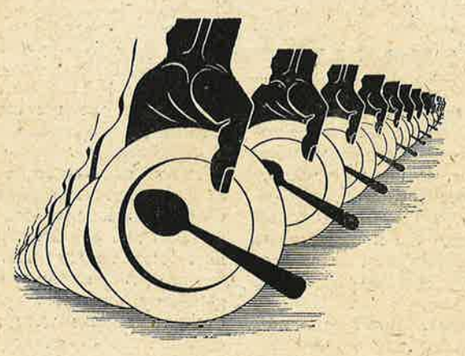
of what may be called our high-grade capital; but it should postpone the final onset of bankruptcy by making available to industry the low-grade capital which it now costs us too much to spend. In combination with a reasonable population policy, a reasonable policy for the use of atomic energy might permit some better version of our industrial civilization to achieve stability and a certain permanence.

Applied science can indeed be used in the fight for liberty, no less effectively than in the fight for peace. Let us assume, for example, that a means will be discovered for substantially increasing the supply of food. This would have the same kind of result as the discovery of a second New World. It would make life easier for the inhabitants of overcrowded countries and, by doing so, it would remove the necessity for some of the centralized and peremptory social controls which must always be imposed when the pressure of population upon resources becomes excessive.

Meanwhile, every day brings its quota of some fifty-five thousand new human beings to a planet which, in the same period of time, has lost through erosion almost the same number of acres of productive land and goodness knows how many tons of irreplaceable minerals. Whatever may be happening to the superficial crisis, to the crisis on the political, or industrial or financial levels, that which underlies it persists and deepens. The current almost explosive growth in world population began about two centuries ago and will continue, in all probability, for at least another hundred years. So far as we know, nothing quite like it has ever happened before. We are faced by a problem which has no earlier precedent. To discover and, having discovered, to apply the remedial measures is going to be exceedingly difficult. And the longer we delay the greater the difficulty will be.



THE WAY OUT?

by Sir John Russell
OBE, DSc, FRS

President of the British Association. Director of the Rothamsted Experimental Station, 1912-1943, and Chairman of Agriculture Sub-Committee of UNRRA, 1941-45.

1

THE PROBLEM RE-STATED

AS ONE WOULD EXPECT, Mr. Huxley's thesis is extremely ingenious and well argued. I disagree completely with most of his conclusions, though there are some with which I fully concur, in particular the necessity for more food production.

My thesis will be that the way of mankind has always been and in all human probability will always be hard; that only by strenuous and well-directed work can our problems ever be solved; that we cannot foresee the difficulties and dangers we shall meet but we can train ourselves to meet them with courage, intelligence, and an unconquerable faith that we can overcome them. Science and technology are necessary but not enough: there must be a driving force and a conscious purpose for which to strive; but given all these I am convinced that man can conquer his difficulties as they arise. But, I repeat, the task will always be hard: the old commandment will always hold true: "In the sweat of thy face shalt thou eat bread." The consolation is that in facing and overcoming difficulties men rise to their highest stature.

At the outset I must emphasize the impossibility of setting any limit to the world's resources. Estimates made forty years ago are in most cases far below those that would be made now. New advances in science have opened up great and unsuspected possibilities of new sources of energy, of more intensive food production, and of obtaining desirable materials out of something previously regarded as useless. The union of science and technology is so recent that no one can forecast the results.

The pitfalls of prophecy

It is equally impossible to forecast the world's population over any long period. Judging from the past, it seems safe to assume that where standards of living rise birth-rates tend to fall and the proportion of older people tends to increase: on the other hand, among peasant populations where children are an economic asset the birth-rate is high but the value put upon individual life is small. These simple generalizations are complicated by political and religious factors, but the declared aim of all governments is to raise the standard of living of their people. In general, where this is achieved the birth-rate is likely to fall.

I shall deal mainly with world food resources: these depend on the amount of land available, the use to which it is put,

and the size of population that has to be fed. The world population is estimated at about 2,200 millions and the present rate of increase at about 20 millions per annum. I shall assume that this rate continues.

Is there enough land to feed us?

