AGRICULTURAL SCIENCES AND THE WORLD FOOD SUPPLY

MISCELLANEOUS PAPERS 3 (1968)
LANDBOUWHOGESCHOOL WAGENINGEN
THE NETHERLANDS

AGRICULTURAL SCIENCES AND THE WORLD FOOD SUPPLY

AN INTERNATIONAL SYMPOSIUM ORGANIZED BY
THE AGRICULTURAL UNIVERSITY WAGENINGEN,
THE NETHERLANDS,
ON THE OCCASION OF ITS GOLDEN JUBILEE
4-6 MARCH, 1968

H. VEENMAN & ZONEN N.V. – WAGENINGEN – 1968

Honorary President of the Symposium

S. L. Mansholt

Organizing Committee

S. J. Wellensiek, president
J. F. van Riemsdijk
Th. Stegenga
J. M. G. van der Poel, secretary

CONTENTS

PREFACE

This preface is no exception to the rule that it is written after the work has been completed. Since the big lesson which was taught by the present symposium is the need for synthesis, this epi-prologue will be an attempt to synthesize both my welcome address and my closing-words.

Fifty years in the history of the Universe is a negligible lapse of time. Fifty years in the history of mankind, however, may be an important period. But fifty years of recent history of a branch of science is certainly a period of the utmost importance. This justifies to consider 'fifty years of agricultural sciences' as the subject of this symposium on the occasion of the 50th anniversary of the Wageningen faculty.

What have been the achievements of these sciences, in general, in plant production, in animal production, in technological production and what will be their development? These are briefly the topics for this symposium. In other words: an evaluation of the present state of agricultural sciences with an outlook on the future.

The five lecturers deserve our great acknowledgement for the excellent treatment of their subjects. Although naturally these subjects and the ways of presentation varied, a general trend can be concluded and this is a need for synthesis, for integration, for coordination, or however it may be called. From and via specialization and analysis we must proceed to synthesis.

During the symposium many exciting developments in all fields of agricultural sciences were discussed. Optimistic sounds regarding the world food supply were heard. But we also learned that more problems remain than have been solved. After having considered the present state of our sciences and after having learned our lesson from this consideration, there is all reason to go back: to work.

S. J. WELLENSIEK,
President of the
Organizing Committee

OPENING ADDRESS

S. L. MANSHOLT

Honorary President of the Symposium,
Vice-President of the Commission of the European Economic Community
(Brussels, Belgium)

'Wageningen' represents 50 years of agricultural science, 50 years of education and instruction. Starting on a national scale, the Agricultural University became in the course of years an institution of world-wide importance. I think that 'Wageningen' could not do better than to celebrate its golden jubilee with a symposium on 'Agricultural Sciences and the World Food Supply', for food supply is a world-wide problem and it demands integrated and international collaboration, not only in scientific development, but also in technical aid, in means of finance and in market organization.

In general, it needs a strong coordinated policy and last but not least a strong world-wide organization with power to handle the problem.

The world population numbers to-day 3000 million people and it is estimated at 7400 million in the year 2000. That means that the world population in the coming 40 years will grow faster than in the whole history of mankind.

Although science is at the base of every development, agricultural science has never been of such a great importance as it is now.

The challenge agricultural science has to face, is not only to feed people, but to feed them better.

Five years ago I said during the celebration of the 700th anniversary of this town: 'The problem is not only a problem of quantity, but it is a problem of time and of the better distribution of the food and also a problem of who will be producing that quantity'.

I am sure that during this symposium we shall hear the answer on these questions from the very qualified technical scientists and economists who are invited.

I will not deal with this subject now, but let me say a few things as a politician who has to deal with the question of 'World food supply'.

I am sure that the development of science in the next decades will not be the bottle-neck. This will be avoided by giving our scientists the absolute necessary tools. That means not only enough financial support and equipment efficacious to the purpose, but also freedom to create. In general, we have to provide the favourable circumstances to work.

However, are we sure that we organize ourselves to bring the fruits of scientific research into practical application?

Here is a real bottle-neck! Of course in the developed countries, there is no problem in this respect, but for the developing countries it is World Problem I. It is there that the population grows faster and it is there that the food supply is lacking. The L.D.C.'s are now exporting 1 billion $ worth, but in the year 2000 they will be importing 35 billion $ worth! How are they to pay for this immense stream of goods?

The answer can be found through export of industrial goods and this will require a tremendous increase of agricultural and industrial production in those countries. Only by means of industrialization, can we rationalize agriculture.

It seems to me that this can be done only by means of a much greater effort than has been exercised up till now. There is an immense need for education, for popularization of knowledge etc. etc. That means much more money for investments than 1% of our national income and a better organization of the development aid.

Here the politicians have a task. They have to build the effective bridge between science and the man in the field.

Our present organizations are not well fitted. We have the FAO, UNCTAD, the UN and they are of good intentions, but they are likely to fail. Years and years have already been lost now through talking, talking, talking.

We are very clever nowadays when we have to organize ourselves in industry and trade, and even when we have to fight a war. Therefore, why are things done so clumsily between states; why are we often so hopelessly behind when the problem of welfare in the world is at stake?

The need for better, more powerful organizations is clear. We are starting in Europe. Let us hope we can accomplish our task instead of growing into old-fashioned nationalists.

What we have to do on world scale is to introduce new institutions with special power (i.e. with a super-national character) in the United Nations Organization.

Only then there seems to be the chance that the world in 2000 will be a better world in which to live in!

With this wish I declare the symposium open.

WORLD POPULATION, FOOD DEMAND AND AGRICULTURAL SCIENCES DURING THE LAST FIFTY YEARS

by

EGBERT DE VRIES

Professor of International Development, Graduate School of Public and International Affairs, University of Pittsburgh

The transformation of the College for domestic and tropical agriculture at Wageningen into full university status, now fifty years ago, was an act of conviction and faith. Conviction that the growing demand for food and agricultural raw materials necessitated concerted scientific research and teaching. Real and threatening food shortages during World War I promoted political action by the Ministry of Agriculture. Faith in the newly developing methods of increasing production and dissemination of results to farmers motivated the faculty. Faith also was prevalent in the integrative and comparative approach at least among students, as a freshman in that year I can remember this vividly. It is significant that Wageningen, almost from its inception, could build upon observations, experiments and experience in the tropics as well as in the temperate zone.

World War I was the end and the beginning of important periods in the field of food and agriculture. The world wide political, military and economic dominance of Europe had come to its end with the exception of Italy and Japan, there were no more colonial adventures – and both were illfated; Western Europe was exhausted. It was no longer assured that Europe could buy all the food and raw materials it wanted and sell what it wanted to sell around the world. It was the beginning of strong economic overseas expansion of the United States and Japan. It was the beginning of the end of a system of free trade and free capital movement.

In one field Europe still had a monopoly, the application of inputs to achieve higher yields per hectare of agricultural land, although Japan also had made a significant start.

Average yields of wheat and maize in the United States had in 1930, before the drop on account of a long dry period, not yet risen above the 1880 in a year level. In cotton, yields started to rise only after 1925. But in some European countries, notably the Netherlands and Denmark, average yields had started to rise, slowly but perceptively, even before World War I and for some crops for half a century.

The end of World War I was the beginning of a one-world society. Agriculture in Europe, in the tropics, in North America and down under lived through a short reconstruction and development boom and a long, sobering deep depression. Governments, including the Netherlands government made frantic efforts to save the farmers from doom, with only partial results. It showed the inadequacy of national policies, and the need for international policies. It also showed the flexibility and resilience of agriculture under adverse circumstances – including survival under stringent government regulation.

Then came World War II with unprecedented destruction in Europe, the Soviet Union and South East Asia. Already during the war, North America became the arsenal for one of the most potent weapons of peace – the food to feed a hungry world. The next phase was reconstruction in Europe and, thereafter the unfinished business of the developing countries to produce sufficient food for their major needs.

In all these events, *food* was a crucial issue, either because of disastrously low prices or because of serious shortages. Regional and world-wide measures became a necessity for survival. Thus, in the field of food and agriculture, mondial problems developed. The turning point in this new concept is the 1942 Hotsprings Conference.

There are some overriding elements in agriculture itself which caused these developments to become inevitable. First of all, I would mention substitutibility and interchangeability of a small number of main products in world trade. There are only 78 agricultural products, excluding ornamental plants, and only 12 major domesticated animals. Technology has promoted the link between markets, notably in fats and oils and in grains through chemical and mechanical processing technologies. This is in contrast to industry, where the variety of products is endless. Traditionally, agricultural prices everywhere are linked to a few world market prices.

But one of the significant phenomena of the last half century is the effort by governments to break these links. In importing countries, levies are being manipulated; in exporting countries an array of export subsidies, export duties and other measures have been invented during the period under review. State controlled and mandatory cooperative marketing organizations have been established in many countries. Although in general aimed at supporting or equalizing prices received by farmers, it seems as if the old characteristic – taillable a merci, still holds for farmers.

Have governments succeeded? Only to a limited degree. In the late twenties, for a number of tropical export-crops, intergovernmental measures have been forged – commodity agreements on rubber, sugar, tea. After the war, international wheat and coffee and other agreements have been tried. But these again have had only a limited success. Nevertheless, the international commodity agreements have been accepted as the beginning of an international orderly marketing process for primary products, notably for agricultural products.

A very important societal variable has changed the food and agricultural situation structurally. During and after World War I, western Europe was the main importer of food. The United States shared in imports of agricultural raw materials but had traditionally a surplus in food. Even during the thirties, western Europe almost had a monopoly as a buyer of food and agricultural products. One could still dream of a 'natural' division of labour, where Europe would export industrial products in exchange for agricultural products. This dream has been shattered.

At present, the so-called developing countries take over half of the net exports of grains, with western Europe and Japan both importing food and exporting manufactured products. But North America is not only the main source of food exports, it also is heavily industrialized and an exporter of industrial products.

The main force in this shift of export-trade to low income countries is the shear movement in population growth – the so-called population explosion.

Until World War II, Europe and North America, the areas inhabited by Caucasians, in United Nations terminology, had a much more rapid population growth. Against 1.5 – 2% increase in these areas, Asia had 0.8%, Africa even less population growth. This has been changed completely. Now Europe is below 1%, and the developing world is approaching 2.5%, Latin America topping the others with 3–3.5%. Coupled with a world-wide effort to develop economically, this has boosted demand for food in the developing world towards a level of over 3.5% compound. We are in the midst of a dramatic process of mutual adaptation to this post- World War II phenomenon.

Thus, our first conclusion can be that the main problems facing agriculture and farmers during the last fifty years have become of a continental and inter-continental nature. They have been economic, social, demographic, political.

The *managerial* problems in agriculture also have shown a remarkable development. Fifty years ago, everywhere, the family farm owner operated, was considered the optimal solution of managerial problems. There were remnants of community owned lands in subsistence agriculture; there were large holdings with tenants, like in Central and Eastern Europe or paid labourers as in South America. These, we were sure, had to make place for the family farm. The only exception, strangely enough also accepted without much questioning, was the tropical plantation.

But exactly fifty years ago, one of the most farreaching experiments in agricultural management, since Joseph in Egypt during the lean years, occurred in the Soviet Union. In Russia, as you know Joseph made all independent farmers serfs of the state. The seignorial and post-feudal owners of land were expelled, but his sharecropper did not long remain the owner. The large holding became a large enterprise, a state operated large enterprise. During the last fifty years, we have seen under the impact of political and social philosophy an unprecedented series of managerial experiments with agriculture in rapid succession. Rural structures, as much as productivity is at stake. Perhaps, in western countries, we have looked too one-sidedly at the political objectives and social implications of the various types of farm management in communist countries. The fact that it has been very difficult to reach all-around satisfactory results has only led to new experiments, not to a return to old structures, anyhow impossible, or the adoption of 'western' types of enterprise.

But in other parts of the world also various new forms have been tried. I might mention the Kibbutz and the Moshav in Israel, the guided land reform in Egypt, the various communal enterprises with state interference and modern machinery in Africa, various 'cooperative' experiments in India and other countries. I might mention the para-state organization in the Gezirah in Sudan and in the former Zuyderzee polders.

In a number of cases, *technological* desiderata have played an important role, especially farm-mechanization. In western Europe and North America, land consolidation rather than subdivision of large holdings became a necessity. But here, the one-family farm, with a small number of labourers, remained the prevailing type. In managerial terms they became more of an enterprise and less of an occupation. And, of course, the majority of holdings in the developing countries were and remained one-family farms with only occasional part-time outside labour.

Thus, basically, it have been managerial changes as well as shifts in demand, change in markets and marketing systems, which have asked for technological innovations and new applications of known technology. Of course, there has been the feedback and the spin-off from new techniques.

Quite a number of *new technologies* have entered agriculture in the last fifty-years, and many of these have been developed in society as a whole, rather than only in agriculture or in the rural areas.

As the impact of the major discoveries and new applications vary from continent to continent, the order I choose today is not necessarily one of overall importance. World War I is a turning point in *transportation*. The development of the truck and the rubber tire – the latter giving rise to a violent rubber boom in the early twenties – made road construction, rather than building railroads, the main infrastructure investment for agricultural development.

In Nicaragua, it brought the cost of bringing products from the mountain villages to Managua per ton mile down from 50 cents on muleback to 5 cents per truck. Roads, and this is very important, are economic at far less volume of traffic than railroads. Rubber tires are, of course, a necessity on trucks and cars, but also bring down transportation cost for animal-drawn traction and save a great deal on road maintenance.

Because area is of utmost importance in agriculture and distance can be translated into cost of production, transportation is one of the most important determinants of farm production – not a new discovery at all, as HEINRICH VON THÜNEN pointed out one century earlier. VON THÜNEN saw this static, however, as he could not foresee a revolution on the road.

It would be difficult to estimate the growth of transportation by mechanic power rather than animal-traction or peoples shoulders, but it must be formidable.

The second technological innovation also dates from World War I – *synthetic nitrogen-fertilizers*. Without these chemical products, we now all would be starving or would have to pay 40% of our income on food. With natural gas or waste from oil refineries, synthetic nitrogen fertilizers come within reach of all countries.

Recent figures on the production of nitrogen fertilizers indicate an annual use of 20 million tons, growing at a rate of about 2 million tons annually.

Europe still uses one third of all nitrogen fertilizers, and since 1950, 1968 will show a three and a half times increase. But in the USSR it was seven-fold in the same period, in North America, Asia and Latin America five-fold. The low 1950 figure for Africa will have grown six-fold in 1968.

Likewise, the use of phosphates and potassium fertilizers, although not growing equally fast, is now around 16 and 14 million tons annually.

In some countries, notably Australia, the scientifically designed use of trace-elements, some 10 or 20 elements which are necessary in small quantities, has transformed agriculture. On geologically old tropical soils and perhaps others as well, a wide field of research and application exists.

Thirdly, I would mention *preservation of perishable products* through refrigeration, down to deep-freeze for many products. This has made the term 'perishable' a very relative term. It enables the production of fruit, vegetables, meat and milk at great distance from the ultimate market. It has brought many more products in the 'world market' category with new opportunities and, of course also sharper competition.

I have not seen world-wide statistics on the spread of the modern storage and food processing industries. There still is a tremendous waste, and although the processes are not inexpensive, a further rapid development of food technology can be predicted with certainty. Of course, we will be introduced into this subject by DR. PARPIA.

Fourthly, great attention is drawn to *mechanization* of farm labour – land cultivation and clearing, harvesting, spraying, dusting and milking and a multitude of other activities are done by machinery rather than animal or hand operated tools. Its application has first of all drastically reduced the number of man-hours work per hectare and enables enlargement of the enterprise with a small number of workers. Its importance depends largely upon the layout of the land – large parcels on flat terrain are preferred, on the size of the farm – enabling both highly capitalized free enterprise and huge collective farms. In the developing countries, where labour often is in surplus, the application of mechanization is much smaller.

Extrapolating somewhat the recent FAO production yearbook, – mainland China excluding – world agriculture now operates about 15 million tractors. Here, the increase in Europe – six-fold since 1950 is very fast. There are another 5 million smaller so called garden tractors with a spectacular growth in Japan.

This implement may find application in many more countries with small plots – rice paddies specifically. Also, there are 2 million harvester/combines and 2 million milking machines. One of the consequences is the substantial reduction of animals, first of all horses, for agricultural use. Esthetically a great loss, but economically necessary.

In these technological changes on and around the farm and in the channels to the consumer, I have perhaps talked too much about developments to be expected. My justification is in the fact that in all the fields mentioned much earlier work in laboratories and research institutes has come out into the open and has changed the agricultural enterprise dramatically.

It may not have been expected, fifty years ago, that mechanical engineering and chemical industries would change agriculture within such a short period as much as the use of the horse drawn plough a thousand years ago, or of irrigation canals six thousand years before.

Now coming to the *performance of* our domesticated *plants* and *animals*, I first of all have to mention changes in their genetic structure on a scientific basis. In wheat, potatoes, sugarcane, maize, sorghum, rubber and rice, to mention a few, great strides have been made. Partly, this relates to productive capacity under optimal growing conditions. But breeding for resistance against diseases – again in cereals, potatoes, sugarcane is at least of equal importance. If I mention only a few staple products, this is not to underestimate the considerable amount of work done on fruits, vegetables and flowers. We are in the midst of far-reaching hybridization experiments and application in grasses and forest trees. These developments have changed and are going to change the productivity of large areas substantially in the next few decades, We will hear about the progress and the potential in these fields to-morrow from DR. DONALD and DR. DE WIT.

The development of *insecticides, pesticides and herbicides*, in order to control predators on our plants and animals also has made great strides. Here again, a very close cooperation between chemical industry and agriculture has been of vital importance. We have not yet solved the problems created by the use of these chemicals – human health and life, as well as animal health and wildlife may be seriously impaired by an indiscriminate use of these products. Much more selectivity of impact and shorter life period of poisonous chemicals must be found, before we have licked these problems.

We are all painfully aware of the dangers of polluting water and soil with poisonous components, which resist a chemical or biological breakdown. Biologists in the most diverse specialization of that rapidly expanding science are warning us of unexpected noxious consequences of the use of pesticides, herbicides and anorganic chemical fertilizers. The agricultural use of DDT may well be 110,000 tons. This dangerous molecule is present in all ocean water, has even been found in the pinguins in Antarctica. On the other hand, our present system of crop production and animal husbandry would collapse if these ingredients were to be forbidden. I might add as a personal note that in 1949, during the General Meeting of the International Union for Conservation of Nature and Natural Resources, I asked for deep and concerted research into possible substitutes for DDT, replacing it with biologically destructible molecules, as was done at a later date successfully with detergents, or through more use of products from plants or animals, or micro-organisms. These generally need a shorter time to be broken up into less poisonous and dangerous material. I am sorry to say that at that time my remarks were not taken seriously among conservationists.

The heart of agriculture is *the farmer and his family*. What has happened to them in the midst of technological change? Here we must distinguish between the developed and the underdeveloped or developing countries. In the first category, the farmer is much better served with all farm requisites than ever before, marketing and processing are being done for him; machinery has relieved his drudgery. He has easy access to the news, to the educational and cultural facilities in the cities. He needs these, as farming has become one of the most scientific managerial and technical operations in our modern society. In Germany, it was noted in 1962, investment in machinery is $\frac{2}{3}$ of total investment in agriculture.

At the same time, farming in these countries is being done with less and less people; local communities lose their economic, social and cultural importance. The differences in attitudes, values and social behaviour which existed between rural and urban societies may still be apparent, but they are less real than before. In his work on the land or in the stable, the farmer may work in solitude and relative isolation, but otherwise he is part of national society. His children are educated for roles in society as a whole.

All this is a far dream for the peasant in developing societies. Farm requisites, like fertilizer, seed and credit reach him in inadequate quantities through long and tedious channels, at high prices and often at the wrong time of the season. True, the merchant or landlord may buy, transport and process his product, but in that case very little of the market-value reaches the peasant. He is too poor to buy machinery; education has hardly reached him or even his son of school-going age. Even if millions from rural areas flock to the cities, generally to the slums in the cities, an already crowded countryside becomes more crowded. The number of peasant families is increasing, in most countries, more rapidly than the cultivated land.

We often speak of a widening gap in productivity and income between rich and poor countries. Nowhere is this gap more and more becoming a chasm than in agriculture. Although we would like to see a reversal in this trend, this certainly has not become within view during the last fifty years. We can express this enormous difference in one variable – the number of people which can be fed by one farmer's families work. In India, Indonesia and many other developing countries this is six–one and one-third family. In the United States it is sixty people – eighteen families. And this figure disguises the great difference in nutritional value of the diet between these countries.

Thus, agricultural development over the last fifty years is a mixture of achievement and bright hopes in one part of the world and inadequacy to solve the problems of population increase for adequate food production, and the impact of urbanization and overall economic development, in another part of the world.

How have *agricultural sciences* been involved in these processes? The answer again shows a mixed picture of success and no-success-yet. They have pretty well absorbed the new potentialities in engineering and industrial development in as far as Europe and North America are concerned. They have reciprocally contributed greatly to the development of genetics, of animal nutrition, of phytopathology and veterinary science. They have followed, but not contributed much to the great changes in world trade, marketing and processing potentials. They are deeply interested, but have not influenced deeply family structures, educational systems and local government in rural areas. They have, however, been instrumental in the study of and subsequent measures in land use and ownership of land.

They have, so far, greatly neglected the great differences between agriculture in the industrialized high income countries in the temperate zone and agriculture in the tropical forests, savannah, humid and arid zones. Too often even agricultural scientists have assumed that it *only* takes the application of techniques known in the Netherlands or in Denmark – and some go as far as to add Japan – in Monsoon Asia, the semi-arid zones of Africa, or the tropical forests in Africa and South America to feed ten billion people. I underline the world *only*, because this achievement would mean an agricultural, industrial, economic and social revolution so far never accomplished anywhere or in any field of development.

In the narrower scientific sense, it even is untrue, as exhibited without doubt in the 1964 Dedhamhouse Conference, sponsored by the Massachusetts Institute of Technology. Most of all, we have no methods to assure sustained fertility on many tropical soils beyond the age-old methods of terracing with irrigation and the use of treecrops. The first method is very capital-intensive and precludes a great deal of mechanization. And we do not have many treecrops which produce basic food in high quantity per hectare.

And I have mentioned already two other areas, where agricultural science is in great need for basic research and guidelines for application – in cooperation with many other branches of science and technology. I like to repeat these – the responsible use of poisonous chemicals on or in our crops, animals, soils and water – and secondly – continued studies on the most desirable and effective production unit in agriculture.

What has happened to the agricultural sciences or rather to agricultural science itself over the last fifty years? Obviously a large number of basic natural and social sciences as well as engineering have contributed to the development of agriculture. In these sciences the adjectives 'agricultural' and 'rural' are generally being used to indicate the relevance to experiments and observations in this field. The obvious danger is that these scientists concentrate only on one narrow aspect of the total agricultural complex. A danger, therefore, of lack of communication between research and application in many vertical columns, in order to serve agriculture as an interrelated whole.

The other direction of development has been entirely different. More knowledge about conditions and processes in an increasing variety of natural and social ecological situations (eco-systems) offers an opportunity to build agricultural science on a comparative basis. All around the world, experiments have been and are being conducted and observations are assembled, which stress the 'environmental' effects on the farmer, his family, his farm and its inventory, his community and his profession.

If we accept the consequences of this ecological factor – much stronger than for instance in manufacturing industry, mining or many service industries – we are led towards agricultural science as a legitimate field of *integrated scientific interest*. The acknowledgement of the ecological component of agricultural science limits the immediate transfer of findings, but also warns against and may prevent unwarranted transfer. On the other hand, it calls for checking of results in a great variety of circumstances and, thereby, enhances our knowledge of their validity and applicability.

In order to carry out these comparative investigations, agricultural scientists have to root themselves more firmly in the *basic sciences* of nature, society and man.

There is an almost universal acceptance of the need to pursue these basic sciences. There is widespread, but no general acceptance of the need for comparative investigations. There is general lip service to the concept of an integrated scientific approach to agricultural problems.

In my opinion, over the last fifty years, under the burden of a demand for quick, if not precise, action and the enormous development of basic sciences – *agricultural science* and the comprehensive approach it stands for, has perhaps suffered.

There has been a tremendous specialization and specification, a widening insight into geographical and ecological limitations, but not so very much of a synthesis. But the concept of this synthesis is still there, as is shown by the rapid growth of methods to relate the findings from one scientific field to another – from biology and soil science to sociology and communications theory. Such methods comprise organizing workshops, or symposia, or field days, or brainstorm sessions.

The agricultural metropolis of Wageningen itself is a good example. You have, fortunately, not divorced the education of agronomists from agricultural economists, nor the biological base from engineering approaches. Fortunately, in the Netherlands, agricultural and rural concerns have not been scattered around all university cities, although at times the temptation has been great. The need for comprehensive agricultural centers or universities by and large is also acknowledged in other countries. But the unity has rarely been achieved.

Admittedly, this is a hard task. We may ask, how the professors, the scientific staff and the students experience the unity of concern in the ever expanding galaxy of legitimate interests. Can one really encompass this widespread horizon of opportunities for development of scientific insights and practical application? Perhaps, there is a need for a *concerted action within the university*, and in its contact with other scientific endeavours, to keep the idea of synthesis alive. Perhaps, we need a specific counteraction again diversification and specialization. I am not only asking this as an academic pastime.

There are tremendous tasks ahead of us, even if farming seems to be a profession in retreat. We are on the threshhold of a break-through in biology, of our knowledge of the processes of life. There is a challenge of factory production of food, at least of amino-acids and proteins from mineral oil and through ureum as a product of chemical synthesis. We still have to harness the multiplicity of production processes in micro-organisms. We have to cope with the effect of various chemical substances, stimulants and poisons on human life or plants and animals. We have to tackle the problems of the tropical, arid and arctic environment much more seriously. We must learn to lead, rather than follow, the social, economic and managerial revolutions in the countryside and relate them to national, continental and world society. We must first among all tasks, solve the nutritional problems of the developing countries. All this challenges our present and future generation of agricultural scientists. One thing appears to be certain – under appropriate political, social and economic impulses, the combined effect of agricultural sciences opens an unprecedented vista for more and better production.

We are in great need for the realization of this technical possibility. In many parts of the world, consumption needs are outrunning the pace of production. Inspite of our achievements, there is malnutrition, hunger and starvation. This is a paradoxical situation. But without the results of agricultural science over the last half century, we all now would be starving.

As it stands, the constellation of economics and political forces, national and international, has kept food prices down. Science and technology have benefited the consumer much more than the producer, *n'en deplaise*, the green-front-politicians in many countries. In my view, it is right that consumers are the ultimate beneficiaries. But this should then be recognized in our national policies and procedures. The benefit to society as a whole rather than to the farmer-producer justifies generous government support from tax money for research, extension and education in agriculture far beyond the interests of the farmer groups. In the western world, farmers by the way, are no more the main supply of marching soldiers or of votes for politicians.

But even if we solve these problems in Europe, the needs of mankind for more and better food remain pressing. In view of the unprecedented increase in world population and the inadequate nutritional situation among two-thirds of these present three and a half billion people, growing by 70 million annually the need is increasing faster than ever. Social and political sciences must more forcefully tackle the ongoing problems of changing systems of production, trade and consumption. I do not doubt the capacity of biology, chemistry, physics and engineering sciences to increase levels of productivity. But they should be aware of the unique man-nature symbiosis which characterizes agriculture and which should permeate all agricultural sciences. *All* agricultural scientists should promote social justice in the numerous conflict situations in and around agriculture. Scientists of great diversity should *think together* and *stick together* in order *to act together* responsibly in a rapidly changing world.

Discussion

Professor JOOSTEN, who was invited to open the discussion, raised the following points:

The per caput food production has kept pace with the increase of population with a few exceptions often due to political instability. In the period 1964/1966 (including the bad years '65 and '66) per caput food production in the underdeveloped countries was 6% above pre-war.

That there are still millions of people going hungry, is primarily not the fault of the farmer but the main trouble is insufficient employment outside agriculture.

The price regulations through commodity agreements as for rubber and coffee, did not solve the problems; instead the problems were shifted from the international field to the interior of the producing countries.

Farmers can only be prosperous if their number is relatively small.

He disagrees with the statement that because market channels are in the hands of merchants or landlords, very little of the market value reaches the farmer. The role of the merchant is often dishonoured; his essential function disregarded. Possibly, farmers' associations or co-operatives might be able to take over this function. In this respect also, the processing of agricultural products is part of our science.

Stating that the farmer is too poor to buy machinery is correct, but that is not the point. Would the farmer in these countries be helped if he was provided with machinery, as long as the relative number of farmers is not decreasing and employment opportunities outside agriculture are still inadequate? He fully agrees with the statement that too often, it has been assumed that it *only* takes the application of western techniques in the underdeveloped tropical areas to feed ten billion people, because this would mean an unprecedented agricultural, industrial and social revolution.

If we are talking about food for the billions, it is necessary that our sciences are not focused on the soil only.

Vast food resources lie bare in rivers, lakes and seas, and the scientific exploration and economic exploitation of these resources are not yet realized.

His last point, which is of great interest for our Institution here, is that he would favour more and larger possibilities for an integrated study aiming at a real synthesis which, in short, might be called the education of all-round agriculturalists.

Summarizing, he presents for discussion the following points:

1. What is the basic cause that per caput food production in the developing countries remains constant.
2. Why is it that the application of production promoting measures lies so disappointingly behind in the developing countries.
3. Should our universities educate more general agriculturalists and how could that be done? Would there be sufficient demand for them? In his opinion, the need is great.

