, notably in birth-control and in agriculture, are applied with equal vigour and with equal success.

Population control and family planning are matters of great delicacy, involving social, racial, religious, and political susceptibilities and presenting special difficulties in many, if not all, of the developing countries. Fortunately such difficulties are not insurmountable. Increasingly effective Government-sponsored and privately-sponsored family planning programmes, supported by supplies of the "pill" and the "coil" from the western world, are emerging in more and more of these countries. Perhaps most encouraging of all, the Roman Catholic church is showing hopeful signs of modifying its former intransigent attitude to the use of contraceptive devices by its members. If this were to occur, it would constitute a major contribution to the world food problem, particularly in those Latin-American countries where the demographic revolution is having its greatest impact.

The impact of western technology on agriculture in the developing countries

The great success of the developing countries in applying modern medical science to their people, which has resulted in so many more mouths to feed, contrasts strikingly with the failure of most of them to achieve comparable successes in agriculture and food production. Indeed the technology of the rich industrialized nations has in some ways worked strongly to the economic disadvantage of the developing countries and has certainly contributed to the deterioration in their international trading position. This fact is so little appreciated in the western world that we should look at the situation more closely.

We must realize at the outset that many of the traditional exports of the developing regions have a low income elasticity of demand. In other words, the per capita con-

sumption of these products does not rise significantly with rising incomes and may actually fall. The demand for such exports has therefore not increased *pari passu* with the increased standards of living of the rich, developed world. In the second place, the traditional exports of the underdeveloped countries are subject to increasing competition from the industrialized nations. This competition from the technically-advanced countries stems from:

(i) the adoption of highly protectionist national policies, with heavily subsidized agricultural industries;

(ii) very substantial increases in agricultural productivity, through the application of science and technology to the land; and

(iii) the development of a range of synthetic substitutes for and alternatives to natural products, through the skill and enterprise of large-scale chemical industry.

The combined effects of such legislative and technical measures in the developed world upon the underdeveloped world have been profound. The present world surplus of sugar and decline in world sugar prices have arisen primarily because total output and efficiency of production of sugar from sugar-cane and from highly protected beet-sugar industries have risen so much more in the technically-advanced countries, as a result of the application of agricultural science and technology, than has sugar production in the less developed countries. The latter, in consequence, are suffering increasing competition with disastrous effects upon their export-earning capacity from this source.

The position in respect to countries dependent upon exports of palm oil, coconut oil, and groundnut oil is not much better. Synthetic detergents, which are products of western technology, are displacing those oils from one of their former major markets, for the manufacture of soap. Moreover, vegetable oil production from temperate zone crops has increased greatly in recent years, especially from soyabeans in USA. The soyabean industry in that country is now an enormous and efficient industry, enjoying every advantage which modern agricultural and industrial technology can provide.

The examples which I have just given merely illustrate a general trend. Productivity and efficiency in the industrialized nations, based on scientific research and continued technological progress, are rising rapidly in all fields where underdeveloped countries are competing and they will continue to do so. Ever cheaper and better substitutes are being discovered and produced by chemical industry, throwing out further challenges to natural products. Already many natural flavourings, essences, and spices are competing unsuccessfully with synthetics. In addition, silk, cotton, rubber, and fats are being challenged by alternatives or substitutes arising from the combined skills of the chemist and the engineer. Before long it is not too much to expect synthetic tea, coffee, and cocoa. Since all these commodities are vital to the economies of some of the developing countries, further deterioration in their trading position and further difficulties in improving their living standards can be expected.

You may well be asking at this point, "Well, what is the answer?" The answer does *not* lie in suppressing or limiting scientific and technological advances in the rich, industrialized nations. This would be impossible, anyway. The answer lies firstly in a clearer recognition of the ways in which those advances hamper the export opportunities, agricultural development and economic advancement of the underdeveloped world. These should form the basis for appropriate fiscal and capital investment policies, international trading agreements and price control mechanisms specifically directed at remedying the increasing disparity in prosperity between the developed and the underdeveloped world. The need for such measures is highlighted by the President of the International Monetary Fund's recent statement that aid from the industrial countries in proportion to income declined last year for the fifth year in succession.

The second part of the answer to the problem must come from a more informed

and more realistic approach to the technical needs of agriculture in the developing countries. Most of these countries lie in the tropics or sub-tropics, whereas modern agricultural science is overwhelmingly a product of temperate regions. Many of the failures in agricultural development schemes and much of the disappointment with the results of technical assistance programmes in the underdeveloped countries can be traced to a failure to recognize sufficiently this simple fact. Temperate zone technology can rarely be applied directly to the tropics, quite apart from the profound social, educational, and organizational differences that exist.