The total land area of the world is about 36,000 million acres, but only a fraction of this can be cultivated. The estimates vary because the cultivated land, especially grasslands, merges into the uncultivated, and no consistent line of demarcation can be drawn. Fawcett (1930) estimates that about 30 per cent.[1] is climatically suited for food production, Prasolov (1946) that about 10 per cent. is actually so used, and Pearson and Harper (1945) that about 4 per cent. (1,400 million acres) is used for human food crops (i.e. excluding hay-fallows, etc.). These figures are not incompatible, but they are necessarily only very rough approximations.

The amount of land needed per head in order to provide the accustomed dietary varies less than might be expected. The chart opposite shows how the actual land available varies considerably. In Europe, countries with less than about 1½ acres per head of arable and tended grass lands have to import food[2], while those with more usually produce a surplus for export. The amount and kind of food produced per acre varies considerably in the different countries; it is much higher, more varied and more attractive in Great Britain and North-West Europe than in Central Europe, and still more than in Southern and Eastern Europe and the U.S.S.R., but the standard of living varies in the same way.

Fears of food shortage

The food problem is most serious in Great Britain, North-West Europe (excepting Denmark) and India. The possibility of trouble was foreseen by Malthus in 1798, but the fears were allayed by the opening up of North America, the potentialities of which were not fully recognized in his time. For many years the new lands were brought into cultivation at the average rate of two new acres for each head of white population increase. Instead therefore of the Malthusian hunger, the world food markets were abundantly supplied; peace and plenty abounded; there was a lively spirit of optimism and a firm belief in the progress of mankind upwards and onwards for ever.

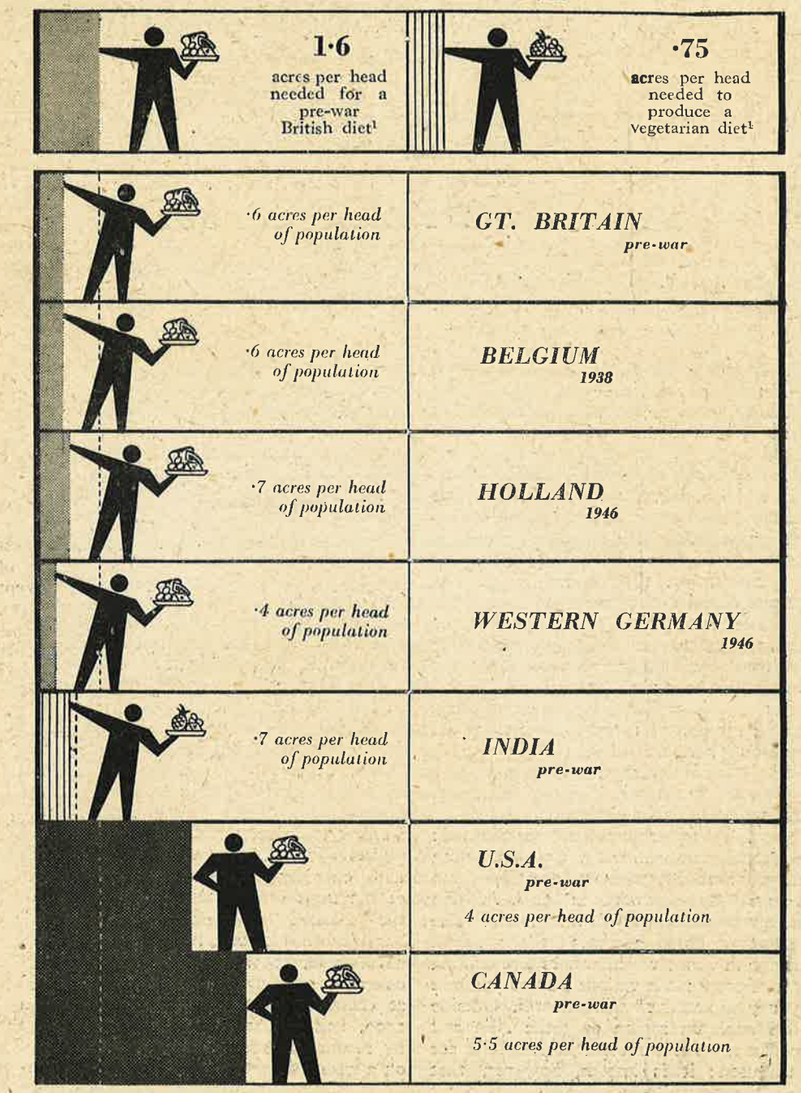
At the height of this boom came a second warning. At the Bristol meeting of the British Association (1898) the president, Sir William Crookes, pointed out that the easily cultivable virgin lands of the world had nearly all been taken up; and unless yields were improved the growing population of the world would be faced with hunger about the 1930's. He suggested that the way out of "this colossal dilemma" was to increase enormously the production of nitrogenous fertilizers, and he showed how this could be done by the fixation of atmospheric nitrogen. These fertilizers would ensure adequate food supplies.