As various questions, including those raised by the audience are inter-related, Prof. DE VRIES answered them integrally. His views can be summarized as follows:

The demand for food is increasing rapidly, expecially in the developing countries, due to population increase and economic development. Every percent of economic development creates an additional demand for food of 0.6 or 0.7% (in the western world about 0.1–0.2%, so that here a surplus can be obtained by a much smaller increase of agricultural production than is needed in the developing countries). Six percent more food per capita therefore is poor performance, as indicated by rapidly increasing food imports.

Political instability may be a factor of inadequate food production increase, but it cannot be considered a general reason. The most important reason is the rapidly increasing demand due to the population explosion. In the developing countries the increase in food demand can be estimated at about 4% per annum which never applied to the western world. The main bottle-neck is the inadequacy of measures to improve and organize production through the necessary research, extension, credit, marketing processing, etc., in these countries themselves, and of the international community to promote this process. To a certain extent political factors also play a role.

Things would be better if there were more job opportunities outside agriculture but the reality is that not enough job opportunities can be created fast enough.

Even when the industrialized countries would spend twice or thrice as much on economic development of the developing countries, much would have to be done *within* the developing countries to raise food production and promote economic development in general.

Although Prof. JOOSTEN does not agree with the opinion that the merchant usually takes too much of the margin, there are cases where the farmers' share in the value of the product is definitely much too small as in rubber exports in Palembang, where the farmer is not left with any incentive. Also, fertilizers, seed and other requisites often are much more expensive than in the industrialized countries.

A study of marketing systems and efforts to improve these, are urgently needed. Organization of co-operatives is very difficult in these countries due to lack of adequately qualified people to organize those co-operatives.

We need not be dishearted because many developing countries are making headway and grain production in the developing countries over the period 1960–'66 reached a 3½% increase per annum. What these countries mostly need is organization of their own institutions in agriculture (including agricultural research). 'Wageningen' could help some of these countries to equip themselves properly and in adapting techniques to local conditions. Fortunately, 'Wageningen' is expanding its facilities for students from overseas.

To decide whether we should educate more general agriculturalists is a difficult problem. Nowadays, we cannot be trained any longer to become 'Robinsons Crusoe'! This would not be the future for Wageningen. We need people with a strong base in one or two basic sciences and thereafter a thorough training in integrated development of agriculture (especially in team work).

There might be a danger that a so-called general agriculturalist would not be at par with a top sociologist or a top biologist. The synthesis should be at the top and not at the bottom.

Price instability is indeed one of the main reasons of insufficient incentives to farmers. The results of national and international price regulations do not depend on the farmer or the scientist but on the political will of the nations. Also, export taxes do not induce higher production.

Gradually, things will improve in the next ten or fifteen years if we do not indulge too much in national or group interests.

Micro economic studies or incentives to farmers are indeed very important, because in the developing countries, nobody has yet been able to organize the necessary supplies of seed and other farm implements, credit, etc., without proper encouragement to farmers.

The question whether students of the sociological disciplines find enough work in the tropics unfortunately has at present to be answered in the negative, but prospects seem brighter in the future, expecially if these students look forward to the future development of institutions in these countries, rather than study stagnant societies.

Some questions of a general or more political character could be dealt with as follows:

Is there no world policy for food?
The World Agricultural Indicative Plan of the FAO, may lead to a world policy, but up till now, we do not have such a policy, although there are some continental plans like the one of the European Common Market.

Maybe too much funds and efforts are used for military purposes, as one of the participants suggests, but even without that, we would not yet have a real world food policy. We can only work in that direction until the politicians are convinced that a world food policy has to be adopted.

What can international organizations do?
The present organizations are not supra-national structures with enough power to create an international world food policy. Therefore, they are not in a position to solve these basic problems.

The difficulties in spreading the European continental agricultural policy along the Atlantic Ocean and into other continents are great, as is well known.

For the time being, we have to muddle through with the inadequate international organizations presently in existence. In the meantime we should continue our research, training , organization and all other efforts on a micro and macro level, regionally, nationally and internationally, keeping in mind that the ultimate aim is food, peace and prosperity for everybody.

The question whether we could solve the food problem by eating less animal products and more vegetable products, was doubted. A large part of our world is grassland and only suitable for fodder for animal production. Besides, there are other sources of protein food, so that there is no reason why we should change our diet so drastically.

One of the former Wageningen professors used to say 'hard work is for the dumb and the lazy'. This might be reversed; the dumb and the lazy never achieve their goal. 'Hard work is for the bright and industrious people'.

Some supporting and commenting remarks were made by DR. PARPIA from

India who emphasized the need for organization, internationally and nationally, and further the dependence on resources. The budget of India, for instance, is not much more than the budget of New York municipality! A third comment was that the investments in research and technological development in the field of agriculture are not commensurate with the problem. Of the millions of rupees spent on food imports, a modest part should be used for technological development.

National and international organization could play an important role in promoting this development.

As to assistance from abroad, it may happen that some international organization would be interested in a $2. mill. project, of which $1. mill., however, goes to the experts! These countries should resume more responsibility for technological and economic development on their own.

Prof. DE VRIES illustrated the situation by stating that some years ago, there were 143 agricultural scientists per 100,000 rural population in the Netherlands against one in India! Therefore, the growth of indigenous institutes is very important, and in the long run may prove to be the most efficient way to reach economic development.

Also, the approach of international technical assistance has to be altered. We need a completely different system of technical assistance.

DR. MANSHOLT questioned whether the plans for new polders in the Netherlands like the Waddenzee would be of much use, considering that everything to be grown in these polders, is already in surplus in Western Europe. Milk, for instance, is already costing the six countries nearly $1,000 mill. per year. Every ha of sugarbeets costs the community Df 3,000 in subsidy. Wouldn't it be better not to make these polders, but to use the money in the underdeveloped countries.

Prof. DE VRIES answered that we have always been very eager to develop overseas territories, and that we are now developing 'underseas' territories! He agrees with DR. MANSHOLT's opinion the Waddenzee might become a European supersonic airport. The best policy seems to be to strenghten the whole economy (without much difference between rural and urban areas) and invest overseas instead of in new sugarbeets.

Prof. WELLENSIEK recalled that the Dutch have been poldering all their history and will continue to do so!

Answering a final remark of one of the participants, Prof. DE VRIES restated that the basis of a world food policy should be the political will among the nations involved. Unfortunately, there are still too much group interests.

The situation will improve, however, under the pressure of an objective clear-cut diagnosis and some preaching. To start with preaching before studying is wrong.

To think that the co-existence of two economic systems, capitalist and communist, will make a solution impossible, is, in his opinion, not justified.

PLANT PRODUCTION

by

C. T. DE WIT

Professor of Theoretical Agronomy
Agricultural University, Wageningen
Agronomist Institute for Biological and Chemical Research on Field Crops and
Herbage (IBS) Wageningen

A poor man's world

During idle periods in one of the military campaigns in Europe at the end of the Napoleontic time, CARL VON WULFFEN aus Pietzpuhl developed 'Das Statische Gesetz', in which the productivity of the land is understood as a resource that is depleted by cropping and replenished by natural factors and agronomic measures.

Historians may consider this law one of the famous dead ends in agricultural science, but it is the first and an excellent example of operations research in this field and it also summarizes the state of the art at a time when no artificial fertilizers were available in a remarkable dynamic fashion. (42, 43, 44).

Four quantities are considered, which are presented in a relational model as is nowadays customary in the management sciences (figure 1, left). The richness of the soil and the total yield since the beginning of the rotation, are two tangible quantities expressed in the same units. The rate of transfer from one state to another is governed by the yield in the current year. This yield in its turn depends on the richness and the activity of the soil, as presented by these lines of information flow. Obviously, the yield in one year feeds back on the yield in the next year by the decrease in richness.

This information-feedback system was quantified by an assumption which is given here in the form of a graph (figure 1, right). The richness in one year is presented along the horizontal axis and in the next year along the vertical axis. For zero activity the activity line coincides with the 45 degree line. The richness

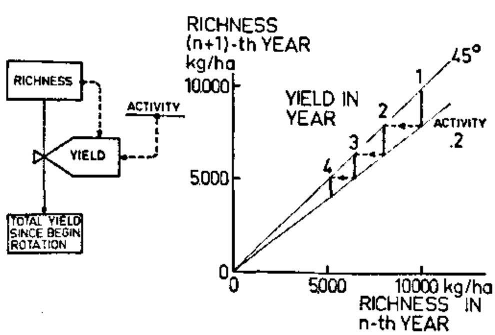

FIG. 1. A relational model and a graphical representation of 'Das Statische gesetz'.
'Man dividiere das Quadrat des Produkts der ersten Ernte mit dem Minus der zweiten und es ergibt sich der Reichtum des Bodens. Dann dividiere man damit der Fruchtbarkeitsgrad den der Boden durch Hervorbringung der ersten Ernte haben musste und es ergibt sich sein Thätigkeitsgrad'.

is then the same in successive years and the yield is zero. The dotted line presents an activity of 2. This means that in a year when the richness is 10.000 kg/ha, the yield is 2000 kg/ha, and the richness 8000 kg/ha next year. This produces a yield of 1600 kg/ha and a decrease in richness to 6400 kg/ha and so on, gradually downwards till exhaustion.

The richness and activity of the soil was obtained by VON WULFFEN by determining the yield in two successive years, and by growing two crops side by side it was possible to express the richness and activity for any crop in terms of a standard for which rye was chosen. Likewise he compared various cultivation practices. The richness of the soil could be restored again by fallowing and applying manure. Again it was possible to express the value of these measures in terms of rye equivalents. Thus a challenging link between theory and experiment was established, which led to considerable experimentation.

More complicated situations were considered. He took into account that a part of the yield was sold and a part was transferred through the animal to the manure yard from where it was returned to the individual fields, depending on the amount of manure available, the richness and activity of the soil and the crop to be grown. The source of richness due to fallowing was rather a mystery. Whatever the complications, it remained possible to present the whole farm in what we now call an open recursive system, in which the rates of transfer and the management decisions depended in a unilateral, causal way on the state of the system and the market situation.

The consequences are presented graphically for the simple case of yearly cultivation of rye (figure 2). Each year, the richness is replenished at a certain

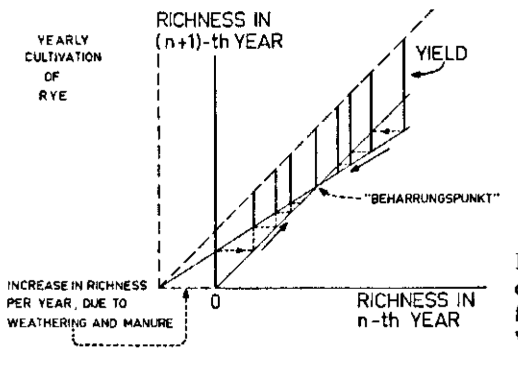

FIG. 2. The approach of the dynamic equilibrium (Beharrungspunkt) of a farming system according to VON WULFFEN.

rate by the return of manure and by fallowing. Starting from a poor soil, the yield and the richness increases until the 'Beharrungspunkt' or the stationary state was achieved. Starting from a rich soil richness and yield decreased gradually to the same Beharrungspunkt. Hence, in due course a stationary state for the richness and the yields was obtained which did not depend on the original richness of the soil, but could be evaluated by keeping careful records of the farm operations. This theory formed the starting point for VON THÜNEN to develop his theory of marginal utility and the concept of the 'Isolierter

Staat' in which the localization of the type of farming under influence of the distance to and the size of the market was explained (39) (figure 3).

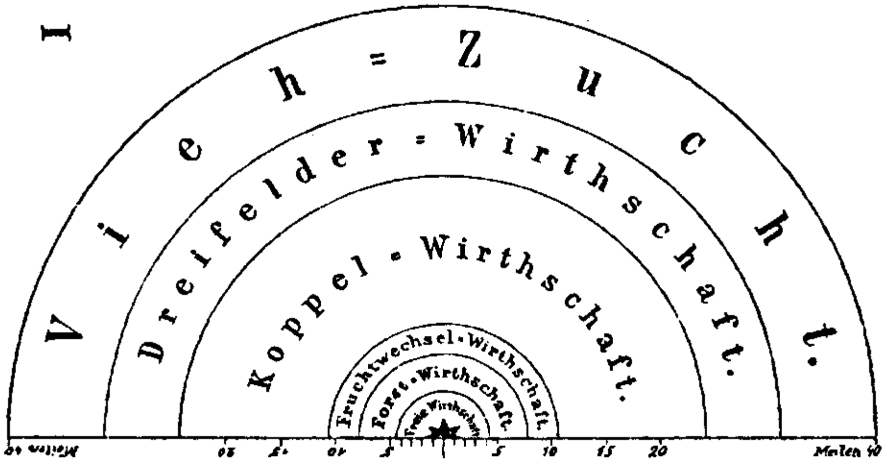

FIG. 3. The isolated State of VON THÜNEN in which the location of the type of farming is determined under the influence of the distance to and the size of the market.
'Man denke sich eine grosse Stadt in der Mitte einer fruchtbaren Ebene gelegen, die von keinem schiffbaren Flusse oder Kanale durchströmt wird. Die Ebene selbst bestehe aus einem durchaus gleichen Boden, der überall der Kultur fähig ist. In grosser Entfernung von der Stadt endigt sich die Ebene in eine unkultivierte Wildniss, wodurch dieser Staat von der übrigen Welt gänzlich getrennt wird'.

This dynamic insight in a human endeavour was perhaps only surpassed thirty years ago by that of KEYNES in his 'General Theory of Employment, Interest and Money'(23), an approach which has – at least to an outsider – much in common with 'Das Statische Gesetz'.

It was stressed by VON WULFFEN that the richness of the soil was not measurable, but could only be determined by keeping track of all farm operations, although contemporaries tried to associate it with the humus content of the soil. However, it is fair to remark that at present very similar dynamic approaches are used in humus research, be it that any reference to VON WULFFEN is lacking (24).

Without outside manures, the yield appeared to be about 700 kg of rye per hectare at the 'Beharrungspunkt'. This yield level could be increased to about 2000 kg per hectare by the Flemish method of agriculture, a very sophisticated system in which the more marginal land was reserved for animal husbandry, cash crops were alternated with forage crops and the manure was carefully saved for the arable land (38).

This careful management of the soil was not practiced everywhere. As for instance in Missouri where according to an indignant writer in the Cultivator of 1849 (2) '...Farming is executed according to the regular skinning system: scratch over a great deal of soil... cultivate none. And where some farmers have the foresight and sagacity to avoid hauling manure by building their stables over a ravine by which they are drained so that each shower abates the nuisance'. Here the farmers had the soil to begin with, which European farmers should like to make with their manures. Although much land was wasted in this way it must be realized that the rapid expansion of agriculture made the development possible of an urban population in the East of the United States; in other words: hoarded capital was transformed into working capital.

Mineral nitrition

The breakthrough came in 1840, when LIEBIG collected all the evidence that plants needed only water, minerals and nitrogen out of the root medium and killed with intelligence and sarcasm the theory that humus as such was a plant nutrient. He formulated the famous law of the minimum (27) (figure 4).

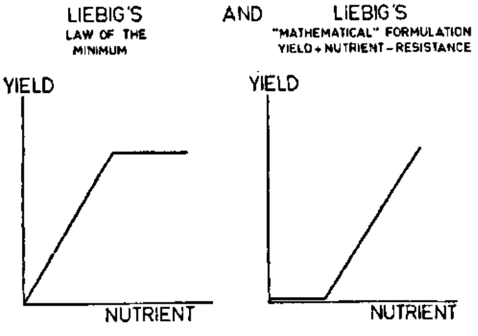

FIG. 4. LIEBIG's law of the minimum. 'Die Höhe des Ertrages eines Feldes steht im Verhältniss zu demjenigen zur völligen Entwicklung der Pflanze unentbehrlichen Nahrungsstoff welcher im Boden in kleinster Menge vorhanden ist'.

Curiously enough, his mathematical formulation said that the yield was proportional to the nutrition minus all the resistances that prevent the use thereof, which is the law of the minimum in upside-down form.

But more serious errors of judgement were made. LIEBIG's patent manure contained phosphate in a rather insoluble form and did not contain any nitrogen, because he presumed that there was sufficient ammonia around, especially in the air to serve the needs of the plants. Moreover, VON WULFFEN's conception, rightly based on an analysis of the results of experiments, degenerated into a kind of balancing system in which it was thought to be sufficient to replace the minerals which were removed with the crop in order to maintain the fertility of the soil.

No wonder that LAWES (26) of Rothamsted remarked that 'the contempt the practical farmer feels for the science of agricultural chemistry arises from the errors made by its professors'. LAWES and GILBERT based their conclusions mainly on the results of field experiments and came up with much better and sensible advice than LIEBIG, who qualified these Englishmen as 'fertilizer manufacturers'. Like the qualification 'amateur scientists' by HUDIG (20) this was meant as an insult. However, their approach, characterized by freedom from prejudice became traditional in England and led in the twenties of this century to the development of the 'analysis of variance' by R. A. FISHER, (16) a brilliant mathematician at the experimental station founded by LAWES and GILBERT. And this statistical theory is one of the main contributions of agriculture science to science at large.

Work of both schools showed that the plant-soil relationships were much more complicated than originally supposed, and at the beginning of this century the study of the physical, chemical and micro-biological aspects was well established. But this research did not provide the farmer with a straight-forward answer on the question how much plant nutrients could be mined from the soil and how much had to be added out of the fertilizerbag.

Their needs were served 50 years ago by MITSCHERLICH, who supposed that the form of the yield response curve (figure 5) depended only on the kind of

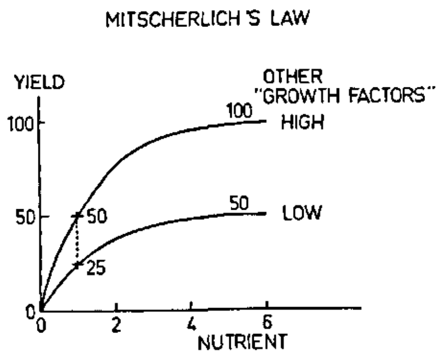

FIG. 5. MITSCHERLICH's law.

fertilizer and was independent of crop species, soil and other conditions (30). This enabled him to calculate how much fertilizer had to be applied in the field on basis of pot experiments in the greenhouse. Because he based his calculations only on yield determinations, this approach was appreciated by the agronomists, but soil science was too far advanced to get away with it without severe criticism. The controversy stimulated the evaluation of chemical soil and plant analyses on basis of fertilizer experiments in situ and this shows that a theory needs not to be correct to be useful, but MITSCHERLICH was not the man to appreciate such a point of view.

The Soil Fertility Institute in Groningen has truly pioneered in the field of soil fertility. In 1919, HUDIG introduced the electro-chemical determination of the pH of the soil, which enabled the lime-requirement to be estimated and the pitfall of overliming to be avoided. This was followed by the development of methods to determine the phosphate, potassium and magnesium status of the soil, so that now a basis for advisory work is available, which ranks among the best.

However, the situation remained obscure for nitrogen. Nitrogen is subjected to such a high turnover rate between the organic, ammonium, nitrate and elementary form in the soil medium that the approach which was so successful for the more stable elements failed with this one. It appeared that for this element and to a less extent for potassium a regular essay of the nutrient status of the plant on basis of leaf analysis is indispensable at the present high application levels (25) to avoid the damaging results of overdosing. How the situation has changed in the course of time is best illustrated by comparing the composition

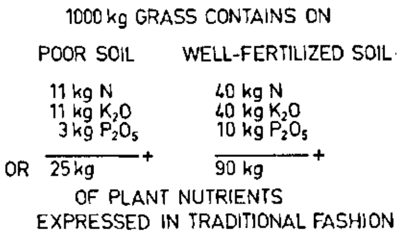

FIG. 6. The uptake of nutrients by grass.

of grass, grown on a poor and on a well fertilized soil (figure 6). Under poor conditions 1000 kg of grass contains about 25 kg of plant nutrients and this is about the amount released by one hectare of exhausted soil in one year. Well fertilized grass contains 90 kg of nutrients per 1000 kg, so that a yield of 10.000 kg per hectare needs 900 kg of nutrients. The increased supply of artificial fertilizers provided indeed the leverage for the spectacular increase in yield in Europe during the last 80 years (figure 7).

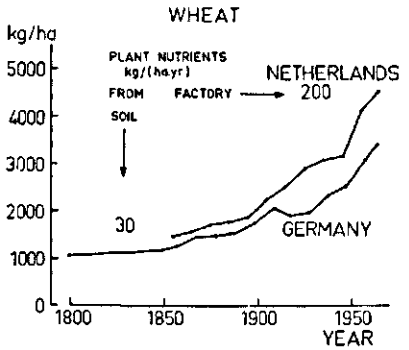

FIG. 7. Yields of wheat in two European countries. (Sources: official statistical year books and BITTERMAN (3).

Conservation

From the beginning farmers recognized the importance of good drainage in humid regions and good irrigation in arid regions and were able to develop the ways and means for this, and this may be the reason why the development in the field of water management has not been very revolutionary. Advances in this field are mainly due to the increased capability of moving water and earth.

There is a continuous interest in the economy of water use. In irrigated areas, a large proportion of the water may be lost even before it reaches the field: this is sheer waste. However, once on the field, part of the water has to move downwards out of reach of the roots to carry away the salts that would otherwise accumulate to a harmful level at the surface, this especially so under conditions of no financial constraint on the use of fertilizers. The failure to recognize this problem or the impossibility to do something about it still compels many farmers to leave their fields.

Large areas of arable land are also lost by wind- and water erosion, a process considerably promoted by intensive cropping systems and the too liberal use of the plough and other tillage implements. At least the major grain crops may be grown without any tillage at all, provided effective herbicides are used.

These zero-tillage methods may become one of the major tools in controlling erosion, especially in the grain belts of the world.

Potential photosynthesis

Many experiments are still carried out to show that without proper treatment yields are only a fraction of the normal, but more and more attention is paid to the crucial question how high yields may be under conditions where all soil factors are at their optimum, and to judge on this basis how much room there is for improvement.

The sun rather than the earth is harvested under these conditions, as was already clearly expressed by ROBERT MAYER (29) who wrote in 1845: 'Die Natur hat sich die Aufgabe gestellt das der Erde zuströmende Licht im Fluge zu haschen, und die beweglichste aller Kräfte, in starre Form umgewandelt, aufzuspeichern. Zur Erreichung dieses Zweckes hat sie die Erdkruste mit Organismen überzogen'.

It was recognized (28) that plants perform better under high than low light conditions, but only in the beginning of this century research was far enough advanced for BLACKMAN to be able to formulate the principle of the limiting factors of carbondioxide assimilation: at low light intensities the photosynthesis of a leaf is proportional to this intensity and independent of the carbondioxide concentration, but at high light intensities the reverse may be true.

Plants use their photosynthesis products to grow and as long as new leaves are formed and contribute to the interception of more light this occurs in an exponential fashion. But crops are often planted so densely that after some time a closed canopy is attained, in which new leaves do not contribute to the interception of more light, but increase the mutual shading and from then on a crop is bound to grow at a more or less linear rate.

Such canopies display their leaves in every direction. The way in which the light is distributed over the individual leaves was first seriously considered by BOYSEN JENSEN (6) who summarized his views in 1930 in the monumental monograph 'Die Stoffproduktion der Pflanzen'. Firstly he determined the relation between the photosynthesis of a single leaf of mustard and the light intensity and found the familiar saturation curve. Then he measured in comparison the photosynthesis of a canopy consisting of 3.5 cm^2 leaves per cm^2 soil surface in their natural position. The respiration of this crop was about three times higher than that of horizontal leaves (figure 8). At low light intensities the slope of both curves was the same. But the photosynthesis of the single leaf was at its maximum at light intensities, in which the photosynthesis rate of the crop continued to increase, because of the slanted position of the leaves and mutual shading. Hence, the performance of the crop surpassed considerably that of the single leaves in the higher light ranges.

By keeping balance sheets, based on measurements in the laboratory and in the field, BOYSEN JENSEN came to the conclusion that the gross photosynthesis of a crop surface may amount to 300 kg carbohydrates per ha per day during the growing season in this part of the world. The potential growth rate of the

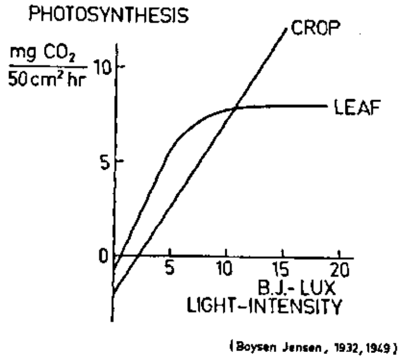

FIG. 8. The photosynthesis of horizontal displayed leaves and a crop of mustard (6).

crop was estimated at 200 kg per ha per day, taking respiration and the growth of roots into account.

Since then experimental techniques have been refined beyond recognition, and paper and pencil have been replaced by the computer. Present models enable a better evaluation of distribution of the light over the individual leaves of a canopy, depending on the height of the sun, the condition of the sky, the canopy architecture and the photosynthesis function of the individual leaves (41).

It has been found in this way that the influence of variations in the canopy structure often is disappointingly small. The estimate that the gross photosynthesis of a closed crop surface is about 50.000 kg per ha for the growing season in the Netherlands is therefore reasonable for many crops. The potential production of overground parts will then be about 25.000 kg per ha per year, which amounts to an average growth rate of close to 200 kg per hectare per day during 150 days. Hence, BOYSEN JENSEN's estimates still stand unchallenged.

This conclusion is corroborated by a comparison of the growth rate of various crops under near optimum conditions in the Netherlands (figure 9). Oats, barley, Indian corn, peas, potatoes, sugar beets, grass and algae grow all

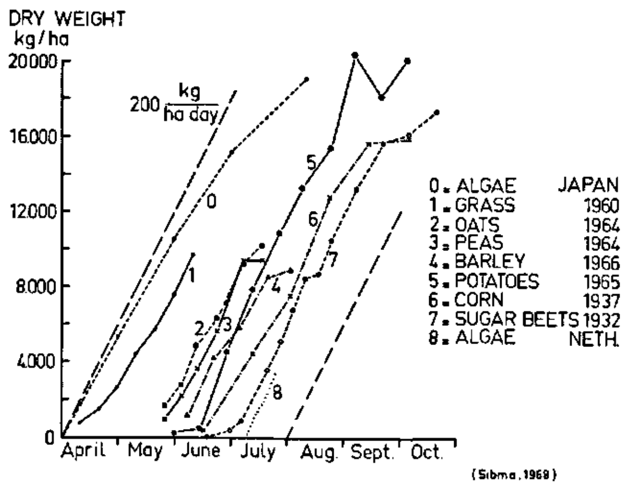

FIG. 9. Growth rates of various crops in the Netherlands and of algae in the Netherlands and Japan (36).

at a rate of about 200 kg per hectare per day and differences in dry matter yield are mainly due to differences in the length of the growing period. The influence of the weather is also surprisingly small as is clearly shown by an impressive series of growth curves (figure 10) of grass swards throughout the

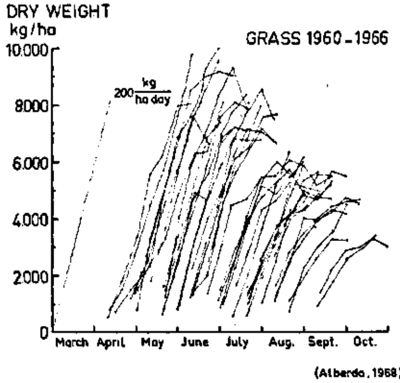

FIG. 10. Growth rates of grass swards in the Netherlands (1).

seasons of 1960–1966. All the growth rates are again close to 200 kg per ha per day, except at the beginning when there is no closed crop cover and at the end when the leaves seem to deteriorate.

Pastures

Taking this into account ALBERDA (1) came to the conclusion that a total production of grass of 20.000 kg dry matter/ha is possible in the Netherlands, an amount which has actually been achieved. This is in good agreement with the estimate of DICKINSON (12) about 120 years ago, in case of the proper species being frequently cut and liberally supplied with a mixture of water and horse urine by means of a London water cart. Indeed considerable amounts of fertilizer are necessary: about 800 kg of nitrogen and 8000 kg of potassium are taken up on the process of producing this 20.000 kg of grass with 25 percent protein.

This potassium may give problems. The element is absorbed by clay and humus so that hardly any may be lost by leaching on many soils. If the farmer is unfortunate enough to have a good storage system for liquid manure, practically all the potassium is returned to the field, and together with the potassium entering the farm with outside food and an occasional potassium fertilization, he may end up with too much potassium in the soil. This potassium may interfere with the uptake of magnesium by the plant and by the animal, so that the danger of grass tetany is a true one (22). Fortunately, nitrogen losses in the manure and soil are larger and this enables the farmer to control the nitrogen content of the grass to some extent, although his freedom in avoiding the growth of grass with an excessive nitrogen content is uncomfortably small, if he is aiming at high yields.

Grazing cows have the habit of walking and disposing of their waste on their own dining table. The surface which is maltreated in this way increases linearly

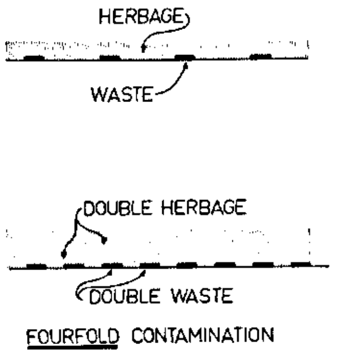

FIG. 11. Waste on the dining table.

with the yield, but the amount of plant material suffering increases in a quadratic fashion (figure 11). The digestive tract of every animal is infected with para sites, eggs are excreted with the faeces and consumed again with the grass. Their number is at a stationary and harmless level under systems of extensive grazing, but under intensive grazing such a high percentage of bites may contain larvae that an explosive development of parasites takes place at the expense of especially the young animal (37).

