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GLOBAL ASPECTS OF FOOD PRODUCTION

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1. Our agricultural balance sheet and the quest for food self-sufficiency

Food is the first among the hierarchical needs of man. To end the uncertainty in the supply of food, man changed over 10 000 years ago from gathering food to growing food by domesticating plants and animals. This process started two significant developments. First, various forms of energy (collectively termed "cultural energy") were introduced to enable green plants to give stable and higher yields (Figure 1). The relative contributions of the different forms of cultural energy in agricultural production have varied over time and geographic regions. Secondly, from the millions of species recorded in the world flora and fauna, only a few plants and animals were chosen for domestication. Thus, there are now only about 30 plant species whose individual world production exceeds 10 million tonnes per year and six animal species whose production in the form of meat exceeds one million tonnes per year (Figures 2 and 3). Such dependence on a few species for meeting the food needs of the growing global population has increased the vulnerability of food production systems to hazards arising from weather aberrations and pest epidemics. Compounding the problem of man's dependence on a few plant and animal species for his survival is the fact that at present less than 10 countries in the world have surplus foodgrains for the export market (Figure 4). A response to this dangerous situation has been the initiation in recent years of steps for developing global and national food security systems.

While the need for introducing an era of accelerated agricultural advance is becoming increasingly urgent, the process of man-made damage to agricultural assets is proceeding unabated. Desertification has been defined as the diminution or destruction of the biological potential of the land ultimately resulting in desert-like conditions, and the entire process was reviewed at a UN Conference held at Nairobi in 1977. Immediate action to combat desertification is essential since, apart from the extreme deserts, about 45 million km^2 of productive land is threatened, distributed among 100 countries and comprising about 30 per cent of the world's land surface /1/. Lowdermilk /2/ in a study of the conquest of the land through 7 000 years, has stressed that while maintaining soil fertility is the duty of the farmer, conserving the physical integrity and production potential of the soil resource is the duty of each nation. In a series of thought-provoking publications, Lester Brown, Eric Eckholm and their associates of the World Watch Institute have drawn attention to the fact that

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apart from the fast depletion of the Earth's non-renewable resources, even the potential for renewable wealth is being destroyed /3, 4/. The impact of man-made activities on the climate, such as the effects of increasing carbon dioxide and of the release of nitrous oxides, freons and other trace chemicals on the ozonosphere is also a matter for serious concern. Above all, the pathway of agricultural advance so far adopted places a heavy reliance on non-renewable forms of energy and if the same pathway is followed in the future, a blind alley could be reached in the matter of improving food production /5/.