Few addresses have aroused more interest or been more fruitful. The fixation of nitrogen, only a small laboratory experiment in Crookes's time, is now a vast industry, and enormous amounts of nitrogenous fertilizers thus produced are used in many countries, adding greatly to the world's food supply. By a curious trick of Fate, however, these fertilizers did not solve the wheat problem as Crookes had anticipated, because wheat is usually grown in moderately dry conditions in which nitrogenous fertilizers are not very effective. The main difference was made by wholly unexpected developments which greatly extended the area of cultivable land, and when the 1930's arrived, instead of the expected shortage of food there was such a glut as seriously to embarrass the world markets. This, of course, was only a market surplus, not a surplus in relation to human needs.

[1] Pearson and Harper (1945) give 34 per cent. as the area receiving adequate and reliable rainfall: 15 or more inches, except in equatorial areas of high evaporation, where 40 inches are needed. This is the essential condition for agriculture.

[2] In discussing available land the arable and tended grass areas should be added together, because they are usually largely interchangeable. Arable land produces more food per acre: grass land produces it more cheaply with less labour. The dividing line is set by economic considerations.

FOOD PRODUCING LAND



[1] *These two estimates of needs are more cautious than Mr. Huxley's 2.5 acres, suggested on page 4.*

Fears of impending shortage have been recently revived by Sir John Orr, first director of the Food and Agriculture Organization : a flood of literature has resulted, some pessimistic, some sensational, some scientific. But Sir John has raised a new problem : the need for rectifying the under-nutrition from which a large part of the world suffers.

2

MORE LAND TO GROW FOOD

Expanding into the dry regions

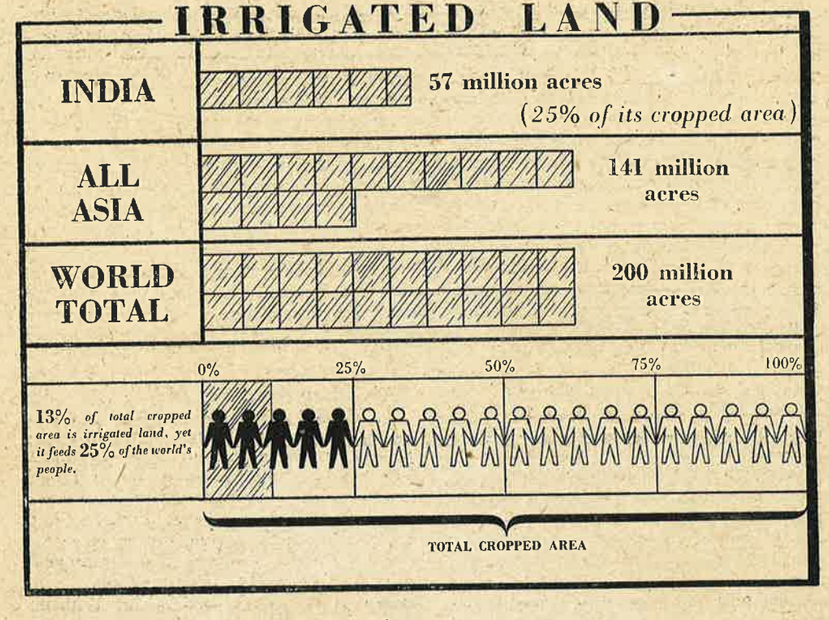
The customary methods of farming break down when the annual rainfall is less than about 18 inches. The North American pioneers who pushed westwards beyond the 18-inch region — particularly the Mormons—met the difficulty by developing methods of soil management which conserved moisture, and by modernizing the ancient art of irrigation ; these methods were all empirical, for science had not yet come into the picture, but they worked. Dry farming methods were extended to Canada and Australia. New varieties of wheat were bred tolerant of dry conditions ; others were produced for the northern part of the cultivable zone of Canada, where the summer months are good but the killing frosts come in autumn before the older varieties are ripe : the new sorts ripened earlier. This work still goes on and the U.S.S.R. has now entered the field ; the range of cultivation widens still.