These difficulties already occur at the present yield level of 8000 kg/ha and in due course may force the farmer to switch over to stock feeding in summer.

In regions where crop and animal husbandry occur in close proximity the farmer may be able to use or sell his farm-yard manure, but in other regions he may soon come into the situation in which he has to pay for the privilege to get the waste hauled away and we are approaching the situation in which it would be wise for the farmers 'to have the foresight and sagacity to built their stables over a ravine (or the sea for that matter) by which they are drained so that each shower abates the nuisance'.

Technological production

Such problems may arise during the process of converting a possible 20.000 kg of dry matter in the form of grass into 2.500 kg dry matter in the form of animal products. Since NAPOLEON III offered in 1839 a price for 'the discovery of a substitute for butter, suitable for the marine', industry has worked on the problem and achieved the making of a vegetable 'butter analogue' which is much cheaper than animal butter and comparable in quality and taste. Likewise, fine leather and wool analogues are available and at present we seem to be at the stage where meat analogues may be marketed much cheaper than the classical product (40). Taste and texture of these analogues are good and the nutritional quality of the protein can be upgraded by adding industrially produced amino acids. Economic extraction of sufficiently pure proteins from grass seems difficult, so that the future of intensive grassland husbandry does not look too bright, unless this is remedied.

The proteins in algae are said to be more easily extractable and because the production is also high, there is a continuous interest in the growth of algae.

Small scale experiments showed that yields of about 30.000 kg/ha on a yearly basis and about 20.000 kg/ha on a seasonal basis are possible with this crop in the Netherlands (31). However, the necessary technical installations are probably more complex than conditioned greenhouses, so that the costs of production may be estimated at more than 100.000 guilders per hectare per year. With a protein content of 50 percent, this amounts to 10 guilders per kg protein, if one indeed succeeds in maintaining potential rates. This is prohibitively high compared to the cost of good quality protein in concentrates of oil seeds, remaining after extraction of the oil for butter analogues. It is also prohibitively high, because 20.000 kg dry matter per hectare per year may be produced in the form of vegetables at a cost in this order of magnitude.

Potatoes

High yields can also be obtained with potatoes. A long living variety has to be chosen, and the seeds should be sprouted in spring, so that at the beginning of June a closed canopy is achieved. Under favourable conditions the crop is then able to accumulate weight at a rate of 200 kg per ha per day during summer and to maintain growth until the first killing frosts.

The liberal supply of water and minerals, necessary to maintain the green canopy, results in considerable stem growth so that a too small portion is obtained in the form of tubers. At present attempts are made to control this excessive growth by means of chemical growth retardants, and it may appear feasible (figure 12) to transfer in this way over 80 percent of the dry matter to the storage organs so that the tuber yield may be increased up to 19.000 kg dry matter or 90 tons of potatoes per hectare. This amounts to 40 percent of the potential photosynthesis.

So many things may go wrong along the line, that even on selected experimental fields it is not possible to obtain such yields at every attempt. But on the

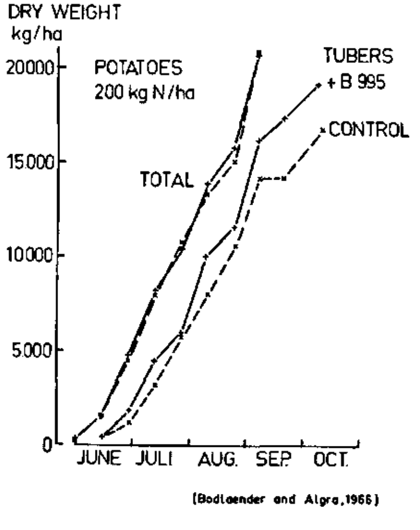

FIG. 12. Growth rate of potatoes and the influence of a growth retardant (4).

other hand, this maximum yield is so much higher than the present 50 tons/hectare on good farms in the Netherlands that the trend of increasing yields can be maintained for many years. Although plant breeding will be essential in this, its present contribution should not be overrated. After all, the most prominent variety – Bintje – is already 60 years old.

Potatoes much more than any other crop are subjected to diseases, crop losses being estimated at around 25 percent in this part of the world. Virus infections are at present pretty much under control due to the pioneering work of Prof. QUANJER of this University 50 years ago. Nematodes were supposed to be kept under control by a three years' rotation, but it is now apparent that a more positive approach aiming at the introduction of nematode-tolerant varieties and the use of systemic nematicides is necessary to enable the cultivation of potatoes at the present scale in the Netherlands.

Bordeaux mixture has been used against potato-blight since 1882, but repeated spraying is cumbersome and not sufficiently effective in late summer and autumn, so that more or less blight resistant varieties have to be introduced to achieve higher yields. Vertical and horizontal resistance (33) can be distinguished (figure 13). Vertical resistance may be 100 percent effective, is specific for

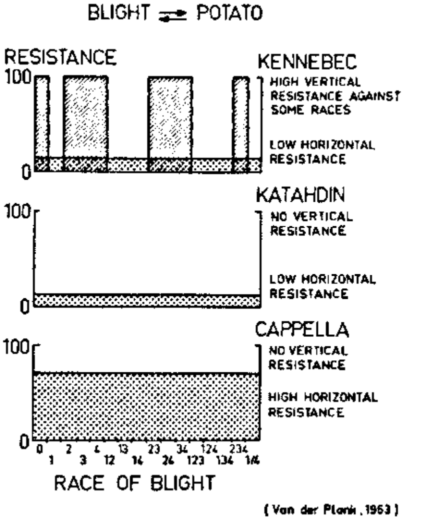

FIG. 13. Horizontal and vertical resistance of potato varieties against various races of blight (33).

the various races of the fungus and mainly controlled by a few major genes. Horizontal resistance is never 100 percent, consists out of various elements reducing the multiplication rate of all races of the fungus and is controlled by many minor genes. Breeders mainly aim at varieties with 100 percent vertical resistance, but are in this process not able to screen their varieties on horizontal resistance, so that new races of the fungus that break vertical resistance may spread at a disastrous rate.

More detailed knowledge of epidemology may enable fungi to be tolerated and crop losses to be controlled by using varieties with a reasonable horizontal resistance in combination with hygienic agricultural practices and the use of chemicals. A remark not only meant for blight in potatoes but also for rust in small grains.

Small grains

Growth rates of close to 200 kg per hectare per day may be obtained also with small grains. In case of winter wheat, this is possible during the 90 days from the beginning of May to ripening around the first of August, so that a total dry matter yield of 18.000 kg per hectare is achievable.

The dry matter formed up to flowering at about the 20th of June is used for the vegetative structure and the dry matter produced after flowering may be recovered in the seed. Hence, under favourable conditions only 50 percent of the total dry matter produced or 9.000 kg per hectare can be obtained in the form of seeds. In regions where the radiation is higher and the period from flowering to ripening longer than in the Netherlands, as is the case in the North of Italy and the North -West of the United States 20 percent higher yields may be expected (7).

To achieve such yields, it is necessary to keep the crop surface green up to the end of July, which is only possible if sufficient water and nutrients are available and diseases are absent. However, a high nitrogen supply may lead to leafy plants, which are not only susceptible to lodging, but in which the vegetative growth encroaches upon seed formation. Although grain yields of 8.000 kg per hectare may still be obtained, the fraction of seed in the harvest will be too low then.

Already 125 years ago ROBERTS remarked (34) in his excellent price essay on the growth of wheat that early nitrogen applications yield too much straw and that many farmers apply the soot out of the London chimneys as a topdressing in May rather than in March. Present experience at a 4 times higher yield level confirms the wisdom of this. It is indeed worthwhile to supply the crop during its vegetative stage with just enough nitrogen for ear formation and subsequently to keep the crop surface green as long as possible by a topdressing with N shortly before ear emergence. In this way crops with a relatively high seed yield and low straw yield are obtained. However, the fertilizer level is at present so high and labour so scarce that it is often difficult to carry out such a fertilization scheme.

Under those conditions, however, a similar effect may be obtained by spraying chemicals, like CCC, that retard the vegetative growth and divert more dry matter to the seed (figure 14). This again is an example of the phenomenon surprizing perhaps for an older generation that fertilizers are so cheap, that there is much more need for growth retardants than growth stimulators in modern agriculture.

In his price essay ROBERTS also remarks that the most productive wheat varieties seem to tiller the least. He recommends a short variety with the characteristic name of Piper's Thickset for rich land, whereas the more leafy types are better used on land with a light crop. The amount of seed expressed as a percentage of the total production varied in his experiments from 35 to 46

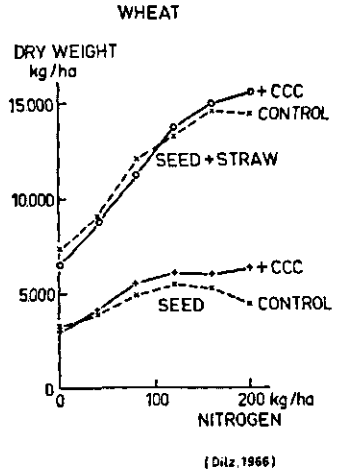

FIG. 14. The seed yield of small grains in dependence of nitrogen fertilization and the influence of a growth retardant (12).

percent. The tendency to select short stiff varieties with a high seed fraction holds up to the present time: plotted against the year of their introduction (figure 15), the relative seed yield of the varieties used at present in the Netherlands increases, whereas the relative straw yields decreases, as is illustrated here for oats.

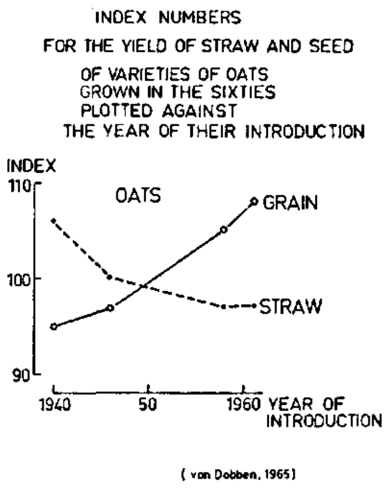

FIG. 15. The success of breeding for more seed and less straw (40).

As for wheat, Juliana an old Dutch variety is outperformed in this respect by Heines VII and Felix, more modern varieties with short and stiff straw and not too leafy. In spite of this the present percentage of seeds is not higher than 100 years ago. Obviously the continuous improvement of varieties in this respect has been counterbalanced by the opposite effect of the improved nutrient supply.

This illustrates that it is rather futile to calculate how much of the yield increase over the last 100 years is due to breeding, increased fertilizer use or other factors. It is therefore fitting that most investigators attempting this, divided the almost 2 percent per year about equally among the claimants (19).

Rice

History repeats itself for rice, but now more consciously. A great deal of paddy is grown on wet but poor soils in the tropics. These are puddled as long and as deep as possible to make the most of the nutrients and to control weeds. Plants from the nursery are then planted in the mud at a rather wide distance compared to other grains. All this trouble gives around 1000–1500 kg of paddy per hectare and much more straw than the farmer needs.

The suitable varieties have a very high tillering and rooting capacity, but they are also tall and leafy and very susceptible to lodging. Hence they cannot stand high nitrogen fertilization and have a hulled seed fraction of only about 30 percent. However, there also are semi-dwarfs with short and stiff straw that can stand high fertility levels and which have close to 50 percent of their dry matter in hulled seeds, so that the edible portion is about the same as that of wheat.

The International Rice Research Institute in the Phillipines obtained (21) grain yields of 9500 kg paddy/ha with their recent semi-dwarfs. These are day-neutral varieties taking independent of their time of sowing only about 100 days in the field, so that at least on paper three crops may be grown in one year in suitable tropical regions. In due course annual yields of 24.000 kg hulled rice can be expected there.

Heterosis

However small the plants, the main stem and tillers of the small grains always terminate in an inflorescence that carries the seed, so that these plants can stand the miniaturization, occurring in dense plantings, without reduction of the fraction of seeds (figure 16). On the contrary, the main stem and tillers of

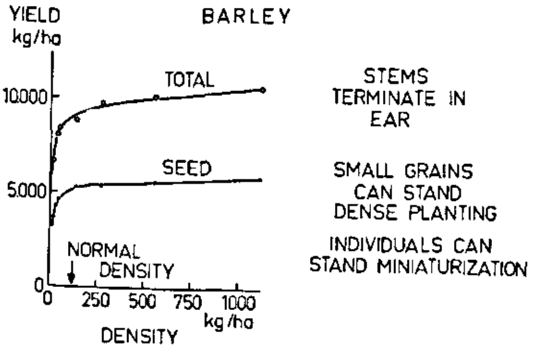

FIG. 16. A spacing experiment with barley up to extreme high densities.

Indian corn or maize terminate in a male inflorescence, whereas the branches that arise from the nodes above the soil surface may terminate in a female inflorescence, normally already initiated when the stem is still growing. But this does not occur in dense plantings, because a too large part of the photosynthetic products is then monopolized by the stem itself. The amount of dry matter

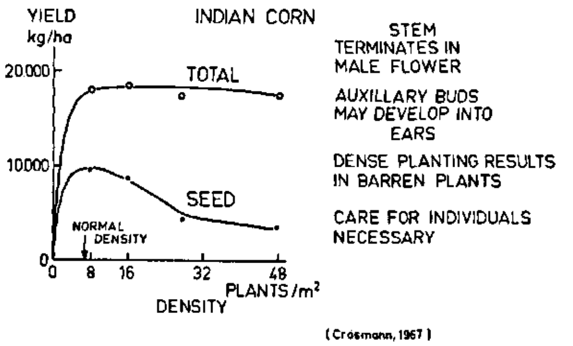

FIG. 17. A spacing experiment with Indian corn up to extreme high densities (10).

which is ultimately recovered in the seed may become disastrously low under those conditions (figure 17). To obtain a good yield, it is always necessary to keep a green crop surface after flowering as long as possible, but in case of corn it is also necessary to achieve this with a small number of stems of uniform size.

Since 1930, this has been considerably facilitated by using heterosis or hybrid vigour, originally defined by SHULL (35) as 'the greater capacity for growth frequently displayed by crossbred species as compared to those resulting from inbreeding'. This phenomenon could be used so successfully in corn, because this is a cross-pollinating species of which the male inflorescences can be easily removed. Likewise hybrid vigour is valuable in Brussels sprouts of which the marketable part is also formed by the auxiliary buds. In general it may be said that the heterosis effect is particularly useful in those cases in which the growth rate in earlier stages or the size of the individual plants is of importance.

Rice, wheat, barley and oats are self-pollinating and therefore necessarily inbreds. However, the knowledge of the genetics of fertility and flowering has advanced to such an extent that it is at present possible to produce hybrids of these species under field conditons, although this is much more costly than with crossbreeding species. And indeed these species show considerable hybrid vigour, but this phenomenon is not so profitable here contrary to Indian corn and Brussels sprouts, because small grains can stand miniaturization. At the International Rice Research Institute in the Phillipines hybrids of rice have been obtained which yield 50 percent more than the highest parent when planted wide apart, as is customary if only few seeds are available. However, the hybrid vigour manifested itself by a high tillering capacity and leafiness and these are properties which proved to be not very useful. Forwarned, a field experiment was executed at normal densities and indeed it was found that at the earlier stages the hybrid did much better than both parents, but this advantage disappeared in the crop situation and in the end the hybrid yielded distinctly lower than the parents (figure 18).

Of course, this does not mean that hybrid varieties of these self-pollinating crops are not worth looking at. After all, many desirable plant characteristics are governed by dominant genes and it may be more economical to realize a promising combination in a hybrid variety than in a pure line. Moreover,

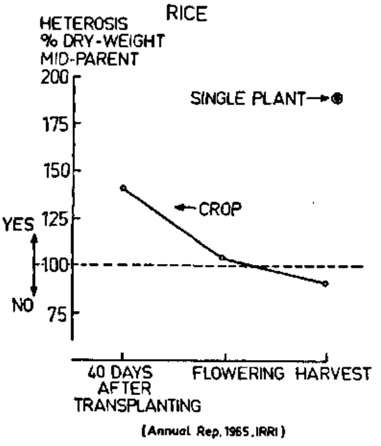

FIG. 18. The relative unimportance of heterosis for plant species that can stand miniaturization, illustrated with an experiment with rice (21).

variations in photosynthesis (figure 19) are genetica controlled, and it is not unlikely that heterosis with respect to this may exist. This should be particularly valuable in the crop situation.

Whole-plant physiology

This would mean breeding for yield ability, a field in which up to now most advances have been made by simple selection. Especially with grains, breeding has been restricted to yield stability by continued development of varieties more or less resistant to rust and other diseases, to adverse weather conditions and to lodging on basis of a thorough genetic analyses of the available material. However, BROEKEMA (8) already remarked in his inaugural address at this University in 1923, that 'the direct application of genetics to increase the yield ability has to fail because of our lack of knowledge of the detailed morphological and anatomical structure and the physiological characteristics of the plant material' and that 'as long as this is the case Mendelism is doomed to be relatively barren'. He realized that the use of yield components as tillers per hectare, seeds per head and weight of seed is misleading, or that it is necessary to breed for income and not for purses.

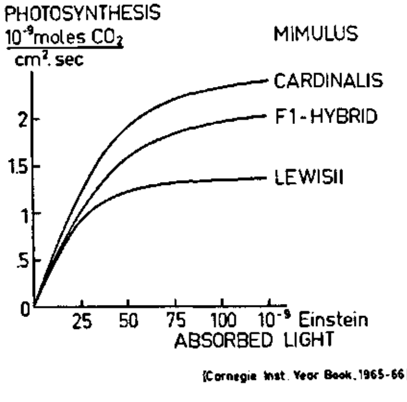

FIG. 19. Photosynthesis functions may be genetically controlled (9).

BOONSTRA (5), probably the first crop physiologist in the field of plant breeding, already 40 years ago drew attention to factors like photosynthesis, respiration, adsorption, translocation and transpiration. He embarked upon a careful analysis of the strong and weak points of the most productive varieties of peas, beets and potatoes in order to base a breeding program on this. The work had to be stopped because of the war. This is the more unfortunate, because the physiological know-how has rapidly increased since then, but the fertile link between physiologists and plant breeders is still too often lacking.

There is a difference in approach. Field trials are rightly the traditional tools of crop scientists and plant breeders, but these do not enable a sufficiently detailed analysis of the chain of events leading from primary causes to ultimate effect. The plant physiologist simplifies the experimental situation by control of the environment and simplifies the problems by studying the effect of environment and variety on the rate of individual processes rather than ultimate results. For instance, the effect of temperature is considered on growth and development rate rather than on yield, and the effect of varietal differences in canopy architecture is analysed on photosynthesis rate rather than on ultimate production. Of course, he does this in the firm belief that in due course it will be possible to come up with an integrated view to fill the gap that exists at present between the plant physiologist and the agronomist and plant breeder, but the ways and means to achieve this have not been sufficiently explored at present.

System synthesis

It may be possible to formulate the problems in terms of an open, recursive system, so cleverly used by VON WULFFEN 150 years ago, at a time when limited knowledge and limited computing capability only allowed for the distinction of a few levels and rates of transfer and made it necessary to advance in time with huge steps of a year.

Since then, the basic knowledge has advanced considerably and the computing capability is now so large, that it is worthwhile to consider open, recursive models of plant and crop growth in such detail that time steps in the order of one hour are necessary. This means that every hour the rates of photosynthesis, respiration and translocation, the rates of leaf, stem and root growth and the rate of development are calculated from the state of the crop and the environmental conditions. These rates are used again in calculating the new state of the crop in the next hour. In this way it is possible to integrate the present state of crop physiological knowledge and to extrapolate the results of the experiments in the laboratory under controlled conditions to field conditions. A comparison of simulated growth with actual growth in experiments reveals gaps in our knowledge. But experimenting with the model shows where to the best of our knowledge research and breeding efforts should be directed.

The crop scientist may thus use simulation to synthesize facts learned from observation of system elements into a complex model, which performance is a prediction of the behaviour of the whole system. The approach may prove to be especially useful in fields such as micro-meteorology soil fertility, epidemiology and crop husbandry in which a larger amount of spade work has been done.

The model builder is not restricted to problems for which an analytical solution can be found and is therefore able to shift emphasis from solution techniques to results and conclusions. Simulation models are therefore open-ended, so that it is a relatively easy matter to combine models developed in different fields and to study in this way the behaviour of more complex systems, with less restrictions dictated by solution techniques (18).

The modern, fast speed, high memory computers should be of little use for these purposes without the proper simulation languages to facilitate programming. Many of these languages and associated new ideas are being developed by research workers in economy, sociology and management. These sciences may become an unexpected source of inspiration for natural scientists which are now somewhat one-sided orientated towards physics and chemistry.

At last we are again at the threshold of a decade in which the efforts of the natural scientist, the crop specialist and the agricultural economist and sociologist may be truly integrated, but now at a far more sophisticated level than VON WULFFEN ever dreamed of.

Food for the billions

It is worthwhile to consider the world food supply under the condition that maximum yields are achieved on a part of the arable land.

Potential photosynthesis in the Netherlands during one growing season is 50.000 kg per ha and potential yields of food averaged over various crops, are found to be not below 10.000 kg per ha or 20 percent of the potential photosynthesis (figure 20). Assuming that this fraction holds also for other parts of

	NETHERLANDS	WORLD AVERAGE	
POTENTIAL PHOTOSYNTHESIS	50.000	78.000	kg/ha
FOOD	10.000	15.700	kg/ha
ENERGY	40	62.5	10^6 kcal/ha
PEOPLE	33	50	Number/ha

ARABLE LAND:			
	PRESENT	11 %	OF TOTAL LAND
	RECLAIMABLE	7 %	" " "
	TOTAL	18 %	" " "

25 % OF ARABLE LAND OR .6 10^9 ha IN POTENTIAL PRODUCTION IS SUFFICIENT FOR 30 10^9 PEOPLE OR FOR 10 x PRESENT POPULATION

FIG. 20. Potential production.

the world, the potential food production is guesstimated to vary from 2400 kg per ha up North to 25.000 kg per hectare in the tropics. On an average this amounts to 15.700 kg per ha which means that 50 people could cover at least their caloric needs from 1 hectare, taking into account 20 percent losses.

The world is very large, but only a small portion is suitable for intensive production. The sea can be ruled out in this respect because of the long food chain between photosynthesis products and harvestable fish and because it is impossible to bring the nutrients in this large body of water up to a reasonable level. The polar ice caps, tundra's, mountain regions and desert, most of the sub-arctic green forests and savanna's, and large parts of the tropical rain forests and even of the soils in the temperate climates are unsuitable to reclaim. Only 11 percent of the land surface is at present cultivated and given the present technical means this can be increased with another 7 percent (32). The total land surface suitable for agriculture is therefore only 2.4×10^9 hectare. However, if we could succeed in bringing one fourth of this into potential production, this 4.5 percent or $.6 \times 10^9$ hectare should provide enough food for 30×10^9 people or 10 times the present world population and they should have still 75 percent of the arable land and the whole of the sea available to supplement their calories with proteins and to provide industrial raw materials.

Hence, to feed the billions, these high production rates are not necessary for years to come. However, high production levels and a concurrent decrease in the land surface used for agriculture may be necessary in due course for economic reasons and to ensure the supply of cheap phosphate fertilizers. But perhaps the most important aspect is that in this way the use of biocides and other potentially dangerous chemicals can be restricted to a few percent of the global surface.

A poor man's world

Compared to the potential production the present situation is indeed deplorable. In large parts of the world, the soil releases only 20–30 kg of plant nutrients per hectare per year. Like in Europe 100 years ago, this enables only yields of 1000–1500 kg of food per hectare, as may be illustrated by the irrigated rice yields that are at present obtained in India (figure 21). Like in Europe, artificial

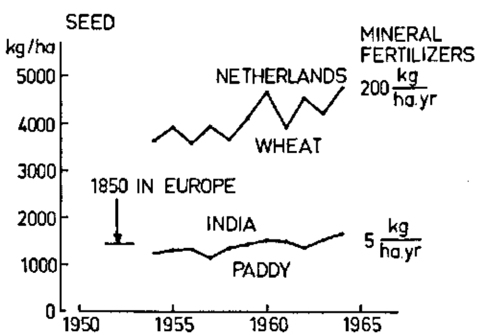

FIG. 21. The yield of low land rice (paddy) in India and wheat in the Netherlands. The yield of upland rice is so low that the average rice yields in India are somewhat less than 1000 kg per ha. (Sources: official statistical year book).

fertilizers have to provide the leverage for increasing yields. However, at present only 5 kg of nutrients per hectare per year are available (15) in the form of artificial fertilizers, compared to 200 kg in the Netherlands and it cannot be stressed enough that all attempts to increase agricultural production are futile unless fertilizer factories are built there where the suitable land is and the mouths are, and the infra-structure is created which enables the farmer to market his surplus. An integrated effort to increase agricultural production can only succeed within such a frame work.

Without underestimating the value of irrigation in regions with irregular rainfall, it can be said that the supply of water is a secondary problem. After all, it is much cheaper and more sensible to provide the millions of hectares where water is now available with sufficient fertilizers than to build irrigation systems and fertilizer factories in the dry zones of the earth. Even India could become a food exporting country without extension of irrigation, if gradually sufficient fertilizers should be made available (17).

Literature

1. ALBERDA, TH. and L. SIBMA: Dry matter production and light interception of crop surfaces III. Actual herbage production in different years as compared with potential values. *J. Brit. Grassl. Soc.*, 23 (1968), 206–215.
2. BIDWELL, P. W. and J. I. FALCONER: *History of agriculture in the Northern United States (1620–1680)*. New York, 1941.
3. BITTERMAN, E.: Die landwirtschaftliche Produktion in Deutschland, 1850–1950. *Kühn-Archiv* 70 (1956), Halle.
4. BODLAENDER, K. B. A. and S. ALGRA: Influence of the growth retardant B 995 on growth and yield of potatoes. *Europ. Potato J.*, Vol. 9 (1966) 242–258.
5. BOONSTRA, A. E. H. R.: *Physiologisch onderzoek ten dienste van de plantenveredeling*. Thesis, Univ. of Utrecht, 1934.
6. BOYSEN JENSEN, P.: *Die Stoffproduktion der Pflanzen*. Jena, 1932.
7. BRIGGLE, L. W.: Breeding short stative, disease resistant wheats in the United States. *Eucarpia-Symposium*, Wageningen, 1967.
8. BROEKEMA, C.: *Plantenveredeling en Wetenschap*. Inaugural Address Agr. Univ., Wageningen, 1923.
9. CARNEGIE INSTITUTE: *Annual Report of the Director of the Department of Plant Biology*, 1965–1966.
10. CRÖSSMANN, G.: Standraum und Stoffproduktion bei Mais. *Zeitschrift für Acker- und Pflanzenbau* 125 (1967) 3 : 232–253.
11. DE DATTA, S. K., J. C. MOOMAW and R. S. Dayrit: Nitrogen response and yield potential of some rice varietal types in the tropics. *Int. Rice Com. Newsletter* XV (1966), 18.
12. DICKINSON, W.: On a variety of Italian Rye-grass. *J. Royal Agr. Soc. of England*, Vol. 8 (1847).
13. DILZ, K.: Stikstofbemesting van granen. *Stikstof* 5 (1966), 174–187.
14. DOBBEN, W. H. van: Systems of management of cereals for improved yield and quality. *The growth of cereals and grasses*. Easter School Nottingham (1965), 320.
15. FERTILIZER ASSOCIATION OF INDIA: *Production and consumption of fertilizers. Annual review* 1965–1966, New Dehli, 1966.
16. FISHER, R. A.: *Statistical methods for research workers*. 3nd ed. (1930), London.
17. FLACH, M.: *Landb. verslag van onderzoek naar de mogelijkheden ter verbetering van de voedselproduktie in de Indiase deelstaat Maharashtra*. Gestencild verslag, Afd. Tropische Landbouwplantenteelt, L.H., Wageningen, (1967).
18. FORRESTER, J. W.: *Industrial dynamics*. Cambridge (Mass.) 1962.
19. HEADY, E. O. and L. Auer: Imputation of production to technologies. *J. of Farm Economics*, 48 (1966) 309.
20. HUDIG, J.: *Liebig's oorspronkelijke inzichten bevestigd*. Voorlichtingsdienst Superfosfaat Wageningen, 1967.
21. INTERNATIONAL RICE INSTITUTE: *Annual report* 1965. Los Banos, Laguna, Philippines.
22. KEMP, A.: Over het ontstaan en de preventie van hypomagnesemie bij rundvee. *Tijdschr. Diergeneesk.* deel 87, afl. 8, 1962.
23. KEYNES, J. M.: *The general theory of employment, interest and money*. New York, 1936.
24. KORTLEVEN, J.: Kwantitatieve aspecten van humusopbouw en humusafbraak. *Versl. Landb. Onderz.* (Wageningen) 69.1, 1963.
25. KOSTIC, M., W. Dijkshoorn and C. T. de Wit: Evaluation of the nutritional status of wheat. *Neth. Journ. Agr. Sci.* 15, 1967, 267.
26. LAWES, J. B.: On Agricultural Chemistry. *Journ. of the Royal Agr. Soc. of England*, Vol. 8, 1847, 226.