Before discussing some of these differences I will spend a few minutes documenting the disturbing disparity between the agricultural productivity of the rich, technically-advanced countries and the countries of the underdeveloped regions.

Comparative crop yields in developed and underdeveloped countries

Since yield data for cereal grains are more complete and more consistent than those of most other crops, I propose to use these as a means of comparing crop yields in developed and underdeveloped countries. The cereal grains have the further advantage of being grown over a wide range of soils and climates, of accounting for over 70 per cent of the world's total harvested crop area, and of supplying some 53 per cent of man's supply of food energy when consumed directly. They, of course, supply much more than 53 per cent when account is taken of the large amount of grain consumed indirectly by man in the form of milk, meat, and eggs.

The three major food grains are rice, wheat, and corn or maize, in that order. The actual average yields per acre of these grains in the major producing countries, and the changes in yields per acre over the 25-year period stretching from 1935–39 to 1960–62, have recently been studied by Lester Brown and presented in an outstanding publication from the United States Department of Agriculture Economic Research Service, entitled "Increasing World Food Output—Problems and Prospects". Data extracted from this publication for selected countries typical of different levels of technical development are set out in Tables 1, 2, and 3.

The figures in these tables tell essentially the same story for rice, wheat, and corn. They reveal striking differences between the rich, industrialized countries and most of the poorer, underdeveloped countries. The former have achieved substantial sustained increases in the period under review, whereas the poorer countries, with some significant exceptions which tell a story of their own, have either failed to achieve comparable increases or their average yields per acre have actually fallen. A few examples can be quoted to illustrate this dismal disparity. Thus between 1935–39 and 1960–62 rice yields rose from 22 to 35 cwt per acre in the USA, while in Thailand they fell from 13 to 12 cwt per acre. Over the same

TABLE 1.—Rice Yields in Selected Producing Countries[1]
Change from 1935–9 to 1960–2

Country	Yield per Acre[2]		Change from 1935–9 to 1960–62	Annual Compound Rate of Change
	1935–39	1960–62		
	cwt	cwt	per cent	per cent
USA	22·4	35·0	+56	+1·9
Japan	34·1	43·1	+26	+1·0
India	11·6	13·6	+17	+0·7
Pakistan	13·0	14·6	+12	+0·5
Brazil	12·9	14·4	+12	+0·5
Thailand	13·5	12·4	− 8	−0·3

[1] Each country has 1 million acres or more in rice.

[2] In terms of rough rice.

TABLE 2.—Wheat Yields in Selected Producing Countries[1]
Change from 1935–39 to 1960–62

Country	Yield per Acre		Change from 1935–9 to 1960–62	Annual Compound Rate of Change
	1935–39	1960–62		
	bushels	bushels	per cent	per cent
Australia	12·9	18·4	+43	+1·5
Canada	12·2	20·9	+71	+2·3
France	22·8	39·6	+74	+2·3
USA	13·2	25·1	+90	+2·7
Mexico	11·5	25·3	+120	+3·3
Brazil	10·5	10·3	− 2	−0·1
India	10·7	12·4	+16	+0·6
Pakistan	10·7	12·1	+13	+0·5

[1] Each country has 2 million acres or more in wheat.

TABLE 3.—Corn Yields in Selected Producing Countries[1]
Change from 1935–39 to 1960–62

Country	Yield per Acre		Change from 1935–9 to 1960–62	Annual Compound Rate of Change
	1935–39	1960–62		
	bushels	bushels	per cent	per cent
USA	25·0	60·2	+141	+3·7
France	26·9	42·8	+59	+2·0
Brazil	21·5	20·8	− 3	−0·1
Mexico	9·0	13·7	+52	+1·8
India	13·0	14·6	+12	+0·5
UAR (Egypt)	39·5	32·6	−17	−0·7
Indonesia	15·5	14·6	− 6	−0·2

[1] Countries with 1 million acres or more of corn.

period average wheat yields rose from 12 to 21 bushels per acre in Canada, while in India and Pakistan they rose slightly from nearly 11 bushels to little more than 12 bushels per acre. The disparity is even more striking with corn, due to the impact of hybrid corn in the technically advanced countries. Thus average yields of corn in the USA rose from 25 to 60 bushels per acre while, during the same 25-year period, average yields in Indonesia fell from 15.5 to 14.6 bushels per acre.