The most effective way of overcoming dry conditions, however, is by irrigation. The extent of irrigated land is shown on page 17. Two general methods are adopted : from canals and from wells. Canal irrigation is largely concentrated around the Himalayan rivers flowing southwards in India, Pakistan and Burma and eastwards into China. The greatest of these schemes is the Lloyd Barrage in Sind, which waters five million acres of crops ; the various Punjab schemes water in all nearly 18 million acres. Outside this Himalayan region only the Nile and the Murray River system in Australia are much used ; it is known, however, that the Tigris-Euphrates system has great possibilities for the future.

River valley developments, on the pattern of the Tennessee Valley Authority, are under way in many parts of the world. In such projects as Brazil's San Francisco Valley Authority, French West Africa's Niger River Authority, and Mexico's Papaloapan River Commission, irrigation is but one factor in a unified system of power, flood control and soil rehabilitation.

The other method, irrigation from wells, also very ancient, has been greatly improved by the tube wells first developed in California and much used by Sir William Stampe in India. It is difficult to believe that irrigation need be so localized as at present, and Stampe has urged that the possibilities in Africa, Arabia and the Middle East should be investigated.

Irrigation schemes are, however, particularly difficult to manage properly, requiring high technical and scientific knowledge and much probity in administration ; any failure may lead to waterlogging, salt damage, malaria and other troubles. Intensification of cropping greatly increases the liability to insect pests, fungus, virus and physiological diseases which can be dealt with only by competent scientists. One of the most serious troubles following on the so-called "conquest of the drought" has been soil-erosion ; for long it was hardly perceptible, it was not included in the comprehensive symposium on wheat held at Winnipeg by the British Association in 1909, and was unfortunately made worse by recommendations of soil experts based on a wrong theory of the moisture relationships of soil—a striking instance of the



need for a sound scientific basis for advice given to farmers. By 1935, however, it had become so serious [1] that a Soil Conservation Service was set up in the United States ; similar services have also been established throughout the British Commonwealth. Methods of prevention and rehabilitation have now been devised and are being continuously improved ; much of the land has been restored. Soil-erosion is no longer the menace it was—though constant watch by experts is needed.

Widening the temperature range

Canada led the way in pushing the wheat belt further north into the regions where the summer, though hot enough for the growth of wheat, did not last long enough to allow of ripening. Varieties were bred of shorter-growing period that ripened before the first killing frost came : the first yielded poorly but this difficulty is being overcome.

The possibilities of the regions still further north are being studied by the United States in Alaska and by the U.S.S.R. While no surpluses could ever be expected there is the hope of producing more and better food for those who live there.

At the other extreme, cultivation is being pushed into the hotter regions in Queensland. Beef production has long been practised there and in the Northern Territory, at first by ranching, later, in places, more intensively. Expansion is possible but would require improvement of transport, living conditions, and pasture management not at present considered worth while.

A large scheme is projected for the production of millet for which a market as livestock food seems assured. The most ambitious schemes, however, are in Africa and will be referred to later.

[1] It was reported that 330 million acres out of the 460 million acres of good arable land in the United States had suffered—some drastically. In Australia about half the wheat land was said to have been affected.

Science and wheat production

The beneficent results of applying science to agriculture are well seen in wheat production. This is really a dry region enterprise; under better moisture conditions livestock husbandry is more remunerative. The result is that extensions of the wheat area are made into the drier regions, and this should mean a lowering of average yield per acre. But the improvement in soil management, and the new varieties continuously being produced, have obviated this, and even the arch enemy, rust, a fungus disease that for long set a limit to wheat growing, can now be avoided by producing rust-resistant varieties.