27. LIEBIG, JUSTUS VON: *Die Grundsätze der Agricultur-Chemie mit Rücksicht auf die in England angestellten Untersuchungen.* 2nd ed., Braunschweig 1855.
28. LOOMIS, W. E.: Die photosynthese der Grünen Pflanzen. Historical Introduction. W. Ruhland (ed.) *Handbuch der Pflanzenphysiologie* V, 1, 85–112. Berlin, 1960.
29. MAYER, R.: *Die organische Bewegung in Ihren Zusammenhang mit dem Stoffwechsel.* Heilbronn, 1945.
30. MITSCHERLICH, E. A.: *Die Bestimmung des Düngerbedürfnisses des Bodens.* 3rd ed., 1930.
31. OORSCHOT, J. L. P. VAN: *Conversion of light energy in algae culture.* Thesis Agr. Un. Wageningen 1955.
32. PEHRSON, G. O.: Limited land in the world food supply in: T. Greer (ed.). *Genis to Genus. IMC-Symposium,* Sokie, 1965.
33. PLANK, J. E. VAN DER: *Plant diseases: Epidemics and Control.* New York, 1963.
34. ROBERTS, E.: On the management of wheat (Prize essay). *Journ. Royal Agr. Soc. of England,* Vol. 8, (1847). p. 60–77.
35. SHULL, G. H.: What is heterosis. *Genetics* 33 (1948) 439.
36. SIBMA, L.: Growth of closed green crop surfaces in the Netherlands. *Neth. J. Agric. Sc.* 16 (1968), 211–216.
37. SONNEVELD, A.: *Research Project No. 395* (1967). I.B.S.-Wageningen.
38. SLICHER VAN BATH, B. H.: *De agrarische geschiedenis van West-Europa (500–1850).* Utrecht 1960.
39. THÜNEN, J. H. VON: *Der isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie.* Darmstadt, 1966 (reprint 3nd ed., Berlin, 1875).
40. TROUW en Co.: Enige actuele aspecten van eiwit-voorziening van mens en dier. *Mededelingen,* Amsterdam, Jan. 1966.
41. WIT, C. T. DE: Photosynthesis of leaf canopies. Agr. Res. Rep. (Wageningen) 663, 1965.
42. WULFFEN, C. von: Ideeen zur Grundlage einer Statik des Landbaues. *Mögl. Annalen,* 1823, Bnd XI, 391.
43. WULFFEN, C. VON: *Die Vorschule der Statik des Landbaues.* Magdenburg. 1830.
44. WULFFEN, C. VON: *Entwurf einer Methodik zur Berechnung der Feldsysteme.* Berlin, 1847.

Discussion

Prof. DOORENBOS: There is rather a big difference between horticulture and agriculture. The accent in horticulture is more on quality and the accent in agriculture is more on quantity. This has practical consequences.

In 1930, the difference could be defined as follows: in agriculture and horticulture people were striving towards the optimum yield, optimum in relation to the labour and the costs, but in agriculture, the economic optimum was often and usually very far from the optimal production of the plant. While in horticulture, when you aim at optimal production from the economic point of view, you always have to grow the plants in such a way that you are very close to maximum production. This morning, Dr. DE WIT has talked on the potential production of the plant and here agriculture and horticulture come very close together again. I think that we are ahead in horticulture, and therefore I come to my question. In horticulture, we have come to the point that during the 150 days we obtain almost a maximum yield, as all environmental conditions are kept optimal.

Our problem now is to attain this yield during the remaining part of the year, especially in floriculture and vegetable growth. I think that Dr. DE WIT is pessimistic because you have put the potential photosynthesis at about the same value for all different crops. At present, we do not grow tomatoes during the winter but after breeding, we could do so; e.g. ten years ago, lettuce was not grown during the winter time, but at present it is. To summarize, what do we do during the remaining part of the year?

Dr. DE WIT: Light during the winter time is a limiting factor and I do not think that the use of artificial light will be economical. Of course, lettuce is a good example, but it is not an example of calorie production, but of packing water in a highly palatable form. As far as the breeding problem is concerned, the main co-operative project between plant breeders, geneticists and physiologists, is to study how the photosynthesis function is genetically controlled. Of the gross photosynthesis, 40 to 50% is lost to respiration and it may be possible to breed varieties with smaller loss. This means a genetical study, but at present this is not done by the plant breeders, geneticists and physiologists.

Prof. MORRIS: Are there not further considerable improvements obtainable from breeding crops that can be better utilized especially by ruminants (grasses with better digestability) and perhaps also maize being better balanced for human nutrition (high lysine)?

Dr. DE WIT: Many agricultural practices tend to crops which are better utilized by animals and there are, as far as the forage crops are concerned, such large differences between the different plant species, that I am not so sure that within species, selection will really contribute in this respect. The second part is the protein quality. We may improve the quality by breeding and by adding amino acids. The second may be cheaper because with breeding, this may happen at the cost of the calorie production. Calorie production, being the main constituents of fodder, comes first and protein comes second because the need may be reduced by adding proper amino acids.

Mr. KOOPMAN: With reference to your discussion on the various proteins available in traditionally cultivated and future crops like algae, what is your opinion about the difference in *biological value* which, in general terms of 'completeness' is supposed to be considerably higher for animal than vegetable protein?

Dr. DE WIT: This is a similar question. With a good balance, the protein needs can be reduced to 37 g per person per day. This can be done with the assistance of the industry and not so easily with agriculture.

Dr. BRUINSMA: Would the phosphate supplies allow for the large fertilization increases necessary for the enhancement of crop production?

Dr. DE WIT: To make use of phosphate rock of low concentration will be expensive. When we have a higher production on a smaller area, we need less phosphate for most of the phosphate is fixed or lost. It will not be a serious problem: the farmer has to buy more expensive phosphate and the consumer may have to pay more. It is advisable to read Prof. VAN SCHUFFELEN's lecture: *Kunstmest voor Voedsel* (1965).

Dr. WOKES: What proportion of the total land available for food production should be used to obtain food for direct human consumption to ensure optimal yields and the most efficient attack on the world food problem.

Dr. DE WIT: I do not think that an attack on the world food problem at present should start with selecting really the good soils which are the soils from which we may get the optimum production. I calculated how large the yield can be, but not to advocate directly to go to a smaller area and optimum yields. The solution of the world food problem has to come from all the areas which are suitable for a consistent increase in yield. When in due course there is too much soil, marginal soils will be abandoned for economic reasons, e.g. in the USA this is happening. Let me emphasize that, so long as the food problem is not a technical problem in the first place, but a social-economic problem.

Dr. SCHUURMAN: In all cases under natural conditions, root development will restrict the result of higher fertilization. Do you agree?

Dr. DE WIT: No. BROUWER has shown the existence of shoot/root equilibrium. How much root does a plant really need? After removing part of the roots, the plant stops producing shoot and increases its root production. On soil with a low fertility level, the plant, therefore, gets more root and less shoot. By applying artificial manure, the root/shoot ratio is reduced by a higher shoot production. This is an example where the growth rate of the root and the shoot is functionally controlled. When the fertility level of the soil is sufficiently high, the water balance becomes the controlling factor.

Prof. DE WILDE: I missed in your talk the regulatory mechanisms within a vegetation, with regard to growth, and the effects of growth form on the level of yield.

Dr. DE WIT: I will refer partly to the previous questions. The highest economic yield is not obtained at optimum plant growth and therefore the farmer has even to go to the use of less manure, creating sub-optimum growing conditions. At present, there is a big gap between the plant breeders and agronomists and plant physiologists. The last two should suggest morphological goals for the plant breeders, but at present, they cannot. In a physiological field, there is too much lack of knowledge about the possibilities of plant breeding in this respect. It is possible to solve distribution problems with chemicals and to create in this way, desired morphological changes.

Mr. SCHEYGROND: Your example of Bintje is a great exception. Most top-varieties have a short life, often not longer than five years. Bintje is still a top variety for its consumption quality, not for its yield.

Dr. DE WIT: Bintje is a very good example because it is such an old variety. Five years is the maximum for many varieties because we are not breeding for yield ability, but for vertical resistance. It may be quite possible to breed varieties which exist for more than five years if we can apply another method of resistance breeding. The work on the disease epidemology by ZADOKS (Department of Plant Pathology, Wageningen) is important in this respect. The breeders do not like this short life-time of varieties and hope that something can be done about it.

Dr. SINGH: On the premise that vegetative processes in plants are most productive, would it be safe to assume, that potatoes etc., would be more productive than cereals? Provided, of course, that optimum soil and nutrient conditions are made available in comparable climatic conditions.

Dr. DE WIT: Root and tuber crops are the best crops. They yield two times more than grain crops. The protein content of the potato and sweet potato is sufficiently high when raised by an application of nitrogen fertilizers. The protein content may then reach a level of 10% of the dry matter and that is a reasonable protein content compared with small grains. Therefore, in the tropics such crops can be of importance in solving calorie problems.

Prof. FERWERDA: I agree with this but in the humid tropics, it is not yet possible to cultivate root and tuber crops permanently as it is done for grain crops, e.g. rice.

Prof. WASSINK: In agriculture, the energy conversion is the primary problem, whereas the primary problem in horticulture is to manage formative effects. I am quite optimistic that in future (maybe over a hundred years), artificial light can be applied and that we can grow agricultural crops on 2 to 3% of the area potentially available. I think that it is possible that potentially available sources of energy could be stored and re-distributed in a possible economical way in the far future; for instance, storing of excess solar energy, natural gas and nuclear energy. Sunlight is the best, although nuclear energy can replace it to some extent. Therefore, in future, we can also have agriculture in a bad time of the year just like horticulture, and then agriculture and horticulture, with help of technology, can be united.

Dr. DE WIT: I do not like to reveal lack of fantasy by looking into the future. In case of nutrient supply, the industry provides necessary constituents to agriculture. But, if we have cheap energy, industry and agriculture may compete with each other because this cheap energy cannot only be used for light in agriculture, but also in the industry to produce cheap industrial food products, and for cheap transport over larger distances. Why should we burn crude oil to provide light for growing oil crops? Why not use crude oil to make vegetable products directly. It will be very difficult to store solar energy. At present, the biological conversion of solar energy is 8% and in industry, we cannot yet reach this high percentage from a diffuse energy source with cheap methods, but perhaps in future it may become possible if it appears worthwhile.

Prof. MORRIS: I was interested in Dr. DE WIT's discouragement in the possibilities of the animal scientists and the agronomists and the crop breeders getting together to breed crops that can be better utilized. Maybe you do not need better grasses in Holland, but in Indiana, we do. We shall use better grasses to produce more beef. We hope that by breeding, we shall get better grasses. In maize, we have a gene, Opaque-2, conditioning a 12% protein level. This maize is fed to pigs. It is also grown in Brazil for human consumption and this is much better than telling the people to use soya bean meal or to use meat. In the mid-west of the USA, the farmer believes that he can produce maize with a high lysine level, cheaper than factories can make artificial amino acids. These synthetic proteins can be fed to monogastric animals, and that includes man.

Dr. DE WIT: If we grow grasses under optimal nutrient conditions, all common grasses have a high protein content. There are no big differences. However, under low nitrogen conditions (Indiana?), the differences will show up. The danger is that an improved plant which gives a high protein content, does so because it yields less; it takes up the same amount of nitrogen and has then a higher protein content. The same is true for some plants which are drought resistant. Such plants do not yield very much under any condition. Under dry conditions, the water is more evenly distributed over the whole growing period of such plants. We should be very careful with the correlations; low yield-drought resistance, low yield-high protein content and so on. The opaque-2 gene in maize really improves the quality of the protein so helping to reduce the amount of needed protein from 70 to 37 grams.

Prof. DE VRIES; May I contribute to the problem of feeding animals as an inbetween of feeding people. For instance, in farm management with some crops, e.g. alfalfa yields 10 cuts per year, in a desert area. You will get a high protein content in the plants and this is a very good animal forage. In Australia, by using subterranean clover and a supply of some trace elements, a change was obtained from one sheep per four acres to four sheep per one acre, resulting in an increase of 16 times, due to the introduction of this leguminous plant. *Stylosanthes*, 'the Townsville lucerne', discovered in Queensland, has changed the economic potential of Northern Australia. When we have enough space, grasses and these leguminous plants may yield sufficient and inexpensive food production. Formerly, we were told that mixed farming was necessary, but at present, I think it is possible to separate agriculture from animal husbandry, just as we did with the poultry and the Finnish people are doing with cattle. Is mixed farming still needed?

Dr. DE WIT: The difficulties with growing leguminous crops are caused through their lack of persistency. Pests and weeds increase in time and this holds also for alfalfa. It will be difficult to keep a good mixture of clover and grasses. Clover is often crowded out except when the mixture is grown at a low fertility level. In Australia, glycine, a leguminous species, may dominate, but the total yield is then lower than the yield of fertilized grass. What is better – to have clover in a mixture which fixes nitrogen, or to buy this fertilizer. In the Netherlands, the clover is not necessary for grassland. Here, we only cultivate a mixture of some grasses and may even end up in monoculture, as with cereal growing. At present, there is a tendency to move away from mixed farming. This is an economic problem. The farmer prefers probably mixed farming (at least I do) but specialization is needed. In the case of animal farms, we get a big problem in what to do with the manure, so specialization leads to a waste problem and this is expensive.

Prof. FERWERDA: When wages of people are the same and transport is cheap, we may reach a point at which the highest yield (per unit of surface area, per unit of time and per man) will determine the place where a certain crop must be grown.

ANIMAL PRODUCTION

by

H. P. DONALD

Director Animal Breeding Research Organisation, Edinburgh

1. *The bases of animal production*

The history of animal production is a history of intensification. It is a record of slow but successful attempts to increase the disposable surpluses of flocks and herds. Because animal production has brought its past with it into the present, it is possible in many countries to find ancient practices still being followed. Those connected with the provision of food for winter will illustrate the point. There is an island, St. Kilda, off the west coast of Scotland where sheep, very primitive and similar to those in Scotland during the Bronze Age, run wild. They often experience severe winter mortality. Not far away, there is another island, North Ronaldsay, where Orkney sheep are fenced out of the occupied land and obliged to live on seaweed and littoral plants which the beaches afford. Until recently, the islanders plucked the wool and carried out their own dyeing, spinning, and weaving; but the breeding and feeding of the sheep remained uncontrolled.

On the mainland, there still occur flock movements the history of which can be traced back from a modern geographical stratification to forms of nomadism. There is the daily shepherding of sheep on mountains to ensure even grazing; there is winter migration of young sheep to areas where they are better fed and less exposed to extremes of weather; there is an annual transfer of old sheep to lower pastures; and of their crossbred daughters to more fertile farming areas. The matching of sheep with food supplies comes to a logical end with the change from outdoor grazing to permanent indoor feeding. Here, then, is a record of the way in which farmers have tried to increase that part of the input of food which is used for growth and production. High inputs are not always possible; and then the efficiency of food use, as well as the output from land, labour and buildings declines. Although it is often necessary to accept such imperfections, the evolution of high producing animal enterprises is evidence of progress in overcoming them.

If a broad enough view is taken, advances in animal production have three sources, namely,

a. adaptation of genotypes
b. adaptation of environments
c. adaptation of social institutions, chiefly,
   (i). markets, (ii) finance, and (iii) politics and social customs.

As FRANKEL (1962) has already shown, these are likewise the sources of advances in crop production. Collectively, they are the results of the interaction of biology and human culture.

a. Adaptation of genotypes

Domestication was perhaps the most striking phase of genetic adaptation. DARWIN himself gave it considerable attention. It must have been a long process and not an event. As a process, it can be regarded as continuing; and all efforts to modify livestock to fit their purposes better–that is to say, to improve them – are late stages no different in principle from the first.

To this day some species, usually with social habits, seem to be able to move comparatively easily from a wild to a captive state, for instance, elands, camels, elephants, dingoes, seals, and reindeer. Most species can revert to the wild as have the horse and the pig in Australia, and cats everywhere. While such a list may start a discussion about the meaning of the word 'domestication', (see, for instance, the sixth edition of HAGEDOORN's *Animal Breeding*, 1962) it will also serve to illustrate the point that the original achievement of man in persuading many animals to breed in captivity may have been less difficult than arranging to feed them in captivity. Even so, their fertility often leaves much to be desired.

An aspect of domestication that was described at the XIth International Congress of Genetics at The Hague by BELAJEV and TRUT (1963) is very interesting. Working with silver foxes, they came to believe that genetic progress by selection for extended breeding season (which had a low heritability) was faster if the correlated characteristic of a calm temperament was used as the basis for selection rather than extended breeding season itself. Now, whatever the situation may be in silver foxes, it will be clear to those who are familiar with cattle, sheep, pigs and mice, that temperament has a great deal to do with some kinds of reproductive performance, especially lactation; and it would not be surprising if the persistent tendency by man to prefer animals that were easily handled had influenced the development of the good reproductive traits and good appetites necessary for high performances.

Selective breeding, which is the main technique for bringing about genetic change, has to face a growing challenge. Although it remains the activity of a relatively few breeders, in Europe these breeders tend increasingly to be technologists charged with operating large enterprises and they work in a social climate very different from that which was enjoyed by their predecessors. Investment of large sums of money in livestock improvement will be expected to produce animals which are capable of more efficient and economic production and which must demonstrate this in publicly conducted performance tests.

Those who would improve livestock by breeding have to think not only of the performance of the purebreds in terms of meat, milk and wool, but also of the crossbreds derived from them. Of recent years there is the added task of finding suitable animals for the intensive use of grassland. If sheep are to make another great leap forward and be adapted to continuous indoor breeding with high fertility and mechanized feeding within a decade, there will have to be a large and co-ordinated effort by breeders, husbandry experts, and veterinarians.

In general, it looks as if animal breeders face a future in which the emphasis on economic production will be stronger. There will also be a wider range of environments into which livestock will have to be fitted. In addition to all the traditional breeding areas there are new ones in tropical countries.

b. Adaptation of environments

By modifying environment, man has produced the beautiful countryside of to-day. But progress towards it has not been continuous or universal. Sometimes the price of progress cannot be paid and after a period of stagnation animal production disappears. Large areas of Scotland have already reverted to forests although better managed than those the Romans knew. Further areas are likely to follow.

The transition from open fields to enclosed fields which started on a large scale in England in the 18th century, has by no means been completed elsewhere. It has proved to be, however, an essential step towards the highest output which the ingenuity of man can extract from his livestock and from his own labours. Stone walls have given way to electric fences, chemical fertilizers have reduced the importance of farm yard manure. Security of tenure has improved. But each advance towards freedom from want which man strives to gain for himself is accompanied by an encroachment on the liberty of his animals. The results are the battery hen, the pig and the veal calf, whose only liberty is to eat. No emotional overtones are intended by this remark. The ethics of using animals for food is outside the scope of this paper.

Wherever animal protein is eaten, the trend towards intensification will continue, especially if it has good opportunities. These seem to be the improvement of plant and soil productivity by plant breeding, fertilizers and herbicides; increasing mechanization of harvesting and drying crops and feeding animals; and, finally, breeding of suitable animals for processing the crops.

c. Adaptation of social institutions

(i) *Markets.* Of the social institutions influencing an animal industry, a market is obviously essential to any but the most primitive form of activity. At the present time, there are markets in varying size, facilities and complexity from unorganized haggling in the open air to arrangements for handling the total production of a nation engaged in world-wide trade.

What a livestock producer must have is a buyer for his products and, in the long run, a price that encourages him to go on producing. Even in a world short of food, a buyer is not always to be found. There are parts of Scotland where buyers are so far away that transport costs are prohibitive. In large countries with bad roads and poor transport the problem is much worse. India, for example, has many small isolated markets dependent on the operations of middle-men who are often moneylenders as well. Quantity and quality control is lacking and so is hygiene. There are no cold stores. Faulty weights and adulteration are common (Fahimuddin, 1963). In many other countries similar conditions exist with depressing effects on animal production.

Countries with highly developed secondary industries, large towns, and an international trade present other problems for the producer. In these, the emphasis on quality control and grading has obliged the farmer to take more trouble over production and marketing. Eggs must be clean and fresh; milk must have an acceptable composition; and meat must not be too fat. Although the importance of quality and uniformity is now well recognized in Europe, much remains for the livestock producer to do. In addition to reducing the costs of production as far as he can, he must be prepared to raise his standards of quality when his market becomes more exacting. Whilst this sentiment may be acceptable to most people, it is perhaps as well to realize where it leads. Better quality is not just a question of a better average. The variation in quality which can be the raw material of geneticists, and the standing challenge to nutritionists, can also be a grave handicap in marketing (BREIMYER, 1967). While improved grading methods will help, there remains a need to reduce the variation in all aspects of performance by better control of environment and the use of more uniform genetic stock. These improvements are well within grasp and progress towards one will make the other easier to achieve. Already the merits of zero-grazing for dairy cows compel attention where the land is capable of producing heavy crops.

According to KORACH (1964), the range of variability can be held between determined limits only in automatic processes. In animal production these limits are not yet so narrow as to force wholly automatic methods even on poultry producers, but it is clear that the livestock industry is moving in this direction. Factory farming will then be commonplace. Fortunately, there will still be acres where people can watch the lowing herd wind slowly o'er the lea.

(ii) *Finance.* It is not necessary to become an economist to understand that capital resources are the first requirement of a livestock farmer. To-day there are innumerable small tenant holdings where the farmer has little capital and poor prospects of acquiring more. For him, up-to-date buildings and machinery and a bigger farm are unlikely. But there are also farm enterprises in the course of rapid expansion – enterprises that can earn or borrow money for growth; enterprises that can invest in land improvement; enterprises that can apply advances in technology.

The trend to larger units of production is general in capital-rich countries. For politicians this trend brings awkward social problems concerning the hardships of the smallholder who is left behind. Technology, however, is not deterred. In England, where not so long ago (1942) the average number of dairy cows in a herd was 15, there are now nearly twice as many and a growing number of herds of 500 cows. Pig breeding has been similarly affected. At least ten companies have been formed with 400 or more breeding sows which sell male and female breeding stock on a scale far beyond the scope of the traditional breeder. About large breeding herds there is perhaps nothing new. The monasteries of the 16th century, for instance, included some extensive estates. What is new in the 1960's comes from improved methods of production, greater supplies of capital, modern advertising and marketing. For the animal technologist, a better context for his work has developed. It now includes populations of breeding animals, notably those created by artificial insemination. Additionally, his need for extensive and rapidly processed data is conceded by an industry less obsessed than it used to be by the shape and appearance of its protein manufacturing units.

(iii) *Politics and social customs.* In Britain – and it is probably the same in the Netherlands – animal production is much dependent on politics. Among the institutions of general importance are the advisory or extension services provided by governments in many countries. But governments also fix prices, control imports, and make regulations. Semi-public bodies, such as A.I. centres and marketing boards, can make rules which are helpful to some producers and harmful to others. Agricultural research itself is supported by governments for the benefit of the nation as a whole. It is not necessarily beneficial to all producers. But of such matters more will be said shortly.

2. *Inter-relationships*

In a flexible industry like animal production, it is to be expected that a change in any important respect will have repercussions. Perhaps the commonest and most immediately effective change is in the price and profitability of a product. From an increase can flow capital investment and the improvement of production methods; from a decrease, the flight of capital and neglect of land and buildings.

Interactions can be observed in systems as unlike as Siberian reindeer herding and Californian beef lots. According to LEEDS and VAYDA (1965), survival of human communities in the reindeer grazing areas of Eastern Siberia is conditional not only on the genetic adaptation of the animals to the intractable country but also on a careful adjustment of herd size. Herds that are too large are difficult to control and run the risk of overgrazing. Herds that are too small mean a low social status for the owner. From this basic fact springs a set of social institutions affecting the distribution of capital (animals), and labour (women and young men).

In the United States, the modern beef lot presents a very different kind of animal enterprise. To all intents and purposes, it is a large factory for turning the raw material of weaned calves into finished beef. It may have the capacity to hold up to 50,000 or more cattle and is sited and constructed with close regard to keeping capital and feed costs down and labour output up. Markets are watched very closely and there are financial refinements such as beef futures. Oddly enough, the breeding of suitable cattle appears to have attracted comparatively little attention. This is significant. Important though it may be to have cattle specially designed like pigs for fast growth and economical gains on intensive feeding, there is no organization for breeding and selling such cattle. The future no doubt will produce one but meantime store cattle of almost any breed or cross will be bought when the price is low enough. In commerce, there is nothing novel about that. The lesson is that animal production enterprises are very adjustable and easy assumptions should not be made about the economic superiority of any breed or cross.

Unlike poultry pigs and dairy cattle in Britain, sheep have not shared fully in the technological advances of recent years. Consequently, there is not much information about the relative performances of the various breeds. But there has been criticism of their fertility. Whereas an output of one and a half lambs from a breeding female each year was once regarded as acceptable, an output of two to three lambs is now a realistic aim for capital intensive enterprises. All kinds of intermediate situations exist. Sadly, it must be admitted that for one reason or another human beings, including sheep farmers, are sometimes unequal to their opportunities. But where this is not so there are other limitations on the use of knowledge. Given the inherent fertility of Finnish Landrace sheep and the extended breeding season of Dorset Horn, the sheep farmer on good land has a ready means of increasing the prolificacy of his flock. Work done at experimental farms near Edinburgh has shown this quite plainly. But that is not all. With the new techniques of grassland management, of early weaning and indoor feeding, and the growing power of veterinary science to control disease, the sheep producer has many resources at his command. Yet it is no easy matter to determine how to combine them. Sheep are kept under much more diverse conditions than any other kind of farm livestock. For none of these conditions can it be said with assurance which is the optimum litter size. No doubt it depends partly on the live weight of breeding ewes and fleece weight but little is known of this subject.

In such a fluid situation, it is not surprising that traditional breeds and methods of production are being critically examined; or that attempts are being made to develop new breeds and crosses. Of these, the Colbred and the Improver are now well-known. Students will find a study of the origins of these breeds and the methods of the breeders very rewarding. This is true also of the large scale pig breeding enterprises. A willingness to discard worn-out beliefs are characteristic. They have links with big business and advertising. They use new husbandry techniques. They are aware of market potential and are ready to adapt any part of the production system to economic requirements.

A passing thought may be permitted here. Those who aspire nowadays to introduce a new variety or crossbred can scarcely hope for recognition unless they have adequate financial backing. Large sums of money are required to launch new products and the resources of the individual farmer-breeder are rarely equal to the need for financing breeding stock, performance testing and promotion. In future new breeds, either imported or recently bred, will be the concept of a breeder, but success will be made possible only by a powerful organization.

Some breeders now try to sell particular genetic stocks with specific breeding systems, housing and husbandry – in other words, a package deal. In principle, the mutual adaptation of genotype and management is to be welcomed. It probably means, however, that a breeding initiative will have to be broadly conceived and carried out by a group, including financial, commercial and biological technologists.

The small farm problem

As the intensification of animal production goes on, a widening gulf yawns between the personal income of the farmer who can barely subsist on the profits of his small business and the income of the farmer with a relatively large business. Much thought has been given to this question in the Netherlands and elsewhere.

Those who would like to read more about it will find much information in an Organisation for Economic Co-operation and Development Agricultural Policy Report (1964) on low incomes in agriculture. It shows that in many countries the same problems recur: too many old people; too low mobility; erosion of capital; lack of initiative, or of markets; inability to take advantage of technological advances. Quite often nature conspires against the subsistence farmer who tends to find himself on the poorest soils and at the highest altitudes.

On the economic margins of occupied land, the cost, economic or social, of keeping the least productive holdings in use may be too high. Such land has to revert to forestry or to be abandoned altogether. This is occurring in Scotland and also in New Zealand. In countries where most of the land is traditionally devoted to subsistence farming, such reversion does not help to meet the demand for more food or the urge to modernize. Consequently, what is needed is a transition to a market economy which entails convincing farmers that markets work.

A clear and authoritative statement about the interrelationships of the elements of agricultural production is given in a Report of the President's Science Advisory Committee in the United States on the World Food Problem (1967). Although primarily concerned with measures to diminish the threat of worsening food supplies, the Committee's work confirms the belief that the bases of animal production are the same everywhere. They differ among countries only in stage of evolution. But even in the most advanced livestock industries not one of the bases – genetic and environmental adaptation, markets, finance, or government action – has been fully developed. Concerted control is rarely attempted.

New Zealand

It is not necessary to go to impoverished areas to illustrate the argument that a co-ordinated approach to the problem of increasing the productivity of livestock will be the most effective. New Zealand provides some information about rising productivity. Consider, firstly, the contrast between dairy farming in 1906 and 1966 on two farms, one operated by J. R. Ranstead in 1906 and the other by his grand-nephews in 1966. In the space of 60 years, the dairy herd changed from 90 Shorthorns to 450 Jersey cows. But milking has gone down from 2 hours work for five men to 1½ hours work for four men. Production at about 400 lb. of butterfat per cow has doubled and the farmers' price for one pound is five times as high. Instead of 500 acres of land, only 400 are needed, but the value per acre is twenty times as high. And a cow now costs not £5 but £50.

These are remarkable changes but they are not unusual. (Table 1, WALLACE, 1966). The area of occupied land in New Zealand has not risen during the last 45 years. This is because reclaimed land is balanced by other land which has reverted to nature. New Zealand has had its full share of the involved economic and political problems of changing land use.

Here in the Netherlands, where so much has been done for dairying all over the world, the achievements of the New Zealand dairy industry will be fully appreciated. The number of cows in milk there has been increased since this university was founded from 0.8 million to 2.0 million, that is, by a factor of 2½. But the output of the national herd has gone up by a factor of 4½. During the same period, meat production and wool production have more than doubled; yet the farm labour force has declined by about 15%.

TABLE 1. Animal production in New Zealand (WALLACE, 1966)

	Units	*1920*	*1965*
Farmed land	m. acres	44	44
Cows in milk	m.	0.8	2.0
Total butterfat	m .lb.	136	623
Butterfat/cow	lb.	240*	300
Sheep	m.	24	53
Wool/sheep	lb.	8	11
Meat	m. lb.	328	851
Labour (men)	m.	0.14	0.12

* 1935–39

Such are the results of New Zealand's own vigorous efforts to create the conditions for an expanding agriculture. These include highly organized marketing, strong advisory and research services, and marked initiative in farming practice. The way the farmers there have turned the aeroplane into a common agricultural implement is characteristic.