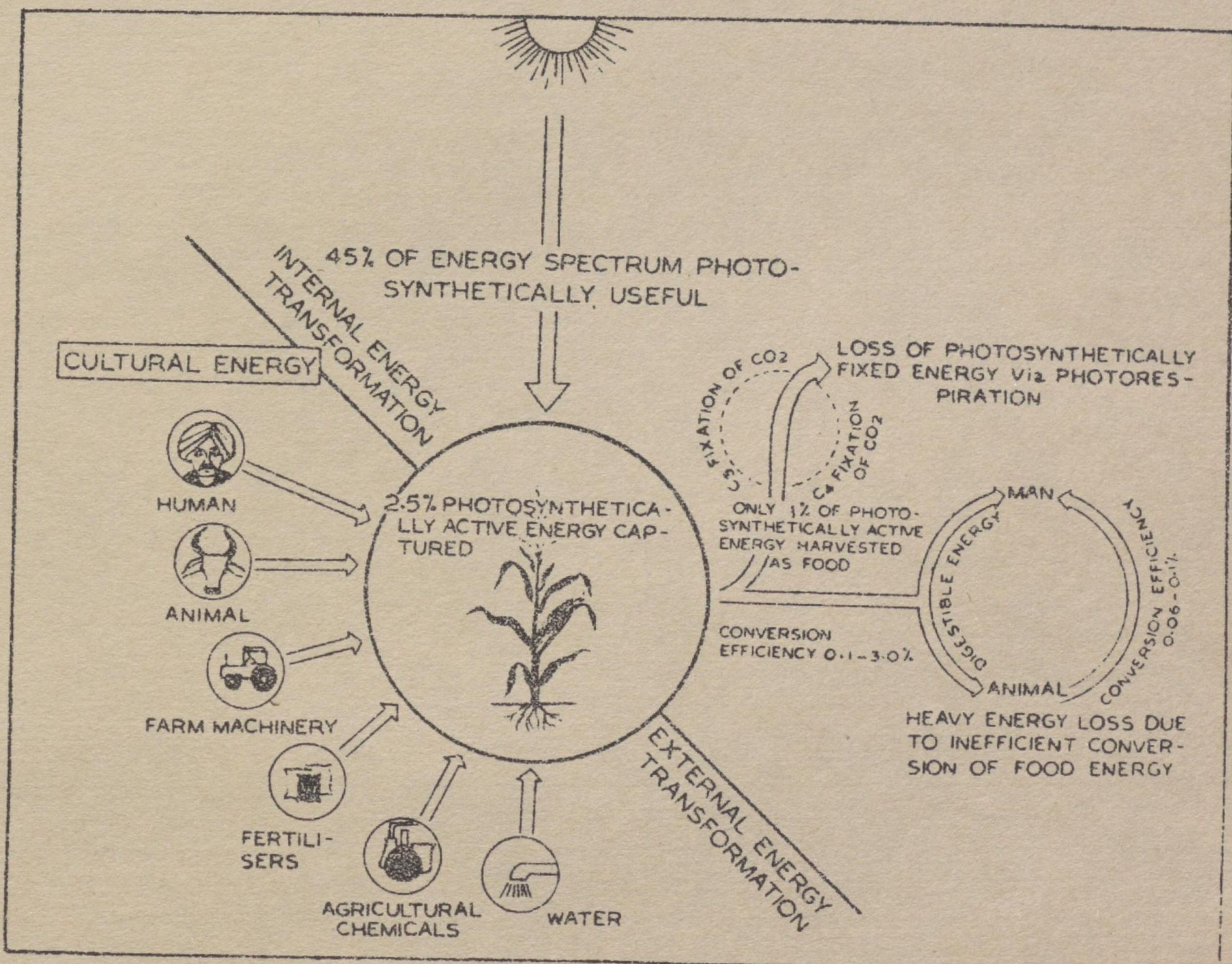

Figure 1. Solar and cultural energy input and output cycle in plants.