Figures of wheat-growing land and yields per acre for some of the largest exporting countries (and for the U.K.) are shown in the chart opposite. The lack of expansion of the wheat area in Canada, Argentina and Australia during the past 10 or even 20 years is not evidence of lack of suitable land. Various estimates have been made of enormous areas that could still be cultivated. Production is limited by the transport and storage facilities available. Canadian farmers in 1940 grew 28.7 million acres of wheat in response to Europe's need, but the difficulties of storing and marketing were so great that in 1943 they sowed 16.8 million acres only. Australian farmers suffered similarly during the first world war. Provision of these facilities is a costly business which can be undertaken only when a permanent demand seems assured.

The United States also greatly increased its production of wheat during the war, and from being only a small exporter, or even an importer, has during the war years produced an additional 300 million bushels, much of which was exported.

There seems every justification therefore for expecting that the great wheat-supplying countries can expand their production considerably if the need arises.

Wheat is rarely the sole product of a farm: other crops, often oats and barley, are grown in rotation with it. These grains are largely fed to the farm livestock as are also wheat offals, so that in providing food for men the wheat growers provide also for the farmers' animals.

There is, however, no justification for hopes of supplying wheat to peoples that have not hitherto eaten it, apart, of course, from any they can grow themselves. At present yields, one acre of wheat in the exporting countries (about 15 bushels per acre) supplies the needs of about three people; the pre-war world wheat area of 360 million acres with an average yield of 14 or 15 bushels per acre provided for about 900 to 1,000 million people, and the prospective increase in supplies should keep pace with their natural increase (which is below the world's average), but with no margin for more than occasional emergency supplies to those who normally eat other grains.