3. *Current research*

In New Zealand, as in other countries with advanced animal industries, rising productivity is associated with a strong technology. It is natural at this point therefore to be tempted to examine the adequacy of animal research in Europe but time permits only two general matters to be mentioned. There are still many opportunities for encouraging the interaction of two or more scientific disciplines. The collaboration of genetics with nutrition and physiology is already taking place. Rewards here are easy to foresee. With pigs and poultry as pace setters, ruminants are on the threshold of important advances in understanding how body size, maintenance requirement and rate of maturing are inter-related. Given a firmer theoretical basis than they have yet had, studies of genetic variation in food efficiency, of carcass quality, and of fertility are likely to become more meaningful and less merely descriptive than formerly. For understanding and for controlling the reproduction and performance of livestock, it is quite apparent that all these sciences must be brought into action together.

There is also profitable research to be found by pathologists working with geneticists. Since so few combinations like this are at work, it is a matter for surprise that so much evidence is building up of inherited susceptibilities to viral, bacterial and metabolic diseases. That sheep vary in the degree and the manner of their resistance to diseases such as foot-rot, scrapie and copper deficiency is now well-known. Before long the no-man's land between genetics and environment will be explored with immunology and pathology as guides, and then at least some genotype-environment interactions will be repeatable and predictable in any laboratory. With all the help that can be had from biochemistry and disease-free stocks there must be good prospects here for research workers for a long time.

Of all the other possible combinations, one more can be mentioned. That is the animal behaviourist and the geneticist. As production methods become more intense they interfere more with the relations among animals. If social stresses are imposed on some animals their growth and reproduction may be adversely affected. In performance testing, the presence or absence of such stresses may influence the results.

Interactions between scientific disciplines depend heavily on information; this is a moment, therefore, to commend the Centre for Agricultural Publications here for its energetic and forward looking policies.

Another general matter concerning research is the desirability of making sure that the administrative machinery is suitable for the task of distributing research funds. Sometimes it needs modernizing to cope with a growing research industry.

In the United States a detailed attempt to develop a National Program of Research for Agriculture (1966) has been made. The central idea is surely very sound. It is not to be expected that the proposals for expansion would be wholly appropriate in other countries. In the first place, the current research effort in the United States is very extensive; and in the second the objectives will not be the same. Research is an industry which is the product of past thinking about present and future problems and its content therefore tends to reflect local considerations. Since research workers influence the character of a national effort, however, there is certain to be much in common among the programmes of all countries. This will apply most strongly to research on the biological bases of agriculture. Developmental research has naturally a much more local flavour.

Of the many interesting features of this American publication there are three that are specially relevant in the present context.

1. There are substantial differences in the funds made available (Table 2) for the various subjects. Social sciences, for instance, attract fewer funds than genetics. From data given in the report it is clear that funds of both public and private origin are attracted mainly to subjects closely connected to production and marketing. These are the protection of crops and animals, efficient production,

TABLE 2. Agricultural research expenditure ($) and scientist-man-years (smy) and their ratio (adapted from U.S.D.A. 1966)

Subject	$ (millions)	SMY	$/SMY (thousands)
Biology-applied	49	1605	31
Genetics	35	977	36
Nutrition	26	659	39
Entomology	24	702	33
Physiology	23	643	36
Biochemistry	22	597	36
Pathology	20	618	32
Others	27	708	38
Total biology	225	6509	35
Physical sciences	76	2482	31
Social sciences	29	1195	24
Grand total*	415	10905	38

* Incl. $ 85 m. miscellaneous items

and product development and quality. Over the next ten years the recommended percentage increases in funds will not reduce the pre-dominance very much. On ambitious young research workers, the point will not be lost; but how are the planners in any country to know where national interests lie?

2. With the apparent exceptions of social scientists and virologists, the annual cost of a working scientist including his salary varies little with subject. The size of the experimental animal does not affect it much. It is roughly 35,000 dollars a year. In the United Kingdom, the comparable figure would be about 25,000 dollars – a considerable investment.

3. The total research effort in each field is measured in scientific-man-years. If, as seems likely, the concept of cost-effectiveness is increasingly applied to agricultural research, this new unit measure of input may come into common use. The implications for scientists in government and university employment are worth pondering. Perhaps they have a duty to measure and assess objectively their own effectiveness.

Forward planning of research and the allocation of priorities are notoriously difficult. No surprise, therefore, is occasioned by the lack of concordance between the research policies advocated by those who worry about improving protein supplies for over-populated and under-developed areas and by those who think in terms of raising the efficiency of more advanced areas. Even when the generally acceptable criteria for allocating priorities are applied, the position is not much improved. If research projects are judged by their significance to agriculture, as well as by their scientific value and the likelihood of success, the combination of these three subjective judgements is still open to error. The probabilities of success can be changed very quickly by a stimulating personality or a new technique.

4. *Research, extension and development*

No matter whether the choice of problems for study is approached from the point of view of increasing food production, or from the point of view of increasing efficiency of production, the rate of adoption of technical advances is a matter of concern. Variations in this rate are very conspicuous. Artificial insemination is a good example. In many countries its rate of growth was slow at first, then rapid, and finally slow again as it approached its maximum usage for the time being. As a rule the advantages of a change in husbandry are less easy to demonstrate and it is less easy to measure the rate of adoption. Nevertheless there seems to be a solid foundation for the belief that where farmers can see a financial benefit for themselves in using a new method or product they tend to respond quite promptly.

Fortunately, there have been some outstanding successes in overcoming unpromising situations. They offer encouragement and guidance in putting the results of research to work.

The story of Borgo a Mozzano in Tuscany has been told by VIRONE (1963). In the face of nearly all the handicaps with which it is possible to load small scale farmers, such as inadequate capital, transport, machinery and technical advice, a spectacular improvement of 60 per cent. in net income was achieved in seven years. Better cows alone would not have helped. There had to be confidence, better food, roads, a market, and a profit. The absence of any of them would have stultified the project.

Mexico is another source of encouragement. In 1943, the Ministry of Agriculture there created an Office of Special Studies with the duty of developing the technology, trained men, and institutions necessary to solve Mexico's food problems quickly. Crop yields were low and the country had to import half its wheat. Only twenty years later, food production had doubled. Meantime, the population had grown from 21 million to 37 million; yet the average daily food intake had risen from 1700 to 2700 calories. Mexico is now a source of improved plant varieties and can spare experts to help other countries.

According to the 1966 report of the Rockefeller Foundation Program in the Agricultural Sciences, this remarkable progress is attributable to a pattern of effort with six clear principles. They are:

1. Crop oriented research and production programmes covering varieties, soil fertility, irrigation, weeds and pests.
2. Screening of the world's resources of germ plasm.
3. Measuring progress by the rise in national average yields.
4. Concentrating efforts at first in one or two stations.
5. Developing extension work among farmers.
6. Allowing farmers to make a profit at official prices.

In both Italy and Mexico much attention has been paid to the behaviour patterns of scientists and advisors as well as of farmers. Another important lesson is that livestock husbandry practices cannot be exported directly from one country to another. They are the outcome of numerous local qualities of soil, climate, and markets and need adapting from farm to farm. This is why that phase of research which is called development is required if the benefits of laboratory and experiment station research are to be obtained in suitable areas at home and abroad.

5. *Relation between research and industrial innovation*

Long term economic growth is primarily a consequence of increasing technical knowledge. Since most countries desire economic growth to support their social ambitions, they desire the knowledge that makes it possible.

What provokes technical progress most effectively is economic opportunity. Heavy capital investment and financial rewards are the soil in which inspiration flourishes. If these fail, so do invention and effort. SMOOKLER (1966) has produced a bookful of evidence of this in four large industries including agriculture. It is important, therefore, that these necessary stimuli should be provided. This is not to say that all farmers and all scientists are just 'economic animals' responsive only to nett returns. But if society wants higher production, it is as well to be practical about getting it.

Successful investigators and inventors tend to be those who have selected the most efficient means for achieving their ends. As time passes, the means chosen tend to change. Thus, when new tools, such as blood-grouping, computers, or radio-isotopes became available, fresh possibilities were opened up in many directions. The best chances will be where there is plenty of money and, consequently, numerous and competent workers able to draw on the whole corpus of science.

In a study called *Operation Hindsight,* SHERWIN and ISENSEN (1967) describe the development of weapon systems in the United States. Many innovations were used, of which no less than 91 per cent. were judged to be of technological origin and 9 per cent. scientific. Unconnected fragments of scientific knowledge do not find ready practical application. As PRICE (1965) puts it, discoveries in science and technology are related but only distantly. A discovery in basic science is far more likely to lead to another of the same than to an industrial innovation. Whilst, therefore, on a long view it is desirable to maintain efforts to expand knowledge of fundamentals in biology, it is also desirable, and this time on the short view, to increase purely technological exploitation. Due attention could be given to removing some of the disincentives to operational research. One is inadequate financial, scientific and social rewards; another is too little contact between technologists and decision-makers; and yet another is poor organization of research at the developmental level. A little less detachment and a little more involvement is required from scientists in high places – a lover's quarrel with the world.

In Britain, there is not yet enough effort to find out how to use existing knowledge of animal production. For an example of this there is the question of crossbreeding dairy cattle. On the basis of the work already carried out, it would appear safe to conclude that the advantages of crossbreeding for either milk or meat can sometimes be economically important. Cattle exhibit heterosis to a degree which depends on the character concerned, but which can be important for health and fertility. So far, however, data from only one research farm in Britain have been obtained. Since, in cattle breeding, the market prices for milk and surplus calves, steers or cows are variable, and the costs of production vary with farm and region, there is a case for a whole set of repeated trials based on local A.I. centres and aimed at finding where local conditions favour organized crossbreeding. Fortunately, this is being done, but unfortunately only in terms of two breeds. Ultimately, the question will have to be extended to others. In England there is a progressive Milk Marketing Board with the A.I. Centres, the scientific staff, the computer and the money. In circumstances where these essentials are not integrated, operational research with animals languishes. This is indeed the position with many potential advances in the production of pigs, sheep and beef cattle. The impetus of a piece of research is lost in spite of the urgency of the times. Farmers themselves, especially in poor countries, cannot be expected to find all the money necessary to increase production. Adapting existing knowledge and seeking more local knowledge will, therefore, be expensive for taxpayers. Good basic research by itself, although essential, is not enough.

Events will sooner or later force a more systematic and competent approach to operational and developmental research. The selection of means for achieving an economic end is itself an economic process. Some economic criteria are needed by which to judge where to invest money and brains and how to measure the economic returns from research effort. A beginning has already been made by those who are refining the techniques of econometrics and systems analysis. From quantitative descriptions of economic and biological systems, it is a short step to determining the consequences of interfering with them, either directly or indirectly, through feedback mechanisms. If securely based on facts, theories of this kind will be of vast importance; but without close and regular observation to produce enough data they must remain academic.

From new techniques for objective assessment of research as an economic activity, there might come guidance on several broad issues. It would be useful to know how to estimate the optimum national investment in operational and developmental research, even if politics revealed competing demands. Economic efficiency requires that available funds should be distributed where they would do most good. On a more technical level, there should be not great difficulty in recognizing the point of diminishing increments from specific activities such as performance testing, or the use of capital for intensifying animal production.

References

BELAJEV, D. K. and TRUT, L. N., 1963. The ways of reorganization of the reproductive function in seasonally reproducing mammals. Genetics Today: *Proc. XI Int. Congr. Genet.*, The Hague, **1**, 250.

BREIMYER, H. F., 1967. The integration of supply, production, and marketing in intensive animal production. *Rep. Proc. IX Int. Congr. Anim. Prod.* 156–161.

FAHIMUDDIN, M., 1963. *Animal production in Bihar.* Asia Publ. House, London, viii + 166.

FRANKEL, O. H., 1962. Plant science. *J. Aust. Inst. Agric. Sci.* June, 1962, 84–91.

HAGEDOORN, A. L., 1962. *Animal breeding* (VIth Edition). Crosby Lockwood, London, xix + 371.

KORACH, M., 1964. *The science of science* (Eds. Goldsmith, M. and Mackay, A.), Ch. 13. Souvenir Press, London, 235 pp.

LEEDS, A. and VAYDA, A. P. (Editors), 1965. *Man, culture and animals*. Publ. 78, Amer. Ass. Adv. Sci., Washington, D.C. vii + 304.

ORGANISATION for ECONOMIC CO-OPERATION and DEVELOPMENT, 1964. Agricultural Policy Report, *Low incomes in agriculture. Problems and policies*. 515 pp.

PRICE, D. J. DE S., 1965. Is technology independent of science? A study in statistical historiography. *Techn. Culture* **6**, 553–568.

ROCKEFELLER FOUNDATION, 1966. *Program in the agricultural sciences*. 1965–66. x + 230 pp.

SHERWIN, C. W. and ISENSEN, R. S., 1967. Project Hindsight. A Defense Department study of the utility of research. *Science* **156**, 1571–77.

SMOOKLER, J., 1966. *Invention and economic growth*. Harvard Univ. Press. xv + 332.

U.S.A. President's Science Advisory Committee, 1967. Report of the Panel on the World Food Supply. U.S. Government Printing Office, Washington, D.C.

U.S.D.A., 1966. A National Program of Research for Agriculture. Report of a study sponsored jointly by Association of State Universities and Land Grant Colleges and U.S. Department of Agriculture. Mimeo. 272 pp.

VIRONE, L. E., 1963. *Borgo a Mozzano. World land use survey*. Occasional papers No. 4. Geogr. Publ., Bude, Cornwall, England.

WALLACE, L. R., 1966. The importance of animal production to the national economy. *N.Z. Vet. J.* **14** (9), 131–136.

Discussion

Dr. POLITIEK believes just as the speaker said that in future, animal production will depend on the economic possibilities. He also believes that the farmers will change their way of producing as they can see financial benefit. Therefore, besides good basic research, there is a need for applied research. If society likes to have higher production, they can obtain this if they are prepared to pay for it.

The first question related to the payment to farmers of their milk on basis of fat of protein content. The main reason for animal production is to obtain animal protein. In the Netherlands, about 50% of the milk is paid for on the basis of fat and protein content. Because a large number of cows are milk-recorded also for protein content, a selection on protein is possible. However, since about twice as much is paid for milk fat as for milk protein, this hardly stimulates selection on protein. Is it right to go on investing money in the recording of milk protein?

In the lecture, attention was rightly paid to the interplay between different scientific disciplines. Is there no need to collaborate between genetics and economics? Genetic progress measured in profit for the farmer is still often neglected.

The third question concerned the distribution of research funds between the animal and plant sciences. Should the amounts be connected in some way to their value in agricultural production?

Dr. DONALD replied to the first question by saying that he was doubtful about the investment of money for recording milk protein. The heritability of milk protein percentage is quite high, but the variation is low, so the prospects for selection are not very promising. This topic would be of special interest if somebody could find a relationship between the efficiency of protein production in milk and in beef.

Dr. DONALD agreed that not enough attention is paid to the collaboration between genetics and economics. He felt that investment in plant science would give greater results in the immediate future, whereas in animal production, the benefits are expected to come over a longer period.

Dr. SINGH asked some questions concerning feed efficiency. Dr. DONALD replied that the feed efficiency of an animal in a given time period depends on a number of factors. However, not only the feed efficiency during this period is important, but also other factors such as the maintenance of the breeding stock and the overhead costs per animal. He hoped that future research will solve a number of these problems. The milk production process is more efficient than beef production. The latter, except as a by-product of the dairy industry, is a luxury which only rich countries can afford.

Prof. STEGENGA said that one of the problems in the intensification process in animal production, is the lack of professional skill of our farmers. How can we make a contribution towards the improvement of this problem? Schools and colleges could educate the farmers in these new methods, but up to date, it has been the tendency for large enterprises to train staff by practical experience.

Mr. YATES then brought up the subject of small farming in relation to the above question.

Dr. DONALD stated that the subject of small farming is more a political problem, rather than a technical one, and preferred not to comment on it.

Prof. MORRIS pointed out that most research is done for training the people, rather than for results. There fore, it is very easy to criticize the research and forget that at the same time, we are developing the people. Concerning the changeover from small to large farming, he said that when the land from small farms is taken over by the large farms, it will result in still more over-production. Models might be constructed to indicate what is necessary to do in given circumstances and university trained people would be needed to study them. However, we must bear in mind that there is no correlation between having a degree and success in the management of a farm.

To these last remarks, Prof. STEGENGA stated that success in farming is generally a result of a mixture of practical and theoretical background. When the farmer has more education, he is perhaps less traditional and more flexible.

Prof. VAN RIEMSDIJK then said that managing is handling what we do not know and research is attempting to understand what we can still learn. The problem is that the farmers are unequal. To have a degree merely paves the way, but the difficulty lies in adapting this degree to farming procedures. The farmers must learn that learning, reading and studying are also necessary.

To the question of Mr. MEYER concerning the chance that soya bean meat has, Dr. DE WIT warned against the underestimation of the possibilities of plant proteins taking a prominent place in human consumption. Contrary to common belief, there is a greater market in developed countries for plant proteins, than in underdeveloped countries.

CONSERVATION AND TECHNOLOGICAL PRODUCTION

by

H. A. B. Parpia

Director Central Food Technological Research Institute, Mysore

Man has lived with food problems eversince his beginnings on earth. The magnitude of these basic problems have varied according to his abilities to control his environment. Man's abilities have changed radically with the development of scientific and technological knowledge which he is able to wield effectively to overcome the odds of nature. Thus from being a victim of his environment, he has become its master.

Although considerable progress in solving the food problem has been made both quantitatively and qualitatively through the use of science and technology, there is a great need to carefully analyse and study the problem more clearly, specially with reference to the technologically less developed regions of the world. Only then can effective and lasting solutions be found.

The 20th century food problem has several dimensions. These are: the rising population, the increasingly limited availability of land for cultivation, agricultural productivity and the application of food science and technology to augment the supplies through prevention of losses at various stages. All these dimensions are affected by the interaction of social, economic and political factors.

The magnitude of the food problem is illustrated in Table 1 which shows that 71% of the human population live in technologically less developed coun-

Table 1. Distribution of the world's population, national income and of food supplies by regions (1957–59)*

Regions	Percentage of population	Percentage of national income	Percentage of total food supplies
Far East (including China Mainland)	52.9	12.3	27.8
Near East	4.4	1.9	4.2
Africa	7.1	2.5	4.3
Latin America	6.9	4.8	6.4
Europe (including USSR)	21.6	39.5	34.2
North America	6.6	37.8	21.8
Oceania	0.5	1.7	1.3
World	100.0	100.0	100.0

* Third World Food Survey, FFHC Basic Study No. 11, FAO, Rome, 24.

TABLE 2. World resources of protein 1963–64

	Production	Protein content	Protein supply *per capita* per day (gm)
		(Million tonnes)	
Vegetable Sources			
Cereals	995.6	96.0	81.7
Pulses	37.1	8.14	6.9
Oilseeds	85.6	22.0	18.8
Starchy roots	472.1	8.34	7.1
		134.48	114.5
Animal sources			
Milk	352.8	11.3	9.6
Meat	67.6	12.2	10.4
Fish	46.0	6.6	5.6
Eggs	14.1	1.8	1.5
		31.9	27.1
Total proteins:		166.38	141.6

N.B.

1. Cereals include: wheat, rye, barley, oats, maize, millets, sorghum and paddy.
2. Pulses include: dry beans, dry peas, dry broad beans, chickpea and lentils.
3. Oilseeds include: soybeans, groundnuts in shell, cottonseed, linseed, rapeseed, sesame, sunflower seed and copra.
4. Starchy roots include: potatoes, sweet potatoes, yams and cassava.
5. Meat includes: beef, pork, mutton and lamb.
6. World population estimated at 3,220 million in mid 1964.

Sources:

1. FAO production Year Book, 1964.
2. State of Food & Agriculture, 1964 (FAO)

tries of the world. They produce only 42% of the world's food and earn 21% of the income.[1] The food problem cannot be studied or its solution found in isolation from the general socio-economic problems. The people in these areas are caught in a vicious cycle of technological backwardness slowing down their economic progress and vice versa.

When one looks at the world food picture in its entirety, the situation appears rather paradoxical. The *per capita* availability of foodgrains is about two and a half times the requirement[1a] (Table 2). If protein is taken as the main qualitative factor and its daily requirement at 70 gms per caput, the total availability of this important nutrient is also more than twice the requirement. Unfortunately, factors beyond the control of the common man are responsible for the widely prevalent conditions of starvation and malnutrition over a major portion of the earth.

In order to solve the food problem, both qualitatively and quantitatively, every country has to make its own efforts to achieve self-sufficiency as far as possible. Emphasis here, therefore, has been laid on the use of science and technology for augmenting the food supplies, particularly in the technologically less developed countries of the world, after a food crop or an animal has been raised. If food technology can be utilized effectively for conservation of food through prevention of losses, both in the field and during storage, in processing of cereal crops, which constitute 80% of the people's food, on the development and utilization of high protein foods from unconventional raw materials and to prevent losses of perishable foods, such as fruits, vegetables, meat and fish, it can make a major impact on the economic progress of these nations and their standards of nutrition.

Conservation of staple foods

Foodgrains constitute not only 80% of the diet for a majority of the world's population, but are also the largest single source of protein. Their conservation, both in the field and during storage, as well as maintenance of their quality, deserve very high priority.

Through systematic efforts to prevent losses, most of the less developed countries of the world can achieve self-sufficiency in food, even at their present level of production. With the efforts to increase food production, which are receiving high priority, losses will increase out of proportion unless adequate steps are taken to prevent them, and the expected economic results will not be produced. This problem needs much greater recognition than it has received so far. UN agencies have given much attention to the control of locusts and malarial mosquitoes. They should give even greater attention to the prevention of food losses due to rodents, birds, insects and wild animals.

Field losses

It is well recognized that very heavy food losses occur in the field all over the world. The figures are, however, available for only those countries who have the technological and economic means to collect such data and take control measures. Table 3A gives the losses in the United States.[2,3] The losses are

TABLE 3A. Extract of the preharvest losses figures of USA[1]

Crop	Per cent			
	Insect	Diseases	Weeds	Total
Maize	12	12	10	34
Wheat	6	14	12	32
Rice	4	7	17	28
Grain Sorghum	9	9	13	31
Soybean	8	14	17	39

Estimate based on full production with causes eliminated

(Ref: Agric. Handbook No. 291, ARS. USDA, 1965. The World Food Problem Vol. II, p. 205, White House, May 1967)

obviously of much greater magnitude and consequence in the technologically less developed countries of the world, where the measures for their control are very inadequate. In 1965, the United States spent $ 3,000 million on the pest control measures alone.[4] It is stated that if this expenditure had not been incurred, the price of food in that country would have been doubled and the quality would not have been good enough. The expenditure in European countries is also of similar magnitude. In contrast with this, the expenditure on insect infestation control in the developing areas of the world is meagre. For example, India spent only $ 4 million on insecticides[4] in the year 1966–67. Most of this was spent on the control of infectious diseases like malaria and plague measures which, in turn, helped the growth of population and accentuated the food problem. About 5% of the cultivated land was covered by plant protection measures.

Insect damage

Technology for prevention of field losses due to insects is highly developed. If the newly developing countries want to achieve self-sufficiency, they should give the highest priority in their plans for the development of chemical industries to the manufacture of pesticides, for use in the field.

The available information, though limited, indicates that by preventing field losses it should be possible to increase the food supplies to an extent which would make these countries self-sufficient even at their present level of production.[4]

Bird losses

Birds also cause very heavy losses of food. It is unfortunate that very little systematic information has been collected on this problem. Some preliminary work is in progress. Individual discussions with farmers in some areas indicate that bird losses can be between 30–35% of certain crops, but it would not be advisable to generalize on this information, until more data are collected. It has been argued that control of the bird population could lend to other problems, such as an unchecked increase in the number of lepidopterous insects. But the Lepidoptera can be controlled by biological as well as chemical means. What is needed is high priority for research to develop modern technological as well as physical methods of bird control.

Rodent losses

Among the agents responsible for loss of food in the field and during storage, rodents appear to take the largest toll. There has been a considerable amount of discussion on rodent control over the last four years. In the USA the losses are considered large enough by the government to propose a $ 1,000 million programme of rodent control. In Europe, the expenditure on rodent control has been estimated at £ 2,000 million.[4]

The following will indicate the potentiality of the reproduction of rats.[5] They breed at the age of 3 to 4 months and probably continue to breed upto the age of 18 months. The period of gestation is 21–25 days. The females come into heat about every 5 days and can breed within a day after giving birth. The young are weaned when 3 weeks old, very often just prior to the arrival of another litter. A female averages between 5 to 7 litters per year of 8 to 10 young ones each. However, litters may contain as many as 20 young ones and as many as 14 litters have been recorded. Many of them die, but in one year's time, a pair often produces 60 to 70 offspring which survive to maturity. While breeding 'seasons' are evident during some periods of the year, 20 to 30 per cent of the female rats in a colony are usually pregnant.

The gestation period of the house mouse is approximately 21 days. An average of 5 young ones are born in each of 5 to 8 litters per year. Juveniles are dependent upon the mother for about 3 weeks and reach maturity in 2 to 3 months. Sometimes, two or more females may produce young ones in the same nest at the same time. It is probable that few wild mice survive more than a year.

It is fortunate that conditions are not fully suitable for the survival of the entire rodent progeny; otherwise man would have been displaced from this earth. With increase in food production, the conditions for the survival of rodents are becoming more favourable but the measures for their control are not improving in the same proportion. On the contrary, natural enemies of rats, such as snakes, have been systematically exterminated by man. Thus, the benefit of high yielding crops cannot be fully realized under the present situation.

There are very few scientific surveys on rodent population, but some intelligent estimates based on field studies have been made. Field studies carried out by RAMAKRISHNA *et al.* have indicated that between 46 and 78% of the crop can be destroyed by rats. This damage can be done at different stages of growth, *viz.*, freshly sown seed, seedling, half-blade and during various stages of storage.

Even on a conservative estimate, India is said to have a rodent population of 2400 million and 6 rats eat the food of one man, being fast growing animals. Even if they eat to the extent of 50%, the foods meant for human consumption, the losses would be tremendous.

An emergency had to be declared on the island of Mindanao in Philippines in 1953 when close to 70% of the crop was destroyed by rodents. A similar emergency was declared on the island of Madagascar in 1965 where 80% of the crop was destroyed by rodents in that year. It is quite obvious that there are many places where such damage may have occurred and gone unnoticed.

Control of rodents in the field can be achieved by using the well-known technique of gaseous fumigation, combined with the newer method of liquid fumigation which are specially suited for the varieties of rats which erect barriers in their burrows. Baiting should also be done simultaneously with rodenticides such as norbormide, zinc phosphide, or barium carbonate incorporated in a low protein bait. Safe methods for the employment of baits under rural conditions have been worked out, so that no harm is done to children and farm animals. Physical methods of rodent control, such as trapping are also quite successful. For effective control, combination of such methods have to be worked out under different circumstances based on a sound knowledge of rodent behaviour.

Losses due to other causes

The damage done to the crop by wild animals and monkeys is quite high in many areas. There is need to assess them and take effective measures for their prevention.

Storage losses

Several estimates on losses due to insects, rodents and microorganisms are available (Table 3A). Although these figures may not be conclusive, they bring out sufficiently well the magnitude of the problem.[2]

Insect infestation control

Depending upon the type of food grain, the loss in storage due to insects varies from 10 to 30% (Table 3B). The climate for insect infestation control is

TABLE 3B. Some estimates of losses in different countries

Country	Material	Loss: * Percentage	Loss: Value	Reference
Nigeria	Sorghum	46		*Colon. Res. Publ.*, 1952, No. 12, 40
	Cowpea	41		
USA	Stored grain		$ 500 million	Metcalf, R.L., *Destructive and useful insects*, 1962, p. 41–43
	Packed Food		$ 150 million	
	All crops		$ 3500 million	
India	*All grains:*			
	Field loss	25		CFTRI, *Res. & Ind.* Conf., CSIR, New Delhi, 1965.
	Storage loss	15		
	Handling and Processing loss	7		
	Other losses	3		
Germany	Harvested grain		DM 71.4 million	Frey, W. Flaugblatt, *Biol. Bundesanstalt* 1951, Nr. 05, 8.
Sierra Leone	Rice	41		*Colon. Res. Stud.* 1959 *No.* 28, 52
	Maize	14		*Tech. Rep. W. Afr. Stores Prod. Res., Unit*, 1962, No. 13
Tropical Africa	All Crops (Storage and handling)	30		FAO *Informal work Bull.*, 24, 1964

* These percentages refer to post-harvest losses unless otherwise stated. Although the figures refer to specific crops in most cases, they are sufficiently indicative to lay emphasis on the problem of food losses.

ideal in most of the tropical countries. The damage done is not only quantitative but also qualitative. Insects carry several types of pathogenic organisms; besides, they eat away the most nutritious part of the grain and add a considerable amount of uric acid.[4]

Storage silos have been very successful in many advanced countries of the world, but they have only a limited place in a number of developing countries where large stocks are not available for storage over long periods. Besides, the cost of silos per tonne of storage happens to be \$ 70 in India as against \$ 15 for warehouse storage. Most of the tropical countries are fortunate in having more than one crop per year and, therefore, the storage period for a major portion of the foodgrain crops is not very long. In view of this, flat warehouses being cheaper are preferable. Also, the marketing pattern is based on jute bags as the main container which of necessity requires a warehouse for storage.