The individual differences between selected advanced and less-advanced countries in respect to grain yields per acre, which I have just cited, are reflected in the overall position. In North America, the most advanced region technically, yield per acre of all grains increased 109 per cent in the last quarter of a century; in Asia, the least advanced region, it increased only 7 per cent; and for the entire less-developed world it rose only 8 per cent.

The factors responsible for what Lester Brown calls the "yield take-off" phenomenon in the developed world and the absence of any such phenomenon over the greater part of the underdeveloped world are many and varied. Three of the most important are the degree of literacy, the average level of income per person and the extent to which commercial or market-oriented agriculture, as distinct from subsistence farming, exists in a particular country. It is significant that those countries which have achieved a yield per acre take-off are those with a highly literate population, with relatively high average per capita incomes and with a highly developed market-oriented agriculture.

Conversely, most countries which have failed to achieve comparable yield-per-acre increases are characterized by significantly lower literacy levels with a consequent slowing of the movement of new ideas and techniques into farming; by low average incomes and a predominantly subsistence-type agriculture, so that cash returns are low and the purchase of yield-raising inputs like fertilizer and pesticides is limited or non-existent.

The situation just described emphasizes the point I made earlier in this address. The special problems of agriculture in the developing countries are not merely technical, they are rooted in the educational and land tenure systems and in the degree of development of the non-agricultural sector of the economies of those countries. In other words, improved production from the land cannot be isolated from improvements in education, in social and economic organization, in marketing and credit facilities and in industrial technology. Some of these changes must come from within the poorer countries themselves but these can only be really effective if the rich nations devote an increasing proportion of their resources to the task.

What can we do?

In my concluding remarks I want to make some more specific suggestions for action. I will not devote any time to various intriguing long-term possibilities such as the building of huge nuclear-powered desalination plants on sea-coasts to provide water for large-scale irrigation or to large industrial plants for artificial food production by synthesis from oil or coal or by controlled microbial growth. These are matters which are likely to engage our attention in the years to come. In the meantime let us look at what can be done to raise agricultural productivity in the underdeveloped world by more conventional means.

The most striking example of what can be done in this way comes from Mexico. In 1943 the Rockefeller Foundation, in collaboration with the Mexican Ministry of Agriculture, initiated a research programme designed to increase the production of the basic food crops of the Mexican people—wheat, maize, and beans. The outstanding success of this programme has been told in a remarkable paper by Norman Borlaug entitled "Wheat, Rust and People". In 1943 Mexico imported wheat and its average yield was only 11 bushels per acre. By 1956 it became self-sufficient in this grain. Today the national average yield and production is four times as high as it was in 1943 and is continuing to increase at a spectacular rate.

What are the key factors in this extraordinary success story and what are the lessons we can learn from it? Firstly, there has been continuity of effort over a long period, with scientists and others working *in* the country being assisted and *with* the people of that country. Most of the highly qualified scientists recruited by the Rockefeller Foundation have been full-time, active participants in the programme who have identified themselves with the basic problems of Mexico—they have not been fly-by-night visiting consultants. Secondly, research was initiated from the outset on a broad front. It was recognized that soil fertility, irrigation, and moisture management, disease and pest control and general farming practices, as well as varietal improvement, are all vital parts of the whole production complex. The third key factor was the continuous training programme whereby a team of Mexican scientists has been trained to undertake an increasing proportion of the work and eventually to assume full responsibility for it.

The most exciting and the most hopeful aspect of the Rockefeller programme in Mexico is its potential for other developing countries. During this year the Indian Government has bought 18,000 tons of seed of the new Mexican dwarf or semi-dwarf varieties, with their high yield potential and their capacity to respond to heavy fertilization without serious lodging. Already the Mexican varieties have been used to produce improved local varieties and at present 6,000 acres of this local wheat are being sown for seed increase in India. Similar work, sponsored by the Rockefeller Foundation, is proceeding in Pakistan, where the representative is a Mexican trained in the Mexican programme. Dr Borlaug claims that there

are no *technical* reasons why yield per acre and national production of wheat in India and Pakistan cannot be doubled within 8 years and tripled within 12 years. Such fantastic increases will only be achieved if the lessons of the Mexican programme are learned in respect to continuity of effort, to breadth of approach and to training of local personnel. In addition, large inputs of capital and industrial expertise from the western world will be necessary to greatly increase fertilizer production in those countries, so that the yield potential of the new varieties and new practices can be realized.