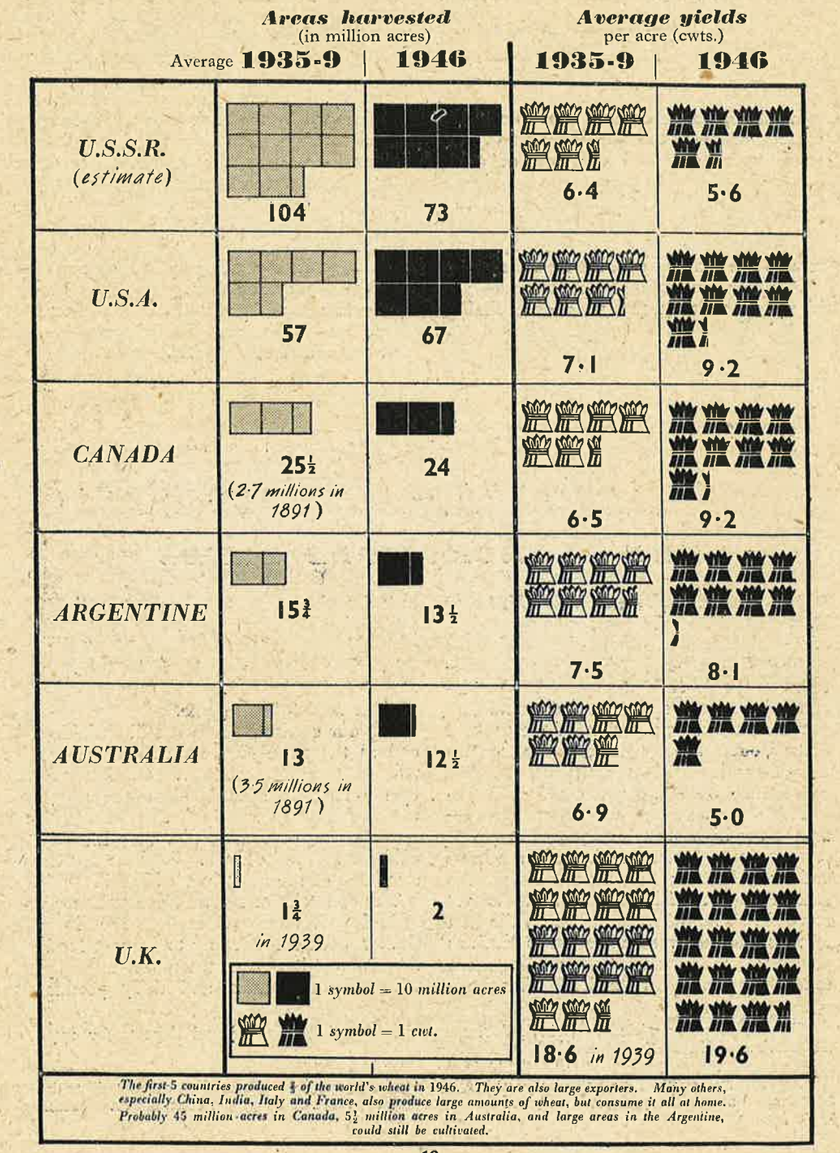
The other food grains

Of these the three chief are maize, rice and the millets. Maize is very fully studied in the United States, its chief producer, and the remarkable results obtained in recent years with the new hybrids give hopeful promise for the future. The millets have not yet been adequately studied. Their tolerance of hot, dry and poor conditions make them extremely important as food in the semi-arid hot regions of India and Africa. We have a special responsibility for them: they are almost a virgin field for the geneticist and plant breeder, but the pioneering investigations promise no easy or spectacular successes. Rice is more important because rice eaters probably outnumber the wheat eaters. It has been much studied in India in recent years and already the yields on the experimental farms are not uncommonly double those obtained by the neighbouring peasants.

Lands still undeveloped

Few tropical regions are suited for white men's habitations, and such developments as have occurred have been by British, Dutch and Belgian planters producing valuable products, tea, rubber, oil seeds, etc., that require tropical conditions. Some upland regions, however, are habitable. British colonists have settled in Kenya since the first war and developed mixed farming; some settlement also is possible in Tanganyika. There is no possibility of a large migration of European populations

CAN WE INCREASE WORLD WHEAT SUPPLIES?



The first 5 countries produced ¾ of the world's wheat in 1946. They are also large exporters. Many others, especially China, India, Italy and France, also produce large amounts of wheat, but consume it all at home. Probably 45 million acres in Canada, 5½ million acres in Australia, and large areas in the Argentine, could still be cultivated.

such as occurred in the nineteenth century, but very considerable quantities of food can be produced, especially oil seeds that cannot be grown in temperate climates, and also meat—probably, however, of inferior quality.

Hitherto, the difficulties have been the noxious insects, the uneven ground and scrub vegetation, and the lack of easily accessible water supplies. Modern insecticides[1], bulldozers and other large agricultural implements, and well-sinking tools can overcome all these at a price, but there remain the farming problems: working out a cropping system that will conserve and improve the naturally poor soil, finding or breeding suitable crop varieties, and coping with the diseases and pests that will most certainly come. All these can be dealt with if the scientific workers are given time and equipment for the job.

A large-scale enterprise recently undertaken in Tanganyika to reclaim some of the $3\frac{3}{4}$ million acres of waste bush and plant it with groundnuts to supply much-needed vegetable oil has, unfortunately, been gravely handicapped by the haste with which it was forced through. No time was allowed for the small-scale experiments needed to discover the unforeseeable difficulties or to find the best varieties, and in consequence the scheme has proved very costly and somewhat ineffective: in place of the 600,000 acres forecast by the political chiefs for 1948-49, little more than 53,000 acres have been planted, and only just over half were groundnuts, the rest being sunflowers. The scientific and technical staffs are in no way to blame, and given time can be expected to overcome the difficulties.

3

THE OVERCROWDED LANDS

(a) Great Britain and N.W. Europe

England and Wales had in 1947 a population of 43 millions, and it was increasing; the cultivated area per head was 0.56 acres—some 50 yards each way—and it was decreasing (see page 15). The area would have provided about 35 per cent. of the pre-war dietary, but by lowering the dietary and modifying the agricultural system it is now possible to produce about 40 per cent. at home.

Yields per acre and output per man are among the highest in Europe and are three or four times greater than in Eastern Europe and the U.S.S.R.; they are still rising. No British expert believes the limit is yet reached[2]. The difference between the best farmers and the average is often as much as 50 per cent., and great efforts are being made to level up to a higher standard. The aim is to raise the present 40 per cent. home production to 50 per cent. by about 1952, and there is a reasonable hope of attaining this. The system would still be based on livestock, but it is hoped to produce more of their foodstuffs at home.