A considerable amount of work has been done on construction of rodent proof warehouses. A 4″ rat guard skirting along the warehouse prevents rodent entry. This technique is being adopted where new warehouses are constructed. Wherever the warehouses are already existing, they can be improved by means of introducing a 6″ polished band around the building and separating the steps by 18″ from the building.

Several techniques developed at the CFTRI for control of insect infestation in tropical under-developed countries have proved very successful. The 'Durofume' process[7] which consists of fumigation of the stacks of foodgrain in bags by a mixture of ethylene dibromide and methyl bromide (proportion varying according to the foodgrains to be treated) is very successful not only in destroying the adult but also the immature stages of insects. One application is adequate during the year, as the grains remain insect free for over 9 months. This mixture also keeps the microbial count low. The cost of fumigant including the cost of application required per tonne of grains is Rs. 0.80 (US \$ 0.10).

Reinfestation can be prevented by making jute bags insect-proof.[8] The technique developed for impregnating jute bags with an insecticidal formulation costs less than \$ 0.015 for a bag of 100 kg capacity. A high viscosity oil base on a composition of malathion acts as a repellent for the rodents making them turn to the poison baits kept nearby.

While these improvements and rodent control measures are being adopted, their use is confined to less than 25% of the food crop which is the marketable surplus available for the urban consumer. Over 70% of the crop is stored and consumed in rural areas where storage practices are very inadequate and need improvement.

Safe and effective methods have been worked out for storage of foodgrains in rural areas:

(i) Improvement in the traditional underground as well as overground structures. This could be done by using a heavy gauge polyethylene film for the lining cementing with a coating of bituminized mud-plaster to prevent moisture migration which is generally responsible for fungal growth.

(ii) Activated clay containing meta-hydrogen halloysite can be mixed in foodgrains to the extent of 0.5 to 1%. It removes the fatty layer from the surface of insect which then dies due to dehydration. The treatment keeps the foodgrains free from further infestation.[9]

(iii) Addition of 0.2% tricalcium phosphate mixture containing pyridoxine and glucose to foodgrains inhibits the growth of insects. Consumption of this mixture in small quantities completely upsets the insect metabolism and change their metamorphosis. Besides being an insecticide, tricalcium phosphate serves as calcium and phosphorus enrichment of the grain.[10]

(iv) Ethylene dibromide adsorbed on compressed paper or cardboard in the form of small tablets strip-packaged in laminated aluminium foil are proving successful in pilot studies. They can be used even in small-scale household storages in both urban and rural areas. These are also very effective in protecting seed material.

(v) After disinfestation of foodgrains in jute bags has been carried out, it is necessary to take measures for preventing reinfestation. For this, a formulation known as Durobase 3, consisting of lindane, DDT and malathion (rodent repellent) has been worked out. It has proved very effective on stacks of food bags.

In rural areas where the percentage of literacy is very low, there is a great advantage in using activated clay and tricalcium phosphate as pesticides, because they are safe. A certain amount of precaution, however, becomes necessary when ethylene dibromide tablets are used. Several other insecticides such as *aluminium phosphide tablets* have been used successfully; but they are dangerous because that their toxic effects on humans are not easily detectable. Moreover, aluminium phosphide in the permissible dosages is not very effective against certain insects, including *Sitophilus oryzae*, which happens to be the main infesting organism for rice.

It should be possible with these treatments or combinations thereof to eliminate storage losses which amount to 10–15% of the foodgrains stored. If the present losses in India were reduced by half, foodgrains to the value of Rs. 4,500 to Rs. 7,000 million (at current Indian prices) would be saved, which equals 3 to 4.5% of the national income. It is necessary to detail the benefits that would accrue to the agriculturists, storage agencies and consumers. The situation in other technologically less developed countries is very similar.

TABLE 4. Average milling yields of rice from paddy in conventional and modern mills

Type of Mills	Raw		Parboiled	
	Total Rice %	Head Rice %	Total Rice %	Head Rice %
Modern Rubber Roller Mills	72.5	55	73.5	70
Conventional Disc Sheller Type Mills	71.0	50	73.0	68
Engelberg Type 'Huller' Mills	69.0	45	72.0	66

Improvements in processing technology of foodgrains

Processing of rice. Most of the countries of South East Asia not only use out-dated milling equipment, which is maintained in very unsatisfactory condition in most cases. A large number of mills are so small that they cannot produce adequate quantity of by-products, such as rice bran, which could be utilized efficiently. Table 4 based on recent studies in India shows that it should be possible to raise the milling yield of rice by 3–5%.[2] If the rice milling industry is modernized in India, even at the present level of rice production, the country should be able to have about 2 million tonnes of additional rice which can almost completely overcome the shortage of this foodgrain, besides reducing the overall food deficit by 25–30%.

India is very short of fats and oils as well as cattle feed and rice bran is an excellent potential source of these. It is important that rice bran be utilized soon after milling in order to prevent the development of hydrolytic rancidity. If the rice mills can be large enough or if several of them could be grouped together in an industrial estate, it should be possible to obtain 10 tonnes of bran per day which would make it possible to set up an economic unit for solvent extraction of the oil. If the bran can be extracted soon after milling, there would be no problem of hydrolytic rancidity which develops on storage of bran. Wherever the mills are located at longer distances, it would be necessary to inactivate the lipase by suitable heat treatment. This high quality of fat could meet the urgently needed calorific requirement in the people's diet. Further, the extracted rice bran containing about 15% protein could be used efficiently for the manufacture of composite cattle feeds and ultimately result in supply of additional food for human consumption. A well organized rice milling industry could also result in development of other allied industries, such as manufacture of activated carbon from the husk and also manufacture of hard board, both of which are required today in sufficiently large quantities.[11]

The above discussion clearly indicates that there is need for a modern rice milling policy of which the Government of India is becoming conscious, but there is no time to lose. The problem in other developing countries such as Philippines, Burma, etc., happens to be the same.

Parboiling. Out of 36 million tonnes of rice produced in India, about half is consumed in the form of parboiled rice. The traditional processing consists of soaking paddy for 2–3 days followed by steaming, drying and milling. This has the advantage of fixing the vitamins present in the peripheral bran layers into the kernel. The traditional practice, however, has several disadvantages in that the product develops off-odour due to microbial fermentation and also produces mycotoxins. Recently, a process has been developed which consists of soaking paddy at 70°C for 4–5 hours, steaming and mechanical drying. This not only speeds up the entire process, but yields a product of high quality. If larger quantities of rice were to be parboiled in India, it would not only improve the nutritional quality of the diet through making more vitamin B available in the rice, but also reduce considerably the breakage during milling. Other countries of Asia could adopt this process to an even greater advantage. Some of these countries are known to have high incidence of beri-beri and have had to resort to artificial vitamin enrichment of milled white rice. Parboiling would eliminate this and supply rice of good quality.[11]

The modern technique of parboiling also eliminates the need for sun-drying, where not only is the dehydration not uniform, but the bird losses are quite heavy.

Processing of legumes. Grain legumes are a very important source of protein for most of the developing countries of the world. In India, they constitute 18% of the foodgrains. Being rich in lysine, they provide a valuable supplement to the cereal diet.

The traditional milling techniques are not only inefficient, but result in losses due to breakage and powdering. Being a small-scale operation, the efficient utilization of the husk as a by-product for the cattle feed industry is not possible. Very useful results of research have been obtained recently for improving the milling of legumes. Essentially this process involves conditioning of the skin for its easy removal and employs the pearling technique to prevent breakage. Table 5 shows the improvement in yields of various legumes. By adopting this

TABLE 5. Milling losses of grain legumes in India

Legume	Yield by	
	Traditional Method (%)	Improved * Method (%)
Chickpea *(Cicer arietinum)*	75	85
Pigeon pea *(Cajanus cajan)*	72	87
Green gram *(Phaseolus radiatus)*	65	85
Black gram *(Phaseolus mungo)*	71	85

* Bench scale results.

milling technique, about 1½ million tonnes can be added to the food supplies. It also could make available about 1.5 million tonnes of husk in making balanced composite cattle feeds. (CFTRI unpublished data).

Milling of wheat. Although production of wheat [12] is the largest among world cereal crops, it is mainly confined to more advanced countries as given in Table 6. Production and consumption of wheat in the newly developing countries is, however, improving. Due to urbanization, the use of bread is becoming quite widespread. Also traditional preparations such as *chapatis* (unleavened pan cake) are also being accepted more widely in countries like India. Most of the indigenously grown wheat is ground in the typical village mill and only about 3–4 million tonnes of imported wheat is processed in the modern roller flour mills. If this wheat supply is to go further, it is essential that the milling of flour is restricted to about 85% extraction, as was done in the United Kingdom during World War II. This flour will also be more nutritious.

TABLE 6. Wheat production in different regions (1965)

Continent	Wheat Production (Million tons)
Asia (including China Mainland)	61.7
Africa	6.1
South America	8.1
Europe	67.4
USSR	59.6
North and Central America	55.6
Oceania	7.3
World	265.8

Source: FAO Production Year Book, Vol. 20, 1966, p. 35–39

High protein foods

Of the world population of 3.5 billion, 20% are children below the age of 6. Two-thirds of them live in technologically less developed regions of the world. They are the worst sufferers as far as the deficiency of important nutrients, particularly proteins is concerned[13] (Table 7A). A large number of them also do not get adequate calories at present. It is, therefore, essential to give priority to the improvement of their diets if economically productive and creative popu-

TABLE 7A. Estimated daily calorie and protein content of natural food supplies in some developing countries as compared with USA (1960–62)*

Country	Calories	Protein (g/day)		Cereals	Pulses	Oils & Fats
		Total Protein	Animal Protein			
				gm/day/caput		
Latin America:						
Brazil	2780	66.3	18.0	303.9	82.9	21.6
Columbia	2170	49.3	22.8	181.4	14.8	10.4
Far East:						
China (Taiwan)	2350	58.5	15.3	463.4	28.3	12.9
India	2020	51.5	6.0	390.6	64.1	10.6
Japan	2230	69.3	16.9	417.8	45.9	13.4
Philippines	1840	44.4	14.4	331.2	18.2	7.8
Near East:						
Iran	2050	59.6	13.4	402.6	10.9	18.5
Turkey	3110	97.5	15.9	624.4	37.0	22.1
Africa:						
Madagascar	2210	48.2	8.0	440.0	13.4	3.0
Sudan	2030	69.3	23.9	317.2	49.3	19.6
Uganda	2240	54.4	10.4	171.1	75.9	6.2
North America:						
United States	3100	91.2	64.2	188.6	22.1	57.9

* FAO (1965) Production Year Book, Vol. 19

lations are to be raised for facing an increasingly competitive and challenging future. Table 7B shows per capita availability of major sources of proteins in different countries of the world. If these resources can be utilized through proper processing and distribution, protein malnutrition can be very successfully overcome. Table 7A shows that the world *per capita* availability of protein is more than twice the requirement. The *per capita* availability of protein in India

TABLE 7B. Availability of major sources of protein per caput in different countries.

	Cereals	Pulses	Meat	Eggs	Fish	Milk
	gm/day					
India	404	61	4	1	3	123
Pakistan	457	17	10	1	4	200
Philippines	365	16	36	7	45	42
Iran	394	11	44	5	2	176
Israel	278	27	128	60	18	391
UAR	586	29	36	4	14	124
Ghana	158	63	27	1	22	8
Madagascar	436	13	42	–	10	19
Jamaica	224	36	47	11	30	170
Mexico	348	65	65	14	7	350
UK	213	17	203	42	26	590
USA	182	22	273	49	14	657

Source: FAO Production Year Book, Vol. 20, 1966

from legumes is 14.5 gm/day and from oilseeds is 9 gm/day. While legumes are a regular part of the daily diet, the oilseed proteins remain a largely unutilized resource. If products can be manufactured in which the latter constitute an important part, the protein content of the diet can be raised to the required level and 4 million tonnes of food added to the present supplies. The situation in many other countries is quite similar, e.g. the Philippines, 1, 446.000 tonnes of copra which can supply 98,500 tonnes of good quality protein.

Methods of producing edible grade oilseed meals and isolates have been developed and these concentrates can be used to a great advantage in a number of ways some of which are discussed here.[14] (Table 9).

Protein concentrates to stretch the supplies of cereals and tubers

Most of the technologically less developed countries in the world are facing shortages of cereals in spite of the efforts being made to increase their production. Such shortages can be overcome in a number of countries by systematic growing of more high yielding tuber crops. Already, tubers such as tapioca are grown quite extensively in some of the countries of Asia, Africa and South America (Table 8). By mixing cereal and tuber flours together, the total availability of food can be stretched considerably but the protein content would be reduced. The protein content could be made up to the desired level by the addition of oilseed flours. Wherever necessary, some of the limiting amino acids which are now available at very reasonable prices in the world market can also be added. Some promising efforts have been made in this direction in India.[15]

TABLE 8. Area and production of tapioca in different regions in 1965

Region	Area (Million hectares)	Production (Million metric tons)
World total	9.108	78.748
Latin America	2.412	30.814
Near East	17*	12.4**
Far East	2.269	18.301
Africa	4.4	29.395
Oceania	10*	114**

* In thousand hectares; ** In thousand metric tons
Source: FAO Production Year Book, Vol. 20, 1966, 113

Mysore flour. This consists of tapioca flour (75%) and edible grade low fat peanut flour (25%). The final product has a protein content of 12%. It has been successfully used in the preparation of several items of normal consumption such as chapati, puree and other sweet and savoury dishes. Its use was extensively tried out during the 1953 famine in South India.[15]

Paushtik Atta. As the surplus wheat available on the world market is of the softer, low protein varieties, efforts have been made to incorporate, low-fat groundnut flour to increase the protein content of the flour. Two formulae of this product have been successfully tried. Formula A: 75% whole wheat flour, 17% tapioca flour and 8% groundnut flour; Formula B: 90–95% whole wheat flour, 5–10% groundnut flour. The former is more suitable for use in tapioca growing areas while the latter in cereals producing areas. Both the formulae have been successfully tried out in all preparations where wheat flour is normally used.[15]

Macaroni products. Rice constitutes 25% of the world's cereal production. It is the principal cereal in Asian and other tropical countries of the world. In India, 50% of the cereal grown is rice.[11] It was, therefore, felt that the consumer acceptance of a macaroni-like product in the shape of rice would be very high. A composite grain was developed and manufactured on a pilot plant scale using the equipment for short macaroni goods. The product consists of 65% tapioca flour, 25% wheat semolina and 15% edible grade peanut flour. The composition of the product could be varied to adjust the protein content wherever necessary. Its acceptance was tried out on a fairly large scale in the State of Kerala which is one of the major tapioca producing centres in India. Specially enriched high protein macaroni has also been successfully produced and found very suitable.[15]

Protein foods. Several protein foods and concentrates based on oilseed meals, legumes and cereals have been developed in different parts of the world to overcome protein malnutrition. These include products like INCAPARINA, Indian Multipurpose Food, Bal-Ahar, Peru-Vita, Lubina, etc. Most of these

TABLE 9. Relative cost, protein content and protein value cost index (PVCI) of some protein foods

Protein food	Cost per kg.		Protein %	Cost per 20 g. protein		Protein efficiency ratio (PER)	PVCI*
	US cents	Indian currency Rs.		US cents	Indian currency (Paisa)		
Indian M.P.F. (Formula A)	0.26	2.00	41.9	1.2	10	1.8	30
Indian M.P.F. (Formula C)	0.33	2.50	40.6	1.6	12	2.4	30
Soyabean flour fortified with DL-Methionine	0.33	2.50	50.0	1.3	10	2.9	44
Protein food (2:1:1) blend of peanut, chickpea and fish flour	0.39	3.00	51.6	1.5	12	2.6	35
Low fat dried vegetable milk (based on peanut protein and milk powder)	0.66	5.00	35.2	3.8	28	2.3	12
Baby food based on peanut flour and skim milk powder	0.66	5.00	26.0	5.0	38	2.4	10
Precooked weaning food based on cereals, peanut, chickpea and green gram flour	0.33	2.50	27.5	2.4	18	2.2	18
Skim milk powder	0.78	6.00	35.0	4.5	34	2.8–3.2	13
INCAPARINA	0.26–0.54	–	27.5	1.9–4.0	–	2.1	11–22

* The protein value cost index (PVCI) is calculated as follows:

$$\text{PVCI} = \frac{\text{Protein content in 100 g. of food}}{\text{Cost of 100 g. food (in US cents)}} \times \text{PER}$$

Thus, the higher the index, the greater is the value of the protein food per unit cost.

products have found good consumer acceptance and some of them are now being marketed commercially. Several of these products, their nutritive values and costs are given in Table 9.

Indian multipurpose food. This protein concentrate consists of 75% edible grade peanut flour and 25% chickpea *(Cicer arietinum)* flour and is fortified with vitamins and minerals. It is versatile and can be used in various dietary patterns. India has 16 distinct cultural groups each with its own food habits. To develop special products for each of them would be extremely difficult. Therefore, work has been done to include the Indian Multipurpose Food in a number of traditional preparations so that the least change in food habits is involved. Five plants have been set up in India for its production. One of the states has been using two tonnes of this product daily in its mid-day school-feeding programme for the last six years. A number of industrial canteens are now showing interest in utilizing it for supplementing the diet of their workers. Recently, it has been used successfully in the distress affected areas of the country. The vitamin and mineral content is so adjusted as to meet about 50% of the daily requirement. The product can be manufactured by any of the existing oil mills with the addition of a small amount of extra equipment[2, 14].

Indian Multipurpose Food Supplement has been adapted for use in the various traditional and modern food preparations which are eaten daily by the people in different parts of the country. The product has also been used in the treatment of protein malnutrition in children.

Weaning foods (pre-cooked). Weaned infants are the worst sufferers from protein malnutrition as the availability of milk per capita in most of the developing countries of the world is very low. In India, the per capita availability being only 4½ oz., a major portion of it goes to the high income groups.[2,14]

Pre-cooked weaning foods fortified with vitamins and minerals and containing 22–25% proteins have been developed. These consist of cereals, oilseeds, and legumes with the addition of limiting amino acids wherever necessary (Fig. 1). These products have a PER of 2.4–2.6 and have been found very accept-

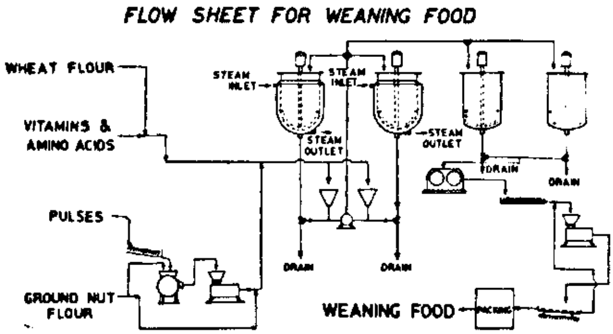

FIG. 1: Flow sheet for pre-cooked weaning food

able (Table 9). They can be sold to the consumer at approximately US $ 0.45 per kg. One such product will be commercially marketed very shortly with the assistance of UNICEF.

Protein isolate. A process for the manufacture of protein isolate from peanut kernels was completed a few years ago (Fig. 2). A proto-type two tonne per day plant went into production in December 1966. This product has proved a very successful substitute for milk powder in the preparation of a number of products including ice cream mixes, infant and weaning foods and in the preparation of 'toned-milk'.[14]

Lac-Tone. Lac-Tone is a product which consists of 50% animal milk and 50% vegetable milk prepared from detoxified peanut protein isolate and carbohydrates. A pilot plant unit is regularly producing 100 litres of this product per day and it will now be manufactured in the dairy plants in some of the large cities in India. It can also be flavoured for marketing as a beverage.[14]

Spray-dried milk food substitutes for children

Baby foods based completely on animal milk are quite popular in many countries. Consumer demand for these products is increasing but it is not

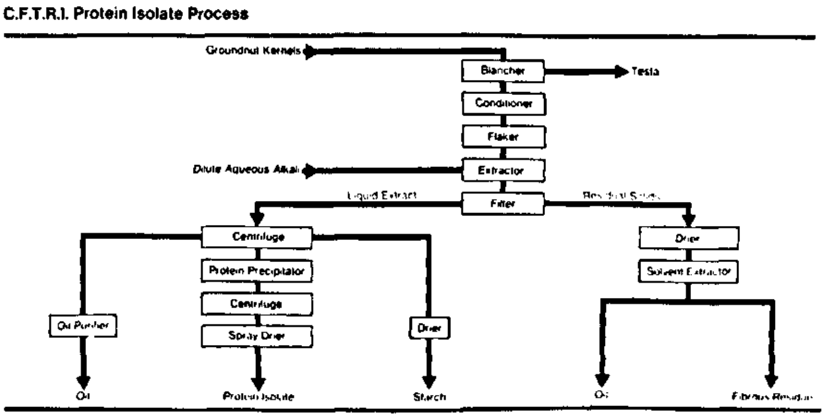

FIG. 2: Process for the manufacture of protein isolate

possible to make sufficient quantities because of the acute shortage of milk. Therefore, a product containing mainly vegetable protein from peanuts has been developed (Table 9). It contains only 25% milk powder and has been supplemented with methionine and fortified with vitamins and minerals. The product can be reconstituted in the form of fluid milk and has a PER of 2.3. The feeding trials carried out by the Christian Medical College and Hospital, Vellore, S. India, indicate that there is no significant difference in the height and weight of children fed on this product as compared with those fed on the milk based product (Table 10). The cost of this product will be about 70% of the one based on animal milk. Thus, it cannot only increase the supply of baby food four times, but will also be within the reach of a larger number of families.[14]

TABLE 10. Study on infant food based on peanut flour (sequential admissions)

Group	No. of children		At the age of 6 months		At the age of 18 months		Increase ± SE	
	Boys	Girls	Wt. in kg.	Ht. in inches	Wt. in kg.	Ht. in inches	Wt.	Ht.
Control (Milk Food)	2	7	5.86	24.73	7.89	29.12	2.03 ± 0.253	4.39 ± 0.216
Infant Food	4	5	6.43	25.36	8.59	29.95	2.16 ± 0.253	4.59 ± 0.241

Leaf protein. With the rising world population and the urgent need for proteins, it has become necessary to explore every possible source of protein in the world. In this direction, the proteins from leaves offer good potential. Table 11 shows the availability of protein per hectare from *Medicago sativa*, Linn. as the highest as compared to hybrid maize, wheat and grain legumes. It can be used as a supplement to the diet where it may not present a problem of acceptability due to its flavour. In different parts of the world, work is being done to improve the technology and quality of leaf proteins for consumer

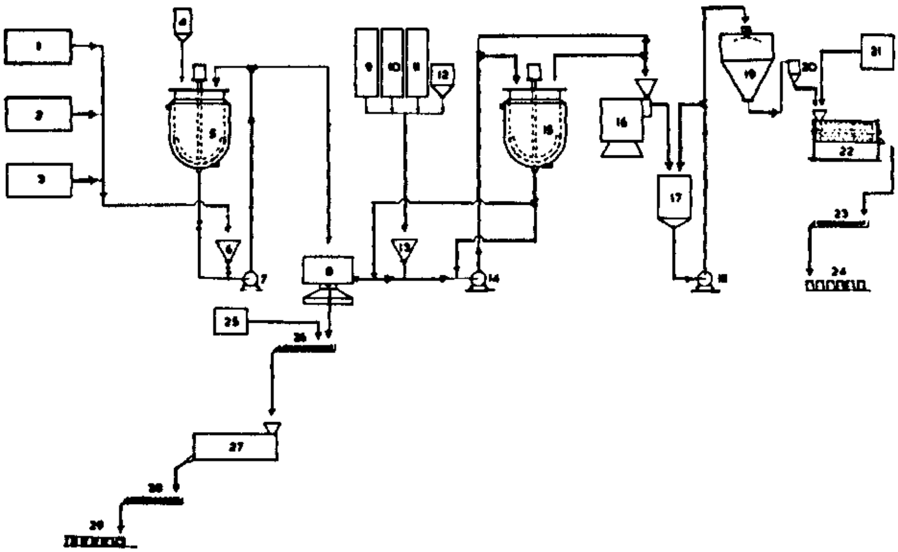

FIG. 3. Flow sheet of groundnut flour based infant food
1,2,3: Storage bins containing peanut flour, barley malt and wheat; 4: Alkali Storage Vessel; 5: Mixing tank; 6: Mixing Funnel; 7: Pump; 8: Basket centrifuge; 9, 10, 11, 12: Storage bins for skim milk powder, hydrogenated fat, salt and buffer salts; 12: Acid storage vessel; 13: Mixing funnel; 14: Pump; 15: Mixing tank; 16: Homoginizer; 17: Balancing tank; 18: Pump; 19: Spray drier; 20: Cyclone Separator; 21: Bin to contain vitamin premix; 22: Mixer; 23: Conveyor; 24: Packing unit for Infant Food; 25: Acid container; 26: Wet mixer; 27: Drier; 28: Conveyor; 29: Packing unit for residue for cattle feed.

acceptance. The PER of the product developed in India is 1.3–1.8 and can be increased two-fold by supplementation with methionine. Besides common legume fodders, the by-product vegetation of green vegetable and commercial crops forms a very important category of raw material for leaf protein production (Annual Report, CFTRI, 1966).[16]

TABLE 11. Maximum yields of edible protein

	kg/hectare
Wheat	440
Maize	480
Dry peas	700
Green peas	950
Grasses*	300/630
Lucerne*	1300/3000
Milk	190
Beef	190
Mutton	180
Pig meat	100
Chicken meat	180

* Leaf Protein, batch/industrial production; NARENDRA SINGH, CFTRI, Unpublished data

Fish protein concentrates

The preparation of fish protein concentrate from low-priced surplus fish which cannot find ready market is being worked on in several countries. This deodorized fish flour[14] offers good potential for supplementing the general diet and also for enrichment of protein foods for the vulnerable groups. The main problem with regard to its production in India is the lack of a well organized fishing operation which could land sufficient quantities of fish at one particular point on the coast to run an economically sound plant.

Fish processing

Oceans cover 71 % of the earth's surface and there are a few hundred thousand kilometers of rivers and rivulets running through the terrestrial areas in the world. Thus, the potential for production of fish is very big. Marine biologists estimate that only a small fraction of the available resources have been used. Scientific fish farming can also be introduced in many areas. The world's fish catch for the year 1965 is given in Table 12. Peru and Japan lead the rest of

TABLE 12. Fish production in the world in 1965

	In thousand metric tons
Peru	7391.2
India	1331.5
Japan	6879.5
USA	2701.2
Norway	2280.1
Spain	1338.5
Canada	1190.2

Source: FAO Year Book of Fisheries Statistics, Vol. 21, 1965, p. a-4 to a-16.

the world. As against the catch of 7.3 million tonnes in Peru and 6.8 million tonnes in Japan, the catch of fish in India with its coastline of 4500 km is only 1.3 million tonnes. This shows tremendous potential. The situation in many under-developed countries is similar to that of India. There is need for a well organized fishing industry using modern craft and gear as well as development of fishing harbours. In addition to this, it is necessary to insure cold storage facilities, refrigerated transport and a well integrated industry capable of processing and preserving the catch as well as utilizing its by-products. Over 70 % of India's population is non-vegetarian and if a higher catch of the order of Peru could be made available to the people, a good portion of the food problem could be solved. Countries like Peru are using a portion major of their catch for preparing fish meal. Developing countries like India, with large populations could use it in fresh or dehydrated form mostly for human consumption. The less marketable grades of fish can be converted into fish protein concentrate.

Considering the limitations under which a technologically less developed economy has to work, simple technology which can assist even the small scale fishing operations has been worked out. A newly developed insulated reusable basket based on traditional packaging materials (bamboo and reeds) is helping to increase the distribution of fish along the coast upto 25 miles on bicycles while it was originally being sold within a radius of 8–10 miles. The basket can also be transported upto distances of 400 kms in trucks and on top of buses. (Annual Report, CFTRI, 1965).[18]

Improved techniques for sun-drying of fish have been standardized. After proper cleaning and treatment with sorbic acid, the shelf-life of dehydrated fish has increased from 3 to 9 months. Such products also have good markets in several countries of South East Asia.[19]

Fruit and vegetable processing industry

The under-developed economy and the consequent technological backwardness are reflected in the fruit and vegetable processing industry also. In the USA over 50% and in the UK nearly 40% of the fruits and vegetables produced are processed into various products, while in India barely 0.4% of the total production of fruits and vegetables are processed.

Due to favourable climatic conditions and the availability of at least some varieties of fruits and vegetables throughout the year in tropical countries, it may not be necessary to process such a large portion of fruits and vegetables as in Europe and North America. Certain seasonal surpluses can, however, be processed for home as well as export markets in much larger quantities. It is estimated that close to 30% of fruits and vegetables are wasted in India at various stages due to defective packaging, handling, transport and distribution; there are hardly any ventilated or refrigerated vehicles in use. Thus, out of a total production of 18 million tonnes, about 6 million tonnes are not available for human consumption. If the wastage can be reduced to even half, the diet will be improved substantially both qualitatively and quantitatively.

Conditions for optimum refrigerated storage have already been worked out for most of the fruits and vegetables in India and the information has been supplied to the industry. The main difficulty, however, lies with the transport and marketing system, a further indication that technology cannot succeed in isolation from other socio-economic conditions.

There is need for integrated growth of the fruit and vegetable processing and packaging industry to insure the consumer both high quality fresh produce as well as standard processed foods and to utilize the by-product economically.

Modernization of food industries

Food processing, which includes storage, packaging, distribution, preservation and marketing, constitutes the largest single group of industries in the world. Its impact on the economy is even greater in the case of technologically less developed countries of the world. It is, therefore, very essential that in order to achieve self-sufficiency in food and to build up the economy, these industries should be placed on sound modern foundation. An analysis of the existing situation reveals:

1. Most of the food processing units, whether they are rice mills, fruits and

vegetable processing factories, or meat and fish processing units, are too small to be economically viable.