Let us now turn from the lessons of Mexico to the lessons of Japan. The Japanese have raised the yield of rice from less than 15 cwt per acre 50 years ago to over 30 cwt per acre at the present time. As a result Japan now produces the bulk of the food required by its large and dense population, even though the country is small and mountainous and is still farmed in tiny units with immense expenditure of labour. Labour inputs per acre are several times higher in Japan than in most other Asian rice-producing countries but so are the yields per acre. The additional labour is used to raise yields by adopting more intensive cultural practices, so that weed control is more effective, less seed is wasted, the growing periods and irrigation periods are shortened and water requirements are reduced. However, more fertilizer is required to take advantage of these practices.

The experience of the Japanese is of great significance to many underdeveloped countries where rice is a major food crop and where human labour is the most abundant resource. The success of the western world in raising crop yields and reducing costs by farm mechanization and the application of external sources of power to the land has led to the assumption that such a technology is a *sine qua non* of agricultural progress in all countries. In the long term I believe this to be true but we should realize that large-scale farm mechanization will be impossible in most of the underdeveloped countries for some years to come for at least two reasons. The first is a shortage of capital, of technical training facilities and of industrial expertise. The second is a rapidly rising farm labour force —an inevitable product of the population explosion—which cannot equally rapidly be absorbed into other occupations. This excess farm labour must therefore be employed on the farm. The agricultural technology of most of the underdeveloped countries, and the attitude of western agricultural experts towards these countries, must be adjusted, for at least a generation, to these incontrovertible facts. Far more attention needs to be given to the possibilities of using human labour more effectively to raise crop yields. The Japanese success with rice provides a useful model which is surely capable of adaptation to other countries and is certainly worthy of more intensive study.

The two success stories from Mexico and Japan are not the only ones with important lessons for the underdeveloped countries. I could also mention, from my own experience, the dairy industry in Puerto Rico, the citrus industry in Israel and the cotton industry in Northern Nigeria. However, Australian agricultural scientists and farmers have certain notable successes with great potential for the underdeveloped world. I propose to conclude this address with some reference to these examples from our own country.

Opportunity for Australia?

During the last quarter of a century an agricultural revolution has taken place in southern Australia, through the development of productive leguminous pastures on huge areas of inherently poor soils. This has been brought about through agricultural research and extension which have (a) defined the significant limiting factors in the soil, that often include the trace elements, zinc, copper, and molybdenum, as well as phosphate, (b) discovered the special microbial or rhizobial needs of different leguminous pasture species and evolved effective means of inoculation so that these plants provide their own nitrogen requirements and more, thus avoiding or minimizing the need for expensive nitrogen fertilizers and (c) evolved systems of pasture establishment, maintenance, and management, resulting in increased yields per acre of both crops and

stock and in rising levels of soil fertility. Furthermore, equally effective leguminous plants and new techniques are now emerging with great promise for the tropical and sub-tropical regions of this country through the outstanding efforts of CSIRO scientists in the Division of Tropical Pastures in Queensland.

In many of the developing countries soil fertility is at a low level through continued exploitative farming or through the intense weathering and leaching characteristic of the tropics. In addition, artificial nitrogen is in short supply or is beyond the means of most farmers. For this reason more productive leguminous crops and pastures, with the ability to fix their own nitrogen, are urgently needed. Such legumes not only have an important role to play in soil fertility, as they have in Australia, but they are increasingly required in the developing countries as direct sources of protein for human consumption. Lack of protein is the most serious and widespread dietary deficiency for millions of people in the developing world. This deficiency will have to be met largely from plant or vegetable sources, rather than from meat, milk, and eggs, for many years to come, if not for ever, because of population pressure on the land.

Australian experience and Australian expertise in the breeding, selection, inoculation, and management of leguminous plants on poor soils, which are in the forefront of the world, thus assume particular significance for large areas of land in the developing countries. I believe that a unique opportunity exists for this country to make a major contribution to the world food problem in this field. I do not suggest for one moment that our knowledge and our techniques with legumes are necessarily directly applicable to other countries, particularly in the tropics. I do suggest, however, that Australia should accept the challenge. We have the trained scientists and we have the resources to send a team to live and work in one of the developing countries with the scientists of that country, just as the Rockefeller Foundation team has done in Mexico. I can think of no better way in which the agricultural scientists of this "lucky country" could help the people of countries less fortunate than our own. Australia is not populous enough or wealthy enough to contribute large amounts of capital to these countries, compared with the great, industrialized nations of the world but it is rich in the science and technology of the land. It is in this field that we have the best opportunity to make our contribution to the most critical problem that has ever faced the human species through the long and moving pageant of history—the problem of "man, land. and food".

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