But our cultivated area is still shrinking, and as the population rises more imports will become necessary; not, however, beyond the visible possibilities of the exporting countries to supply. The inexorable condition is, of course, that they must be paid for by harder work. Without this the standards of life must inevitably fall.

The countries of North Western Europe, including Western Germany, are in a similar position, needing to import food; they were, however, taken as a group, self-sufficing in meat and dairy produce before the war. There was then so much movement of grain from the Danubian countries and Poland to the West that the net European deficit[1] of wheat and rye amounted only to about 5 per cent. of the total consumption; an import of 3.7 million tons only was needed to supplement its own production of 59 million tons. The 16 countries (including the U.K.) associated in the Marshall Plan before the war imported some 14 million tons (515 million bushels), including the Eastern European supplies; disorganization caused by the war has increased the need, but agricultural recovery is proceeding more rapidly than was expected. If the former east-west movement of grain is restored Europe's bread supplies will be secure, but unpredictable political factors come into play. There is no physical reason why North Western Europe should suffer food shortage as long as there is peace.

(b) The Indian problem

Of all the food problems of the world, India's and Pakistan's are probably the most difficult. The population has grown rapidly, from 306 millions in 1921 to 338 millions in 1931 and 389 millions in 1941: increases of 10 and 15 per cent. respectively. It is almost impossible to get exact figures for crop yields in peasant countries, but nutrition surveys suggest that some 20 to 22 ozs. per head daily of all grains were available before the war, corresponding to 2,000 to 2,500 calories daily, without counting vegetables, milk products, sugar, etc. Population increases at the present rate would, unless yields rose, require an additional 3 or 4 million acres of food crops each year. There still remains uncultivated land equal in area to about 70 per cent. of the cultivated land, some of which can be utilized. But the greatest hope is by increasing the ryots yields, now often much below those attained on the experimental farms. More irrigation, more fertilizer, better cultivation and better seed are all being developed.

India's rainfall, however, is always uncertain, and importation of rice is always necessary. There are abundant potential supplies in Burma, Siam and Indo-China, but recently they have not been forthcoming. A difficult human problem thus arises. It seems impossible, however, for India's food problems to be solved if the population goes on increasing at its present rate.

The double task

Increasing output per man, and output per acre, in the old occupied lands is really the crux of the world food problem; for it is estimated that some 90 per cent. of the world's food is consumed in or near the land of its production and only about 10 per cent. is put on to the world market; further, that about 70 per cent. of the world's population are food producers or their direct dependants. It is this 70 per cent. who determine the fate of the remaining 30; presumably they would be the last to feel the pinch of hunger should it come. Most of them are peasants, their chief produce is grain, and much of their farming is very inefficient, with no great possibility of improvement as it stands.

There are no longer peasants in Great Britain but there were up to the 18th century, and their systems and output were on a level with those of the present-day peasants of Eastern Europe. Great Britain then changed its system; farms of a size that one man with his helpers could efficiently manage were established; livestock and arable husbandry were blended together and output per man and per acre rose and are still rising as we have already seen. Denmark effected the change later; the farms had to be smaller, but a system of co-operation has been developed which has led to high efficiency of production and a standard of living that is the envy of most of Europe and far above anything in Eastern Europe and beyond.

The fundamental difference between the peasant and the Western farmer is that the peasant is a self-sufficing unit producing mainly for himself and his family, selling only his surpluses, while the Western farmer is producing for the market; he usually becomes a specialist; but he is

[1] For the present position in British Africa see the Colonial Office Annual Reports for 1946. (H.M.S.O., published in 1948.)

[2] Agricultural production in the United Kingdom in 1947-48 was officially estimated to be 25 per cent. above the pre-war level, and for 1948-49 is expected to be 35 per cent. above. (Cmd. 7545, Oct., 1948.)