2. The machinery and equipment used by them are out-dated and are poorly maintained.

3. There is acute shortage of foreign exchange in most of the technologically less developed countries to import modern equipment and to obtain sufficient spare parts for them.

4. In many cases, imported technology is not suitable. For example, it has been observed that the raw material to be processed may be quite different in many cases to obtain optimum results. Also, the size and design of the plants may not meet the needs. In order to find real effective solutions, the only way would be to develop indigenous technology to suit the specific techno-economic requirements of a country or a region. A major portion of existing food industry neither has the adequate awareness nor the resources to build the indigenous know-how. Thus, the only alternative is for the Government to take the initiative in research with the participation of the industry to build the required technology. Steps are being taken in some countries in this direction, but a more intensive effort is necessary.

5. The small turn-over does not seem to justify employment of well qualified technical personnel to maintain high level of productivity and product quality.

6. The availability of waste is too small to justify investment on manufacture of by-products.

7. The size of operation being small, most of the raw materials required are purchased from the open market rather than through contract with growers. Thus, hardly any of them have control on the quality of raw materials.

8. The knowledge of marketing techniques is meagre and the resources available for this purpose are inadequate.

A suitable plan of action can be devised for placing the industry on a sound economic foundation, only after a clear understanding of these problems.

Research and development

Although it is well recognized that the economic progress of a nation is directly proportional to the use of science and technology, the steps taken to build the base for scientific research and technical development in most of the developing countries are very inadequate. The USA and USSR spend approximately 3% of their gross national product on research. This amounts to about 20,000 million dollars.[20] In India, less than 0.5% of the gross national product is spent on research. According to one of the recents reports,[21] the actual proposed expenditure for the Fourth Five Year Plan period will amount to only 0.25% or 433 million dollars. Thus, if the economically less developed countries are to catch up with the progress made by the advanced countries and to take their place in the comity of nations, they must spend much higher percentage of their national income on scientific research and technical development. They can draw upon the experiences of other countries of the world in preparing their research programmes so that they may obtain maximum return for their investment. The developing countries need to have a technological base to provide the required technical advice and assistance to the industries even where imported know-how is being used. In this context, it may also be noted that even the imported technology goes out of date fast and has to be replaced at frequent intervals in order to maintain a high level of productivity.

The newly developing countries of the world should make an effort to build sound inter-disciplinary programme of research for solving their major problems in the field of food technology and to make faster progress with their limited resources. Where possible, cooperation on a regional basis should be established so that the countries having similar problems benefit from each other's experience and avoid unnecessary duplication of efforts. To achieve this objective, the countries of the region should take the initiative themselves and where necessary, make use of the good offices of the international agencies.

Training

Trained personnel, aware not only of the latest technological development, but also of methods of application under the prevailing conditions play a key role. Importance of such training has been recognized over the last few years by a number of countries that are struggling to achieve self-sufficiency. The international agencies have also shown keen interest in utilizing the existing facilities in some of these countries for training of technologists for the entire region.

The first recommendation to set up a Regional Centre in Food Technology Training oriented to the needs of the region was made by the FAO International Food Technology Seminar in 1959 at the Central Food Technological Research Institute, Mysore. Based on this, a decision was taken to expand the facilities available at the Institute for training personnel from the countries of the region and operate it as an International Centre.

While making the recommendation, the participants took into consideration the fact that the training required for the region has to be oriented towards training personnel who could handle the problems as they exist, utilizing the technology which has been developed specially for the purpose. The courses offered at the Centre differ considerably from those in the advanced countries whose problems are different.

The present course covers a number of specialized fields which are not normally included in Food Technology curricula in the Western countries. For instance, post-harvest infestation control for storage of foodgrains and other products has been given high priority. Similarly, a great deal of importance has been given to processing of cereals and the development of high protein foods. The requirement of basic sciences and engineering have been geared to the needs of the region. Thus, the inter-disciplinary course built for the requirement is proving very purposeful. Also, there is little possibility of persons trained in such centres not returnining to their home countries, as happens to be the case when they study in the advanced countries of the West. The teachers are persons who have actually contributed to the development of technology suitable for the region and are abreast of the latest development, being themselves active research workers. Outside experts are invited where necessary to make contributions in their fields of specialization. It is necessary for the Centre to have its own competent staff as outstanding persons from other countries can rarely be spared.

In addition to this post-graduate training at Master's Degree level, an effort is made to orient the participants towards taking up some research and development work by associating with existing research projects so that they may acquire some problem solving skills required by their countries.

A number of short courses, specially designed to cover only one particular field of food technology, such as standardization and quality control or storage of foodgrains and allied products are being organized to provide better technological background for persons already working in these fields in their respective countries. In giving both types of courses, due emphasis is laid on training of trainers, so that each country may ultimately build up its own national training facilities and become self-sufficient for meeting their personnel needs as far as possible.

As Food Technology is a sufficiently vast interdisciplinary area of study, electives are provided for persons who specialize in certain subjects of their choice, such as technology of cereals or meat and fish or spices and flavour, etc.

The International Training Centre operated for 3 years from 1–11–1964 as a joint effort of FAO and the Government of India, with some financial assistance from the Canadian Hunger Foundation has already indicated the value of such training for the region. Wherever such bases for training exist, they should be utilized for the region or they should be built anew in regions where no training facilities exist at present. Such regional cooperative efforts can produce very significant results.

Future of food technology

It is clear that with the rising world population and increasing awareness for raising their standard of nutrition the role food technology has to play is becoming important. What is needed is the conscious recognition of this fact. Without this, the food losses at all levels of storage, handling, processing and preservation will become out of proportion and the benefits derived will not be fully used for the welfare of mankind. Human progress is represented through change from food gathering to cultivation, and it has to advance now more rapidly towards effective use of technology for prevention of losses through conservation and raising the nutritional standards.

This paper discusses a fair number of non-conventional foods which can supply additional calorie and also improve the quality of diet. There are several newer areas of food technology which offer promise for the future. Some of these are:

1. *Irradiation of foods* to eliminate insect infestation in foodgrains and for increasing the half life of protective foods. The application of this technology first of all requires confirmation of the extent to which it can be effective, particularly in the technologically less developed countries of the world where bulk

storage is practised to a very limited extent. Perhaps with the change of food economy and pattern of handling, this technology will hold a fair promise.

2. *Single cell protein.* A considerable amount of research work is being done now on the production of single cell protein. Microorganisms being some of the most efficient converters of hydrocarbons and carbohydrates into protein, the economy of producing protein through this means is indeed promising. Several organizations, including British Petroleum, French Petroleum Institute, the Regional Research Laboratory, Assam and private food processing organizations in the world are working on the development of single cell proteins for human consumption. Within less than a decade, it is quite possible that some of these proteins may find their way into human food to a considerable advantage.

3. *Amino acids.* Already amino acid production by fermentation as well as by chemical synthesis has begun to offer good promise. Lysine and methionine are available at low enough cost to use them for fortification of staple foods and it is hoped that several other limiting amino acids such as threonine, tryptophan etc., will be available within the foresee-able future to improve the dietary standards. Cereals, being the largest single source of proteins, can be fortified to benefit a large section of the world population. The quality of protein foods and concentrates based on oilseeds and legumes is also being improved by supplementation with limiting amino acids.

4. *Enzyme processing.* Enzyme processing of foods is another promising area of research and development in food technology for the future. If the cellulosic material can be broken down by microbial enzymes into sugar and utilized by the microorganisms for production of proteins and vitamins, it will make a significant contribution both qualitatively and quantitatively, to meet the human dietary needs. Some work in this direction is already in progress and it deserves much higher priority.

Summary

1. It is clear that the magnitude of the food problem is the largest in the developing countries of the world, because of the low level of productivity and very inadequate utilization of science and technology for handling, storage, processing, preservation and marketing of foods.

2. It is urgent that both the qualitative and quantitative aspects of the problem, which are mutually inter-dependent should be given equal attention.

3. If the food losses can be prevented at various stages and processing technology improved to place the industry on sound foundation, most of the countries can achieve selfsufficiency in their present requirements, contribute substantially to their economic progress and improve the level of nutrition.

4. In order to make progress in the field of food technology, it is necessary to create a scientific and technological base for the purpose. This would require adequate financial provision for research, technical development, training and industrial extension. Research organizations in technologically less developed countries have also to function as technical servicing and consultancy agencies.

5. The sucess of food policy depends upon the right decision in laying down priorities. This requires active involvement of the concerned scientists and technologists.

6. Any organized effort to solve the food problem through the use of modern science and technology requires well trained personnel. Adequate facilities for training need to be built up on a cooperative basis by technologically less developed countries in various regions.

7. Some of the most recent developments like use of irradiation for food preservation and controlling insect and microbial damage, production of synthetic amino acids, leaf proteins, single cell proteins, and enzyme processing of oilseed meals and cellulosic material need to be studied on high priority.

Acknowledgement

The help of Shri K. A. RANGANATH, Dr. J. V. SHANKAR, and Shri K. M. DASTUR in collection of data used in this paper is acknowledged with thanks.

References

1. *Third World Food Survey*, FFHC, Basic Study No. 11, FAO, Rome 24.
1a. *FAO Production Year Book*, Vol. 19, 1965.
2. PARPIA, H. A. B., 'Overcoming Malnutrition through Food Science and Technology in Developing Countries with particular reference to India – Paper presented at the 27th Annual Meeting of the Institute of Food Technologists, USA, Minneapolis, Minnesota (USA), May 14–18, 1967.
3. METCALF, R. L., *Destructive and Useful Insects*, McGraw Hill Co., 1962, 42–43.
4. *Report of the Study Group on Food Losses and their prevention of the National Nutrition Advisory Committee*. Government of India, 1967, p. 14 (Unpublished).
5. U.S. Department of Interior Fisheries and Wild Life, *Predator and Rodent Control. Lafayette Indiana Agric. Exp. Sta., Purdue Univ.*, No. 316.
6. DOBROSKY, T. M., FAO Grain Storage Newsletter Abstract, 1966, **8**, (3) 65.
7. MAJUMDER, S. K., *Pest Technol.*, 1962, **4**, 134.
8. MUTHU, M. and PINGALE, S. V., *J. Sci. Fd. Agric.*, 1955, **6**, 637.
9. KRISHNAMURTHI, K., GODAVARI BAI, S. and MAJUMDER, S. K., *Res. & Ind.*, 1962, **7**, 267.
10. MAJUMDER, S. K. and ATHIA BANO, *Nature, Lond.*, 1964, **202** (4939 a) 1359.
11. *Rice in India: A Techno-Economic Review*, Published by CFTRI, Mysore, 1966.
12. *FAO Production Year Book*, Vol. 20, 1966.
13. PARPIA, H. A. B., Some Technological and Economic Considerations for the manufacture and marketing of high protein foods, – *Symposium on 'Protein Foods and Concentrates'*, CFTRI, Mysore, 1967.
14. PARPIA, H. A. B., SWAMINATHAN, M. and BHATIA, D. S., *J. Fd. Sci. Technol.*, 1965, **2**, 17.
15. BHATIA, D. S., *Utilisation of Tuber Crops for Augmenting Food Resources*, Symposium on Food Needs and Resources, National Institute of Sciences of India, 1962, 97.
16. *Annual Report*, CFTRI, 1966.
17. FAO Year Book of Fisheries Statistics Vo. 21, 1965.
18. *Annual Report*, CFTRI, 1965.
19. SEN, D. P., VISVESHWARIAH, K. and LAHIRY, N. L., *Food Sci.*, 1961, **10**, 123.
20. Organisation of Economic Co-operation and Development, *Science Economic Growth and Policy*, Paris, The Organisation, 1963.
21. VIKRAM A. SARABHAI, *Vignan Karmee*, 1967, **19** (11) 11.

In answer to a remark of Dr. De Wit about the poor reliability of the data on field losses, Dr. Parpia admitted the insufficiency of the underlying research. He printed out however, that the losses are high undoubtedly, especially in tropical areas where the climate is ideal e.g. for rats.

Replying a question of Miss Joyce Kibaja on the activities of FAO in respect to the scientific development of traditional storage methods, Dr. Parpia said that – as far as he knew – FAO would be in favour of it, according to a resolution of 1959. The very aim of the International Food Technology Training Centre for South East Asia is to place traditional technology on a modern scientific foundation.

Answering Mr. Meffert, Dr. Parpia enlarged on the necessity of developing traditional technology. Containers used in western countries cannot be introduced in India, because neither raw material for their production nor foreign exchange for their purchase is available. Traditional baskets originally designed for head-loads had to be improved for use in truck-loads. Bananas, mango and fish are transported successfully in the improved baskets.

Faster transport from production to consumption centres is required. Railway authorities and personnel must be educated and trained in handling perishable foodstuffs. Ventilated wagons for transport of e.g. bananas and refrigerated wagons for commodities like fish are needed. The development of a cold storage industry is essential.

On Prof. Moens' question about the possible relation between farm mechanization and field losses Dr. Parpia answered in mentioning the 'Intensive Agricultural Development Areas', districts where very systematically modern means of agriculture are introduced to co-operatively organized farmers. The way of thinking in these areas has changed and this improves, among other things, the storage conditions.

Mr. Molster asked about the acceptability of parboiled rice. Dr. Parpia answered that the so-called converted rice used in the USA is nothing else but parboiled rice. In many countries, e.g. in the Philippines, the introduction of parboiled rice is considered because it is nutritionally better and more easily milled. In the newly developed equipment, the process can be controlled so as to make the difference between parboiled and raw rice undetectable.

A question of Dr. Wokes on the addition of vitamin B12 could not easily be answered, Dr. Parpia being no nutritionist. He thought that vitamin B12 is specially required in food for pregnant women.

In reply to a question on the reasons for addition of milk powder to baby foods, Dr. Parpia gave a twofold answer. Firstly, he said, it is generally accepted that recovery of children from protein malnutrition is accelerated by the addition of milk. Secondly many clinical nutritionists refuse to accept baby foods without milk components as nutritionally good. It is to be hoped that they will soon understand scientific evidence.

Mr. Kim's question on the reasons for addition of wheat in weaning foods was answered by Dr. PARPIA in pointing out that the protein content should not be unnecessarily too high. The protein in excess of about 22% will be utilized for energy production. Wheat is one of the best diluting energy foods and is in fact cheaper than rice.

A second question of Mr. KIM was about the difference between peanut protein isolate and defatted peanut flour. Dr. PARPIA answered that firstly the protein isolate has a higher protein content (85% vs. 50%). Secondly the isolate is or can be free of components like coarse fibre peanut flavour and afla-toxin.

In answer to Dr. LUCAS, Dr. PARPIA said that production of amino acids by fermentation is a commonly applied process now. Attempts are made to apply enzymatic digestion of carbohydrate material, e.g. of the 25% carbohydrate – mainly pentozanes – in peanut flour. Cellulosic foods should be treated in the same way as in the rumen of ruminants. After that the material of cellulosic origin could be used either for direct energy food or for conversion to protein.

A question about the prices of amino acids and milk proteins was replied by the statement that amino acids are cheaper. Given the low availability of milk, products must be developed, as good as milk, but without milk.

Prof. FERWERDA inquired about the export of edible proteins in oil seeds and oil seed meals. Dr. PARPIA said that in developing countries the exportable commodities are limited, so they have to export whatever is demanded in order to get foreign exchange. Frozen fish, a badly needed protein food, is exported also in order to earn foreign exchange for import of machinery and equipment. The suggestion at UNCTAD Conference that developed countries should at least give 1% of their G.N.P. to developing ones for their economic structure should have been accepted.

THE FUTURE OF FARMING AND FOOD

by

P. LAMARTINE YATES

FAO Regional Representative for Europe, Geneva

1. Assumptions

When in Rome do as Rome does and when ensnared into this very distinguished gathering of agricultural scientists it is necessary to conform to the usages of science, at least in my opening remarks. These usages require that every solemn discourse be preceded by an introduction setting out the basic assumptions or what Americans tend to call the frame of reference of the enquiry. This procedure should minimize misunderstandings and help to concentrate comment and criticism on the matters of substance.

Fortunately the organizers of this symposium left the title of my lecture extremely vague so that it is for me to choose my own assumptions. First then we must define the word 'future' because on this definition will depend the whole character and tone of what I have to say. The future can be anything from to-morrow to one thousand years hence or even longer, but in order to focus our thinking effectively a date must be chosen which is far enough ahead not to collide with any of the projection exercises now so fashionable but not so distant as to be completely shrouded in uncertainty. For my purposes I have chosen, quite arbitrarily, fifty years from now as the target for my thoughts, not mainly because the lecturers preceding me have been asked to look backward over the past fifty years and so a looking forward for fifty years would be a nice balancing act, nor even because a reasonable proportion of this audience should still be alive in fifty years time, but chiefly and above all because the Agricultural University of Wageningen in the year 2018 will be celebrating its centenary. On that famous occasion another symposium will doubtless be organized including very probably lectures by some of the younger of to-day's auditors. It seems to me useful and profitable to speculate now on what sort of problems people will then be discussing, what things will have been achieved and what other things will still remain to be done by scientists, economists and political leaders.

Having settled the date you will permit me next to run over briefly some of the other broad assumptions which I propose to make. One is that this planet of ours will in the year 2018 still remain a closed economy, in other words there will be no interplanetary migration and no interplanetary trade, or at least so little that it can be ignored. I leave to cosmonauts the task of making projections on these matters. We shall still be primarily concerned with the inhabitants of our own world and with improving their welfare.

Another assumption concerns population – how many people will there be to feed and to house? Let me boldly state my conviction that by then we shall have entirely outgrown our sensitivity regarding family planning which will be fully accepted in all parts of the world; but that by itself does not give any helpful clue as to what the birth rates are likely to be in different countries and continents. Children will have become a commodity; each country will be able to arrange the production of as many or as few as it thinks fit. However, as with other commodities no country will by itself embark on the limitation of production, it will seek agreement with other producing countries. Very possibly with a world population already of some 8 billion in the year 2018 it will be in the general interest to adopt certain agreed measures of limitation of numbers but it may prove as difficult to negotiate an international Children's Agreement as it is to-day to secure an international Cocoa Agreement. Certain producing countries will be unwilling to come in until they have captured a larger share of the market which, in the language of child production, means until their national population has overtaken that of some rival country with which they are determined to be on terms of equivalent political importance; and since the possession of a large population emphatically gives a country a large say in world affairs the urge not to get left behind in the population race will be a compelling one. Therefore I believe that one of the hotly discussed problems of 2018 will be how to draft a Non-Proliferation of Children Treaty which stands a reasonable chance of being accepted by all the countries of significant size.

As a corollary of the vast increase in population which will already have occurred and the further increases which would accompany any failure to ratify the treaty it must be assumed that most of humanity will have become conditioned to tolerate, perhaps even to appreciate, living in crowded conditions. This at least will be necessary in areas which already to-day are fairly crowded such as Western Europe, Japan and parts of the US eastern seaboard. Indeed, we need have little anxiety; that such conditioning is already taking place can be seen in the behaviour of vacationists nearly all of whom prefer to congregate in masses at certain popular resorts and shun the remoter shores and mountains.

A final assumption needs to be made about economic growth. We can afford to be conservative here owing to the wonderful benefits which the arithmetic of compound accumulation brings about. Thus, if income per person be assumed to grow at the modest rate of 2¼ per cent per annum for fifty years it would treble, while if it grew at 2¾ per cent per annum it would almost quadruple. Many economists predict even higher rates of growth of income, but something between a three or four fold increase would appear sufficiently exciting to stretch our imaginations; in Western Europe it would approximate to between $ 5,000 and $ 6,000 per person at to-day's prices.

As for the low income countries which are not growing as fast, per caput, as the rich countries, a four-fold increase in fifty years would not signify much prosperity – for example, a rise from $ 50 to a mere $ 200 per person. It is fair to hope that well before 2018 economic engineering will have made it possible for the low-income countries' growth rates greatly to outstrip those of the rich countries, so that while the gap between poor and rich will unquestionably widen farther during the coming decades the tide will have turned by 2018 and the gap will be beginning to be reduced.

To sum up our assumptions, therefore, we shall focus on the year 2018; our planet, still living entirely on its own resources, will have some 8 billion inhabitants whose standard of living will be three or four times better than to-day. Serious attempts will be being made to agree on international limitation of population, while the arguments as to how to accelerate growth in the developing countries will still be vigorous but perhaps somewhat less inconclusive.

2. *Farming*

Within this broad framework what will the farmers be doing? What contribution will they be making to the world's food supply? What new tools will agricultural scientists have put into their hands? This is, of course, a guessing game in which everyone can participate; indeed the non-scientist has almost as good a chance of giving the right answer as the distinguished scientist who is completely preoccupied with the work in his particular field. Some classes of prediction are safer than others, for instance the assertion that certain techniques already used in say the USA or New Zealand will be adopted in Europe. More shaky are predictions based on techniques still in the experimental stage in institutes, for experience has many times shown that some techniques take much longer than anticipated to achieve commercial application while others move unexpectedly quickly into common use. I remember well how just after World War II the desalination of water was confidently expected to become very soon economically viable for irrigation, yet twenty years later there is still no sure sign of the break-through in costs. In what follows regarding crops and livestock I have drawn freely on the ideas of my friend at the University of Reading, Professor A. N. DUCKHAM though the various additions and interpretations are my own.*

a. Crops

Notions about cultivation methods particularly of cereals are changing very rapidly. The new herbicides, such as paraquat, and new chemicals available for other purposes open entirely new horizons. Fifty years from now cereals will be grown on large specialized farms, the same crop on the same land for ten years in succession or longer. Ploughing will be a rarity because the seed will be drilled direct into the killed-off stubble or grass and this will have several advantages: it will preserve organic matter in the topsoil, prevent wind-erosion, reduce soil-borne diseases and lengthen the growing period. Drilling will be done by light weight machines capable of seeding 40 hectares or more per day. Harvesting also will be performed by simpler, lighter machines since chemical dessicants will be used to dry the straw and heads and other chemicals to prevent odging. All these chemicals as well as top dressings of fertilizers will be applied

* A. N. DUCKHAM: Forty years on: agriculture in retrospect and prospect, *Journal of the Royal Agricultural Society of England*, Vol. 127. 1966.

by light aircraft or hovercraft operated mainly by contractors.

Undoubtedly we shall have much improved seed. Probably not too much hope should be placed on what the atomic scientists can offer, because radiation merely gives us more mutations to play with and it still remains for the plant breeder to choose the promising ones and to establish and stabilize the new strains. But his record has been so impressive in recent decades that we may confidently expect similar rapid progress in the future. More especially will the new experimental work bring improvements to the low-yield grain areas of the sub-tropics. The breeder in 2018 may also have some promising experimental plots of perennial cereals. Water supply and control will have become an exact science. It will be economic to have built-in irrigation equipment on cereal fields in all Mediterranean-type climates and even in some cooler ones. The moisture content of the soil will be reported by gauges all through the growing season and the supply accordingly kept at optimum levels.

With all these aids an efficient farmer operating under favourable conditions will expect to reap an average grain harvest of 10 tons per hectare.

What of sugar beet and potatoes? Because these need specialized and expensive equipment that will no longer be required by ordinary cereal farmers these crops will be grown mainly by contractors either on specialized farms as in California or on 'visits' to cereal farms if and when a break is found desirable in the long succession of grain crops.

Fruit and vegetables already to-day are in the hands of specialists. A wider range of chemicals for pest and disease control will be available and a number of noxious insects will have been eliminated by the sterile male technique. The breeding of earlier and later maturing varieties will extend the marketing season for certain vegetables as well as fruits as it has already done for strawberries and raspberries.

b. Grassland and green crops

Already it has become practicable to extract protein *direct* from green crops, leaves and grass. The green material is pulped in a mill; the liquid is then curdled and the protein dried. The extraction plant now working at Rothamsted is simple and cheap – £ 6000 for a capacity of 1½ tons per hour – and suitable for developing countries. One hectare of green crops used in this way would provide the protein requirements of 250 people, ten times as much via the cow's stomach.

Permanent grass will be retained in all the wet and cloudy areas where solar radiation is insufficient to make cereals profitable. The enthusiasm for improving hill pastures which burst out thirty years ago and has since gone out of fashion will have revived as we adopt the techniques of using aircraft to change the composition of the sward and its rate of growth, which is already being done in New Zealand.

In lowland areas hay and silage making with their outrageous loss of food value will have disappeared. Chemicals will be used to control the flowering and seeding of grasses which reduces their digestibility and this will prolong the season of useful growth. There will probably be controversy between cattle farmers who prefer to graze most of the herbage in situ and those who cut for zero-grazing, conserving the product by drying, freezing or other new devices. It may be that in districts specially favoured for such grass growing the specialist grass farmers will sell their conserved products to near-by specialized cattle farmers each of whom will feed several thousand head under controlled conditions of light, temperature and atmosphere.

c. Meat and milk

Compared with the recent advances in the scientific feeding rations provided for poultry and pigs the feeding of beef and dairy cattle remains quite primitive. The nature of the protein in cattle feed will be controlled according to the age and function of each animal. To the basic grass or cereal ration will be added synthetic amino-acids such as lysine, threanine and methionine, as well as synthetic volatile fatty acids to optimize the nutritive value of the diet. Some of these may be injected directly into the bloodstream.

In order to control completely the quantity and quality of feed intake, in order to regulate the atmosphere and in order to mechanize all the operations of feeding, milking and dung removal, most beef and dairy cattle will be kept permanently housed in climatically controlled stables. Private or commercial owners of large areas of mountain grazing will still be trying to maintain an open-range system of beef production but the economic pressures will be forcing them out of business.

Cattle breeding will have vastly improved techniques at its disposal. Eggs from high beef or milk yielders will be grown on tissue cultures, fertilized and inseminated into lower yielders. Semen will be treated to control sex – calving will not be necessary. Lactation will be hormone-induced and its period will be adjusted as desired. It may be feasible for lactation to be temporarily halted to give weekends and vacations to cows and workers alike.

The problem of the seasonality of milk production and the more or less level year-round consumer demand for milk will have been resolved in two ways. One method will be to produce all the milk during 6–8 months from spring to autumn, giving the consumer during the winter the various long-life milks which will be on the market, as we shall see presently. In this system calving would all occur in early spring, the dairy cows would either be grazed or be stall-fed on one of the rations already described and then in autumn lactation would be stopped, the farm would close down the staff would go to the Alps or the Bahamas for holidays. The other method will be 365-day production from several hundred cows with a three-shift staff milking 24 hours round the clock. Milkers weekends and holidays would be staggered, it being remembered that in an automated stable their only task will be putting on and removing teat cups. Cows will remain in milk for three or four years before going to the slaughterhouse; such calvings as are necessary will be appropriately staggered. Thus the 'jamais le dimanche' manpower problem which increasingly worries us in dairy-farming to-day will have become a mere memory.

d. Farm management

The farming practices described so far will be those of the progressive farms and then as now not all farmers will be equally progressive. The same applies to farm management where only a minority will avail themselves of the new facilities. Increasingly the work will move indoors, will become less manual and more cerebral. Driverless tractors powered by electric batteries or small nuclear fuel-cells will perform all the field operations of drilling, harvesting, fruit spraying and vegetable weeding as well as the farm transport jobs that cannot be done by conveyor-belts. On farms equipped with built-in sprinkler equipment this will be turned on automatically when the moisture content of the soil falls below a determined point and would also be used to emit warm fog to protect crops sensitive to frost. Chickens, pigs, cows and beef cattle will be kept in buildings whose light, temperature and humidity are regulated from a central control board; their food and drink will be supplied in prescribed quantities according to age and in the case of milk cows individual performance.

In each region there will be a computer centre to which farmers who subscribe will be linked. Each farm and each enterprise and operation on the farm will have a number and thus the farmer by dialling the correct combination can ascertain immediately whether say his north field should be drilled tomorrow, what changes in the amino-acid supplements should be given to the six cows that have already each produced 2,000 kg of milk in the first stage of their lactation. The feed instructions will be transmitted to the cow-building where the scanning device identifies each cow from its magnetic disc and automatically delivers to each the correct diet. The computer centre will undertake bookless bookkeeping, will order supplies, pay bills and communicate to the farmer his bank balance. It will provide market prices and price forecasts and calculate the advantageous moment for selling, for instance, the bacon pigs.

Each farm will have closed-circuit television enabling the farmer sitting in his office to keep an eye on all operations, communicate with his men and with his unmanned machines. Electronic monitoring devices will record the progress of work in all departments. Warning bells will indicate when intervention is required. These things sound fantastic but many factories already have them to-day. The main point is that while the farmer will still be responsible for making decisions he will make them not solely by instinct but also on the basis of all relevant available information that will have been processed into graphs and statistics which he can readily interpret and on the basis of which he can decide his policy. Managers of large farms will require the same business acumen as managers of factories and will receive much the same kind of training.

e. Climate and soil

What has been described up to now while realistic in that it is based on existing knowledge implies rather radical departures from existing farming methods. If I am to continue to be realistic in predicting how far we shall control climate fifty years hence then I must honestly say that I think we shall have achieved very little control indeed. Of course we shall be controlling small patches of micro-climate; we already do. Fruit growers ward off frost by placing heaters in their orchards; airports can keep their runways clear of fog.

When it comes to larger problems one must recognize that a lot remains unknown about the formation and behaviour of clouds, about for example the coagulation of condensation nuclei, and while much knowledge will have been gained by 2018 the very magnitude of the cloud areas that would have to be influenced will still inhibit dramatic action. We shall doubtless in districts prone to hail damage be able to change the hail into rain or snow; in fact the Russians claim good results already.* We already know how to seed clouds with silver iodide and doubtless the techniques will have been improved so that the 10 per cent increase in precipitation which to-day seems the common achievement of experiments in several countries might become a larger percentage; but the fact remains that this represents not a net increment but merely a redistribution of rainfall. Someone goes short somewhere else. In any case we cannot seed clouds where none exist, for instance in the Sahara.

As for changes in the macro-climate such as might be brought about by closing the Bering Straits or melting the ice-caps, though we might possess equipment capable of accomplishing these things it would be extremely perilous to undertake them since far too little is known of what reactions in world climate might follow. Moreover, as we cannot undertake properly controlled experiments with weather – even less than with human beings – our knowledge of cause and effect in macro-weather matters will grow only slowly.

However, while we shall not be able to control or change our weather we shall know much better what weather we are going to get. Weather forecasting will by then have been substantially perfected. Let us remember that it is only within less than ten years that we have come into possession of the tools for the job; satellites to observe the hour to hour changes all over the earth's surface, rapid telecommunications transmitting not 50 but 2,400 words per minute, computers to process the information thus received. Since forecasting depends essentially on noting certain patterns and sequences and observing their frequency, and since the world's cloud systems can produce a vast variety of these patterns and sequences it will require a number of years of experience before we can confidently predict on the basis of past performance. In fifty years' time we shall possess much data and to-day's tentative three-day ahead forecasts will have become 15 or even 30 day forecasts that seldom go wrong. Incidentally, in order to exploit fully the new techniques it will be necessary to rely on a few central well-equipped meteorological centres – one or two for each continent would suffice; the day of the small national weather stations will have gone. Efficient weather forecasting for large districts will also be supplemented by a service of extremely detailed and even more accurate information on small areas and this will be available to farmers by telephone. Hence a major hazard to farm operations will have been removed.

If we cannot draw more water out of the air we can certainly get plenty out

* E. K. Fedorov: The Artificial Modification of Meteorological Processes. *Report to the Fifth World Meteorological Congress*. Geneva. 1967.

of the sea. He would be a confirmed pessimist who maintained that in fifty years we shall not have broken through to desalinate seawater at a price which makes profitable the irrigation of staple crops. At the same time if by nuclear energy or otherwise the necessary heat can be produced cheaply enough so also can be the power required to pump the desalinated water over long distances. Thus in the year 2018 we shall have completed or more likely will still be constructing major engineering works to bring fresh ocean water to the world's great deserts – the Sahara, the Arabian, the Gobi, the Australian. Here could be $1\frac{1}{2}$ billion hectares of newly watered land available for food production, equivalent to the total crop area of the world to-day.

Nor is this all. A great deal more land could be made available for agriculture if the world really needs it. For instance of the forested portion of the earth's surface some 3 billion hectares are at present unused or inaccessible. Fifty years of progress in the development of air and road communications will greatly have reduced the area classed as inaccessible while fifty years of research on the problems of tropical agriculture will have taught us how to farm efficiently and continuously on soils from which the tree cover has been removed. If half the 3 billion hectares could be brought into agricultural use, together with the irrigated deserts, we should have a world cropland area three times as large as to-day.

To undertake both these enormous projects, even with the improved engineering equipment which we shall then possess, would require very large investments and would be justified only if such programmes were necessary to ensure the food supply of the world. From what we shall have to observe later it seems fairly certain that they will not be necessary, or only small fractions of them will be carried out, for there are all sorts of other and possibly cheaper ways of providing the food that people will want to eat.

3. Food

The food industry and food sciences are making as rapid forward strides as agriculture and in several respects the two are likely to be strong competitors in 2018. Already in rich countries the consumer spends more money in having his food processed and delivered to him than he does on the farmer. Fifty years hence the farmer will get less than a quarter of the consumer's food dollar and indeed some foods will not originate on farms at all. What can we expect the food industry to contribute to the problem of feeding the world?

a. Food processing

The main objectives of the food processing activities are two: first to preserve food and second to present it in forms which are convenient to the consumer and appropriate to his mode of life. Obviously in the sophisticated environment of big cities the two are interconnected.

The greatest preservation task for the world to accomplish during the next fifty years is to stop or at least greatly reduce the appalling wastage which occurs in storing and transporting the food produced and distributed in the developing countries. Here no new gimmicks are needed, simply the application of widely known, relatively simple techniques. Nor are the investments involved so tremendous. Since it is primarily a question of organization one can expect that well before 2018 national or district marketing boards or other appropriate bodies will have been given the responsibility of dealing with storage losses and will have conquered the problem in most countries.

In advanced countries food preservation means prolonging the shelf life of perishables and here important advances are being made every year. Since it is their water and protein content which principally makes foods difficult to keep, it is being found that physical methods rather than the use of chemicals are more effective preservatives and better retain the nutritive values of the proteins. Thus in fifty years, to cite just a few examples, a large proportion of our vegetables will be marketed after accelerated freeze drying, milk will undergo either this or ultra-heat treatment, shellfish will be sterilized by irradiation as is already the case in California and Mexico. One great advantage of the new methods such as AFD is that the moisture is frozen and sublimated to give a food free of moisture but with structure intact and no unpleasant flavours*.

These foods which can be reconstituted easily will become standard pack for explorers in outer space, for safaris in hot countries as well as stockpiling for emergencies. It may be that via these techniques rather than via synthetic foods our basic diet could be provided in the form of pills which could be reconstituted in the human stomach by drinking water or some more attractive liquid.

The other purpose, that of convenience, will have become paramount for millions of city dwellers. Because of the increasing number of women in employment, because even those who stay at home tending their children will wish to be liberated from kitchen drudgery, because of the increasing proportion of old people in the population, much more communal feeding will then be provided in factories, offices and apartment blocks and many more ready-wrapped complete meals will be marketed which simply require re-heating or can be eaten cold. There will be complaints about the monotony of taste of the processed cheese and plastic-wrapped fried potatoes but the food technologist will meet this challenge with new flavours and colours.

Cheaper and more rapid air transport will have brought us the delicacies of all the continents at all seasons of the year. Already we buy in our supermarkets fresh flowers from Bangkok and Veracruz; then we shall have from the tropics all their perishable fruits and vegetables while they in return will be able to enjoy ours. The market for the horticulturist and the grower of speciality products will be nothing less than the whole world.

b. The protein problem – synthetics

Most of the food requirements of the world can be met easily enough from conventional sources using modern techniques. Fats and carbohydrates can already be grown cheaply and their abundance will increase. There is no

* J. G. Davis: The Food Industry in A.D. 2000.E. Frankland Armstrong memorial lecture *Food Trade Review*, January 1966.

shortage of the minerals and trace elements needed for healthy diets, while vitamins can be either synthesized or produced by micro-organisms. The real and only problem lies in protein which is insufficiently available in quantity and quality and might still be so in fifty years if purposive policies of research and production expansion are not pursued.

What is required is a far larger supply of animal protein or a similar expansion of foods containing vegetable protein plus supplements to bring the quality of this latter up to the nutritive value of animal protein. To supply a world population two to three times as numerous as to-day's with sufficient protein solely in the form of meat, milk and eggs would be a gigantic task and enormously costly; even if the fish resources of the ocean were added in it would not suffice, though undoubtedly we shall witness not merely greatly expanded fisheries governed by world-wide conventions and regulations but also highly systematized fish farming in both fresh and marine waters.

Various new sources of protein will be being exploited in 2018. One of these will be leaf protein, made available when we process grasses and leaves for digestibility in the human stomach. The nutritive deficiencies in this protein will be made good by the addition of certain amino-acids synthetically produced – notably methionine and lysine. Another will be the artificial 'meat' which is already being spun out of soya beans and which will be similarly enriched with appropriate amino-acids. Yet another will be the yeasts and fatty acids obtainable from petroleum which have already been converted into palatable foods on an experimental basis. In the realm of micro-biological food production quite simple bacteria have been used to make protein and, on a larger scale, higher organisms such as the algae Chlorella which when freeze-dried contains 55 per cent crude protein, all the essential amino-acids and has a high carotene content. As micro-organisms do not need light, one advantage of food from this source would be that the survivors of an atomic war deprived by radioactive fall-out of food from vegetable origin could make their supplies in underground tanks.

Finally and perhaps most important of all comes the question: shall we have really synthetic foods and above all synthetic protein on a commercial scale by 2018? The formation of carbohydrates, fat, proteins and vitamins is brought about by enzymes, and some of these enzymes can already be synthesized. While the synthesis of fats and carbohydrates is, chemically speaking, a fairly simple matter and while peptides and several of the important amino-acids have already been produced synthetically the synthesis of proteins presents more difficult problems. These difficulties may well have been overcome at laboratory level in fifty years time but it must be reckoned doubtful whether production on a large commercial scale will be taking place.

However, even without synthetic proteins, we shall probably know how to produce commercially a considerable range of essential foodstuffs from non-conventional sources – our carbohydrates and fats and vitamins produced synthetically and our proteins manufactured for us by micro-organisms. Some people may fear the monotony of such 'artificial' foods even when jazzed up with new flavours, but present experience with mass-produced products like wrapped and sliced bread shows that the great majority of people eat for business, not for gastronomic pleasure. The small minority of epicures will nevertheless continue sufficiently numerous to support Michelin's two and three star restaurants.

What is significant is that by that date farmers will be having to accustom themselves to the idea that they are only one of the sources of food production, that they have competitors who may well become powerful. Many of us can remember the gentle mockery which greeted the first production of synthetic rubber, yet to-day the rubber plantations, all but the very best, are fighting for their lives. Fifty years on a similar challenge may be facing cereal and livestock farmers; they will have to get better or get out.

4. The Agrarian Economy

This brings us back from the technical outlook for food production to its economic organization. What will be the role of agriculture within the national economy, and how will the structure have changed within the agricultural sector? Here a distinction has to be made between the already advanced countries and the developing ones even though there be some which come in a border-line category.

a) Advanced countries

To-day the agriculturally efficient countries already produce all the food they need by using in farming less than 8 per cent of the national labour force. This farm population is declining rapidly so that almost certainly in the year 2018 not only these but all the rich industrial countries will be using only some 2–3 per cent of their labour force in agriculture. Income parity between agriculture and other occupations will have been attained. But whereas to-day salaried workers are disappearing much faster than family labour this trend will be reversed as a consequence of the re-structuring of farms.

Farmers of the future will specialize in a single enterprise because this will permit more rational utilization of the expensive equipment and because the manager cannot possess the full technical know-how for several different products. They will have large farms – not less than 200 hectares for crops and not less than 300 cows for dairy farming; there will be arguments then at Wageningen as to what (perhaps much higher) figure constitutes the optimum size of farms, accompanied by moanings of agricultural economists at the slowness of the farm structure to adapt itself to their recommendations. That tune will not change at all.

These large farms will require very heavy capital investment totalling several hundred thousand dollars at to-day's prices – amounts which very few individual families could provide and which even if they did would be eroded away in one generation by inheritance taxes. One must reckon inevitably that the practice of setting up private or public companies to run such farms which already exist in a few regions to-day will have become widely adopted. The chief operator will be on a salary basis whether he be the head of a family investment group or the general manager appointed by a public company.

While this will be the organization of the important minority of highly efficient farms, the majority then as now will be lagging behind. They will have progressed, of course, and should be looking then like the best farms look to-day, but they will not have adjusted fully to the forms and practices of agro-business.

In the centrally-planned economies of eastern Europe part of this structure already exists: farms are large and substantial investments have been made in buildings and equipment. One of to-day's major drawbacks should have disappeared in fifty years' time, namely the excessive number of workers sitting on farms only partially employed – up to as many as 70 per 100 hectares on fully mechanized farms in some of these countries. The other major drawback namely the inadequacy of management will have been certainly overcome through better training and more incentives. Undoubtedly, vigorous arguments will then be going on as to what is the optimum size of farms in different regions and for different products and many of to-day's very large farms will have been sub-divided.

Thus it seems certain that progressive farms in eastern and western Europe in the year 2018 will be virtually alike in structure, organization, equipment and management. Indeed one may suspect that it will prove easier for the eastern collective and cooperative farms to reach the position I have described than for the small western family farms to make the transition. We shall see.

b) Developing countries

It is sometimes said that all that is required to improve agriculture in the developing countries is a wide dissemination of existing know-how. This is less than half true. Much more research is required into the special problems of the tropics and sub-tropics, as is shown by the recent efforts to find wheats which under Indian and Pakistani conditions will respond to liberal supplies of water and fertilizer. We have the right to assume that the recognition of this need will soon produce funds for at least some of the needed research stations and consequently in 2018 a body of more precise scientific and technical knowledge will have been acquired.

Much more problematical is the degree of success that will have been attained in imparting this knowledge to the millions of individual farmers. What seems likely is that in most of the developing countries substantial patches of highly modern and efficient agriculture will have come to existence while alongside persists an antiquated primitive farming yielding a very low standard of living. The patches of modernity will generally be in newly irrigated districts where because of the arrival of water accompanied often with changes in land-holding the whole mode of farming has been revolutionized. It is far harder to persuade farmers to change their ways when their general environment remains unchanged.

In the great majority of developing countries there will be a sufficient number of patches of modern farming to assure the national food supply and to enable them to dispense with food imports. This may sound optimistic, but it is no more than countries such as Mexico have already achieved and Mexico has one of the highest population growth rates. There will remain certain countries which have failed to expand their food production adequately and others where the man/land ratio requires them to be permanently food importers. For these there will be no supply problem since food production capacity in the advanced countries will vastly exceed domestic requirements. Indeed production controls will prevail everywhere in the rich group of countries and can be easily relaxed to generate whatever exports are required at any particular time.

The organizational structure of farms will not be the same throughout the developing world. Some countries will have sub-divided their large estates into small family holdings, others will still retain the peasant structure they always had, while yet others will have set up a system of large co-operative farms. What will be common to all of them is a vast surplus of rural man-power. At the present time the farm population in all developing countries is increasing, in some of them quite rapidly, because the rate of increase of employment in other sectors, industry and services, remains inferior to the rate of growth of the labour force as a whole. According to current projections, if all goes well and the goals of economic growth are attained, then the agricultural labour force may begin to decline in 20 or 30 years' time; but where the goals are imperfectly attained the tide will turn rather later. Thus in 2018 while the trend should have changed the farm population will be higher than it is to-day, indeed in many countries substantially higher.

We know that unemployment or under-employment, open or disguised, is to-day a prevalent feature in the rural areas of developing countries. It is sometimes suggested that the modernization and intensification of agriculture will create new jobs and at least partially solve this problem, but actual experience is not in many cases encouraging. Of course in certain instances where irrigation brings hitherto barren land into cultivation or where horticulture replaces general farming, local employment will increase but this will be more than offset by the trend toward mechanization. A recent survey in Sinaloa, one of the most irrigated and agriculturally advanced states of Mexico showed that in over half the villages each able-bodied man had on average less than 20 days work per year. Fifty years hence the rural unemployment problem in developing countries is likely to be far more serious than it is to-day, more serious numerically and more serious socially because of the greater expectations of prosperity that will have spread among the people.

5. *The social pattern*

This brings us to a final question, which can only be touched upon lightly in concluding the present paper, namely what will be the social relationships between food producers and others, between countryside and city in fifty years' time? What changes will have occurred in modes of living and in levels of welfare?

a. Developing countries

In developing countries the contrast between levels of living in the big cities and in rural ones will have become far more painful. Each country will have one metropolis, in some cases having several million inhabitants, which possesses the infrastructure of modern civilization and houses much of the nation's manufacturing industry and most of its commerce. Few other towns will show signs of dynamic growth. Rural areas will remain neglected for the good reason that poor governments cannot afford to equip all parts of their countries with basic services simultaneously. Schools and clinics will have come to most of the villages but employment opportunities will remain negligible.

Because of better education and health and hearsay about the glitter of urban life, village people will become more and more restless. Some will move off to the cities to swell the inhabitants of shanty-towns; the remainder will stay behind disgruntled, a seed-bed for social tensions and a prey to the propaganda of political extremists. In the more totalitarian countries the migration to cities may be checked by systems of permits and economic activity may be decentralized by decree, but this will only spread available employment, it will not increase the number of new jobs. In both types of economy more than half the young men of the village will have no prospect of a full-time job for the rest of their working lives.

Lying outside the subject-matter of this paper are programmes which could stop this disintegration of rural society and family life, programmes for instance for production in the villages of simple manufactures in which the labour component of production was at a maximum and the capital component at a minimum; similarly programmes which in the creation of conventional manufacturing facilities deliberately rejected automated processes and gave preference to labour-intensive equipment. When one takes into account the national pride and business snobbery which mould the formation of most economic development projects one cannot be optimistic that the year 2018 will see much of an attack on this frustrating disease of human idleness.

Mr. Chairman, you may notice that I have said nothing about the future of international aid and technical assistance. Partly because this lies outside the scope of my paper which does not predict FAO's future activities and partly because it is my belief and hope that Aid will be not more but rather less important than it is to-day. If I am right in thinking that the developing countries through a succesful application of science and technology will have solved their urgent food supply problems and will be walking firmly along the road to economic growth, then it follows that the relationship between the industrial and developing countries will be less frenetic, less higly charged with emotiona land moral overtones than it is to-day and will have settled down to something more normal and businesslike comprising capital investment and well-regulated international trade.

I come back finally to the advanced countries and to what new social patterns we may expect to have evolved in these.

b. Advanced countries

Quite different will be the new social pattern common to most advanced countries. Cities will have exploded, flinging their inhabitants into new dwelling zones beyond the present suburban limits; regional development policies will have created new industrial centres; the network of motorways will be a blessing and a curse; workers will not only have five or six weeks paid holiday a year but will be able to afford both summer and winter vacations in resorts which will have multiplied to many hundred times their present accomodation capacity and in country cottages which they will have built to enjoy shooting, fishing, riding and other rural pastimes. The present migration toward the cities will have been completely reversed, with 'back to the countryside' as the most popular slogan.

All this will pose problems as well as bringing benefits. The problems for already crowded countries such as the Netherlands are obvious: how will it be possible to retain sufficient areas for recreation – at least for weekend recreation, assuming that the great majority can go abroad for their main vacations. Likewise the overcrowding of the European coastline will force beach-lovers further and further away to vacation resorts in North Africa and the Near East. Even the more sparsely populated USA and USSR will have their scenic resort areas terribly congested, though the great plains will remain unattractive to tourists, unless indeed tastes change and they revert to the eighteenth century detestation of sea and mountains cultivating a preference for the flat and formal. Land use for recreation will of course have to be planned but because agriculture will be utilizing far less land than it uses to-day there will not be the conflict that some people seem to anticipate.

What will be welcome in Europe will be the obliteration of income, social and cultural differences between town and country. Intermingling will bring variety within equality. The tiny agricultural labour force which remains will be paid the equivalent of their industrial and commercial counterparts and will participate in urban amusements. The ski instructor at Chamrousse will read the avant-garde authors and discuss them with his clients. The steel-worker from the Ruhr will in his spare time have become an expert in vinification and will own a part-share in a Bordeaux vineyard. Gone will be the inferiority complexes of the rural folk. The so-called 'forgotten' mountain farmers will be as prosperous as the tourists they entertain.

Through taxation we are eliminating the rich, through social welfare policies the urban poor. Through agricultural modernization coupled with tourism and regional industry we shall eliminate the rural poor. We shall enjoy an integrated society for the first time since the middle ages when town and country were brothers in poverty. In the twenty-first century they will be partners in prosperity.

This is my brief description of the environment in which I believe Wageningen will celebrate its centenary. Even though agriculture will be a smaller element in national economies that does not mean that eminent agricultural universities will have a less important role. Farmers will still have to be trained, in fact they will have to be much more thoroughly trained especially in business management. Research will still be required, in fact it will be more voluminous and intensive because society expects a continuing acceleration in the rate of scientific progress and therefore ever greater and more beneficial results will be expected from your work and the work of your successors.

That you and they will meet the challenge with brilliant distinction cannot be doubted. May I salute the student class of 2018, may I salute their Rector and his staff, knowing that they will carry forward the grand traditions of this university to further the well-being of generations yet unborn.

Discussion

Prof. HORRING: Your main assumptions about population growth and standard of living seem to be MALTHUS' famous thesis in reverse or even better than that. You only assume roughly two times as many people and not just two to the second power, but even two to the third power or 8 times as much goods and services in total.

Is it realistic to assume, that, in our world full of hazards we may expect over such a long period as fifty years, a steady, uninterrupted growth of production resulting in a production eight times as large as to-day?

You may be right that, in the rich industrial countries in fifty years time, only 2–3 percent of the national labour force will be employed in agriculture as against 8 percent now. I suppose you would not imply that this forms a good yardstick for the increase of productivity of food production as our first speaker Professor DE VRIES apparently did. He told us Monday that in India one farmer's family is feeding only six persons compared with sixty persons in the United States. I think this is not a fair comparison because the Indian farmer is practically the only man who does the job without help from outside, while the American farmer is assisted by at least two workers in industrial plants, transport and laboratories to provide him with the means to do the job. By comparing different countries, or different stages in a development of the same country, I think we have to be careful in distinguishing between a change in location where the work for food production is done (a change from the farm to the factory of farming inputs) and the decrease of the total use of resources (in farming and outside farming) per unit of food. The results of the comparison certainly will be less sensational, but why should we exaggerate the situation?

Sure enough 'underlying economics is technology', but on the other side the availability of technology is not enough for application. The use of extra inputs is decided upon by their costs and the returns of the related outputs. Moreover, for the application of new technology in farming and more generally in food production, large investments will be needed. How much will be needed and will the means for investment be available in large enough quantities? I fully realize that it is most difficult to answer these questions, but they are crucial. What are your reasons for being so optimistic about turning these technical possibilities into a means of obtaining an earthly paradise?

In my opinion there is a large gap between the bright future pictured here and the misery of to-day and even the danger of greater misery of to-morrow in large parts of the world. I expect that this feeling of discrepancy is shared to a large extent by the audience. It seems to me that there is a missing link.

Mr. YATES: Prof. HORRING put forward a question about the effect of compound rates of growth. I was not quite sure whether you were being friendly or hostile or that you yourself believe we shall be fifty times better off in a hundred years time, because you didn't tell us.

I assumed 2½%. Seriously, is it all that over-optimistic? I think if you look back to the beginning of this century and calculate for those countries for which you can calculate, you will find that the average increase (over 60 years) is over 2½% for the rich countries, despite two world wars.

Then you made this point about the slightly misleading percentage of the labour force in agriculture as part of the total labour force. In the most advanced countries a lot of activities are now taking place off the farm which used to take place on the farm. This is true for the input industry whether it is the farm machinery of the fertilizer, or other chemical industries, but it is also true for the industries down the valley. Afterall, the first process we took off the farm, perhaps, was butter-making. However, every kind of food processing and packaging is now done off the farm and manpower is also used in preparing food for the ultimate consumer. Perhaps from the point of view of total economy the best yardstick is the gradual fall in the percentage of consumer expenditure devoted to food, which, of course, is also going down in all rich countries.

Finally, you asked about why am I, the dismal economist, so optimistic. I did not talk about an earthly paradise. I merely said there would be some patches of modern agriculture in sufficient quantity in the developing countries to assure their urgent food needs. I also said that there would be a great deal of rural unemployment and people sitting around in villages. I do not think we could call it a paradise for these people to sit there having nothing to do and having insufficient purchasing power. I think I have painted a picture – and this I sincerely believe even with a rate of growth of population – which allows space for a very generous increase. I do not believe we shall have insufficient food. There will always be rich countries which will help other countries out in an emergency as was seen last year in the case of India. I think those emergencies will get fewer because there are distinct signs in a lot of developing countries today, that the effects of the introduction of new farm practices are really beginning to show some results. It is certainly true in Pakistan and it is becoming true elsewhere. On the food supply side, I am optimistic; on the human side, I am much less so.

There seems to be a number of people in this audience who had a very guilty conscience on the subject of sugarbeet. I had no idea that it was such a political or moral issue in this country. Of course, in an ideal world, everybody should produce the things which have the best comparative costs – so we were taught. But the world is not like that at all. We have been trying in Geneva for the past two years to get a renewal of the International Sugar Agreement which makes no attempt to do anything so sensible as to restrain sugarbeet growing in high cost countries, but merely tries to regulate the free market in relation to the semi-planned markets of USA and the British Commonwealth and it has been absolutely impossible to get any inter-governmental agreement. We are going to have another sugar meeting in April-May which I hope will be successful.

I could very well imagine an international commodity agreement in which the high cost producers gradually scaled down the volume of their production so as to allow access on the part of lower cost producers elsewhere. It will be a doctrine familiar to those of you who studied the attitude of the United States attitude to the Common Market in the Kennedy round in respect of cereals. They were constantly demanding access on the grounds that they could produce more cheaply. The same thing goes for the people who can produce sugar (from cane) more cheaply. But, I think it will be some time before we get that sort of provision into an international agreement. I should, personally, very much like to see it there.

Dr. PARPIA has asked a question about losses of agricultural products. I believe that it is necessary for technical people, when they travel in countries where these losses are severe, to make a noise about it so that governments of those countries begin to feel a little shamefaced and start, to get their technicians going. It is simply a case of allocating funds to provide the necessary protection and measures involving building of the proper kind of silos and storage bins. Up to the moment, governments in the countries where losses are severe, are surprisingly complacent about it and have not given high priority to programmes which any of us could help them to recommend and draw up. The problem is to get them interested and take the initiative and to see through the necessary executive action.

Dr. PARPIA also asks me whether I do not see an acceleration in the rates of growth and of modernization of agriculture. He says what took Europe 150 years took the United States 50 years and Japan 20 years. Therefore, perhaps we can do it elsewhere in an even shorter time. I think, Prof. HORRING has already warned us about extrapolations of trends and presumably the danger in guessing the number of years necessary to attain a goal works downwards equally dangerously as upwards. Otherwise, we would get down to two years! I doubt whether these cases are comparable. There are such a lot of different basic elements in the situations, in the educational level of a population. Afterall the people who colonized the United States came from countries that were beginning, at least, to be literate, and a high portion of the immigrants were fairly literate. They had a tremendous amount of land to play with. They took quite a lot of capital with them and a lot of capital was sent after them. In those days, the money was flowing to the United States, and not in the opposite direction. These facts now are not being reproduced in most of the developing countries and so – I would like to be optimistic – if we get as far in 50 years as I indicated, we should be doing quite well.

The next question regards the difficulties expected in making progress in farming and food production in the next fifty years. The difficulties are much more organizational than they are technical or scientific, organizational in the broadest sense including the programmes of governments and priorities they set up. This includes extension services and the understanding of the social attitudes of village communities and of individual farmers. That whole network of inter-related social institutions and administrative practices is the most difficult jungle to fight through in order to have the farmers practise what is already known. It is a subject on which much remains to be done.

There was another question on that subject. The introduction of a new society will cause serious social tensions. Perhaps these are so serious that this new pattern cannot be realized. Can we hope to overcome these tensions as long as FAO and other organizations do not give much more attention to social science research?

I am sure we need more social science research. Part of the bottle-neck area is that the problem of putting information across to farm people is not sufficiently studied around the world and you can't do too much by generalizing. The ways to overcome these difficulties and even the difficulties themselves vary tremendously according to the old social and cultural background of the society in which you are working. What the problem is in India, is quite a different problem in Tanganyika, or Bolivia, etc. There are very few generalizations possible, and a lot of work has to be done. I am in favour that much more attention should be paid to the problems of the transfer of knowledge and its acceptance.

I am also asked if the existence of the highly technological society in Europe and the USA versus an opposite situation in the tropics with many hungry and jobless people is leading not too much in the direction of a conflicting situation. I am sure that in some senses there is already a conflicting situation now. We see it in the UNCTAD II Conference currently being held in New Delhi. It could become much worse, because as I said in my talk, people in the developing countries are aware of the possibilities of life. They have expectations and this is a definite argument for accelerating aid to get over a difficult period in the next 20 or 30 years.

Prof. DE VRIES asks if it is not imperative to have a 'Non-proliferation of children treaty' in ten years, rather than in 50 years. It would certainly ease matters. I think it is going to be much more difficult to feed the growing population for the first half of the next 50 years, than for the second half. But the demographers tell us there is very little we can do about the population in the next 25 years. Furthermore, it is important that such initiatives must come from the countries that feel they are in need of family planning.

As far as the question about migration is concerned, personally, I don't believe that migration between nations on a really large scale, is going to be important in the coming decades. It is a thing that creates tremendous problems. On seeing what has recently happened in the United Kingdom and looking at the problems caused by labour migration from southern Europe to north western and central Europe, I don't think we are going to see tens of millions of people moving around the world.

I am asked whether nuclear processes and power energy won't be needed to produce synthetical carbohydrates, fats, etc., if these are going to be a large scale source of commercial food. It is quite true that a lot of energy will be required. How much the amount of energy used in food production will be in relation to the future total energy consumption pattern, I do not know. I have only said that synthetic food will be one of the sources of food – I certainly don't think it will be the major supplier.

A last comment was made that while to promote development more modern technology should be applied, extensive research should be promoted, and the organizations for assisting agricultural development, should be improved, a crucial point is omitted namely the role of the farmers. If the governments of the developing countries are not able to satisfy the existing hopes and the objectives of the farmers, every developing plan will be defeated.

My answer to that question is: I am sure that the beginning of the closing of the gap in living standards will have to be a joint effort. It will consist partly of the developing countries organizing themselves into a modern way of life and partly the responsibility of the developed countries to help them to do so and not to place obstacles in the way of their trade and other legitimate ways of expansion. As regards the farmer – of course, he is the key in the whole process but that is the point where, as I said, much more work needs to be done on understanding his attitudes, his responses to incentives, his ties to past traditions and, in short, his acceptance of change. I think I stressed that these are essential elements in the whole development process.