[1] Excluding the U.S.S.R. The United Kingdom produced 1.7 million tons of wheat and imported 5.6 million tons so that the total European and United Kingdom imports amounted to 9.3 million tons, or about 340 bushels.

dependent on a stable and assured market, and his products must satisfy the market requirements. Education and co-operation are essential. But industrialization or an emigration outlet is needed also, for agriculture alone can never fully occupy a rural population. One farm worker in Eastern Europe and the U.S.S.R. produces food equivalent to the needs of some four or five persons, including himself, but in Great Britain and Denmark the production per man is about four times as high, one man feeding perhaps 18 or 20 persons, who thus become available for other occupations.

New methods of farming

An entirely different system, collective farming, has been adopted in Soviet Russia. This requires large areas of land and a special psychology of the workers; it is perhaps better suited for grain production than for livestock.

Peasant farming can undoubtedly be transformed into more highly productive systems capable of producing more food of higher nutritive value and of raising output both per man and per acre.

Meanwhile, the steady advance of science and the practice of agriculture in the more advanced countries can be applied elsewhere when conditions permit. Drainage, better use of fertilizers, better seeds, better control of disease have increased the already high rate of output in Great Britain. Our average yield of wheat is about 19 cwt. per acre (compare this with the much lower yields of the extensively cultivated countries, page 19), and our yield of potatoes is about 7 tons per acre; a good farmer expects at least 50 per cent. higher. The average yield of milk is about 600 gallons per cow, but the good farmer expects 1,000 or more; much higher figures are possible but not usually economical.

There are still possibilities of improvement even in the most advanced countries. Losses due to insect pests and diseases are still high; the current estimate (which is little more than a guess) puts them at 10 per cent. in Great Britain, while livestock diseases are estimated to lose us about 6 million full year's rations of meat, 200 million gallons of milk and 1,500 million eggs[1]. The Food and Agriculture Organization has estimated that mites, pests and rodents destroy some 65 million tons of the world's grain per annum—more than the entire wheat and rye supply for all Europe before the war. Moreover, even in the most closely settled countries there is still unused land and in present economic conditions its area has tended to increase.

4

PROSPECTS FOR THE FUTURE

Two sets of problems are involved in world supplies: the rehabilitation of European agriculture, and the expansion of our present agriculture to supply a world population increasing at its present rate. The first of these should fairly soon be accomplished; first grain supplies, then, more slowly, dairy produce and meat should come back to pre-war level, though political factors may hamper the east-west exchange of food and commodities that secured the near-equilibrium of pre-war days. The permanent expansion of food production can be achieved by increasing the area under cultivation, by increasing the output per acre, and by reducing waste and losses. Only about 5 to 10 per cent. of the world's land area is yet used for food production to any extent and there remain considerable regions in the tropics that can be utilized with the help of synthetic insecticides and modern implements. In all countries there still remain areas that could be cultivated should the need arise.

[1] Annual Health Trust Report, Oct., 1948.

The average output per acre is everywhere considerably less than is obtained by the best of the farmers, and much levelling up is possible by education and co-operation; agricultural science and engineering are continuously advancing, and even in the most advanced countries yields are increasing. The causes of the wastes and losses are gradually being better understood and brought under control. As the need arises expansion of food production can continue and it is impossible to forecast how far it can go.

The hard way

Experience shows that food producers will not go hungry in order to feed others; they will produce and part with surplus food only in exchange for commodities and services they desire. Non-producers can look for food only in proportion as they work for it. The increase of food production whether by bringing in new land or adopting new methods is always liable to raise new problems, often difficult ones; hence the necessity for highly efficient scientific and advisory services. Economic factors may help or hinder developments. The change that would most increase food production would be to transform the present predominantly peasant type of rural economy to a mixed farm type as adopted in the more advanced countries.

While increases in food production can be confidently expected, they will certainly involve considerable work and much scientific study. There is no prospect of easy living: the lot of mankind will always be hard. Each nation must either produce its own food or produce goods and services that will induce other countries to produce it for them.

It is impossible to estimate the rate of agricultural progress and therefore impossible to suggest a safe rate of increase of human population. At present rates there is no need to fear shortage in our time, except in India and parts of Africa. The possibilities of scientific advancement are incalculable. What is needed is to put these advances into practice, and to treat the problems internationally. The key to the problem of FOOD AND PEOPLE is international co-operation.