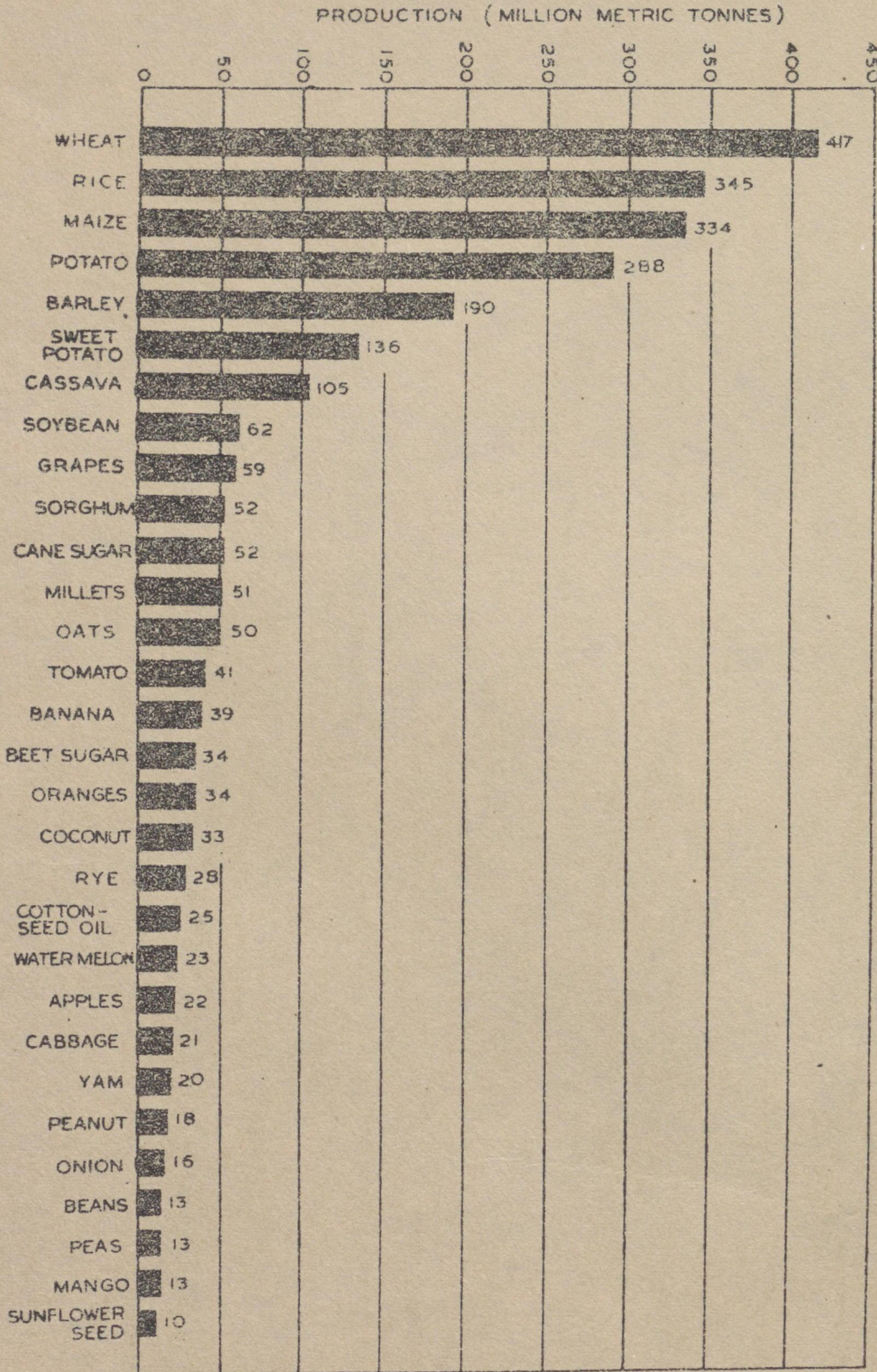

Figure 2. Annual production of the world's major food crops (1976).
(Source: FAO Production Year Book, 1976)

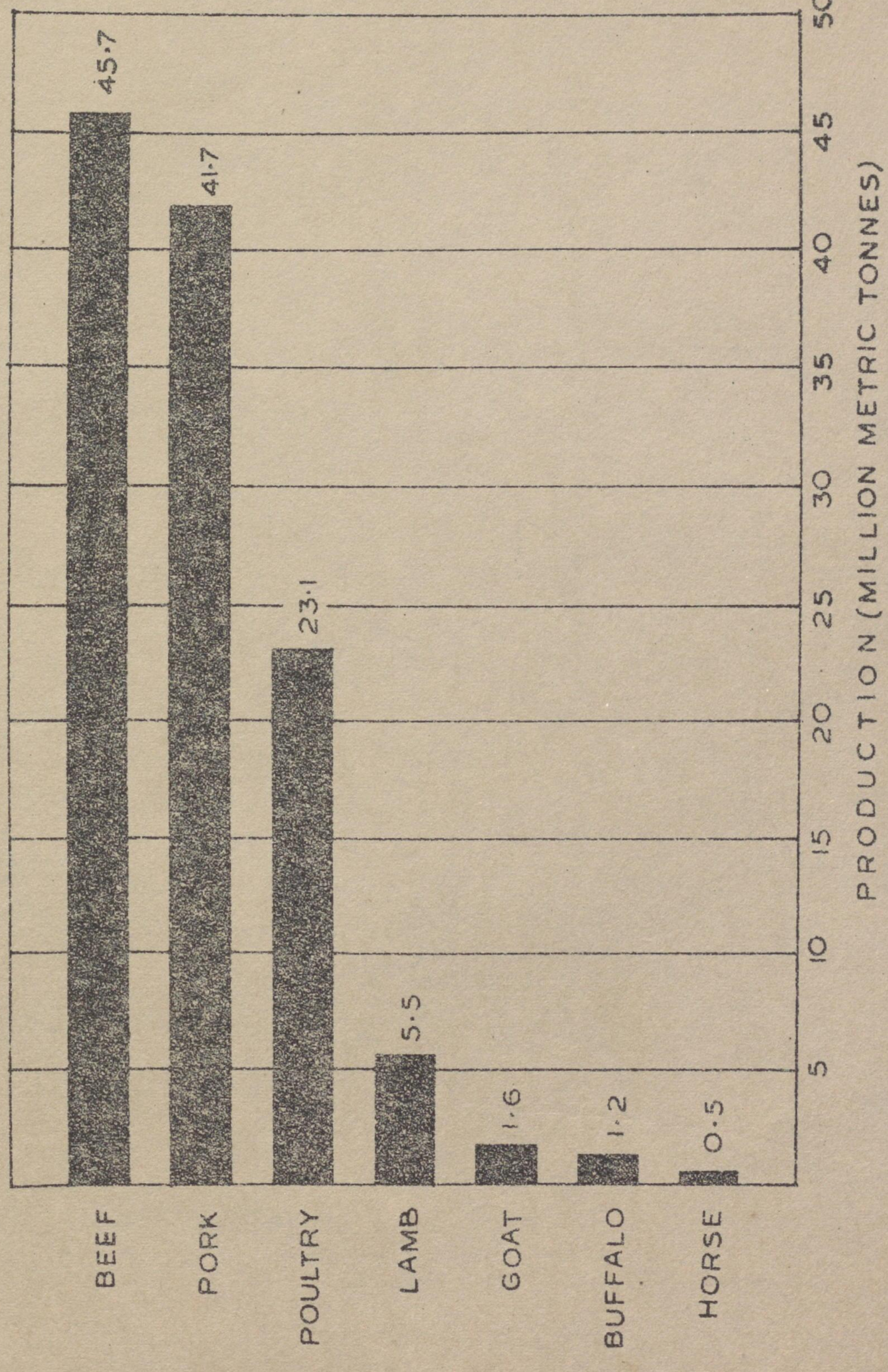

Figure 3 Annual production of the world's major animal products
(Source: FAO Production Year Book 1976)

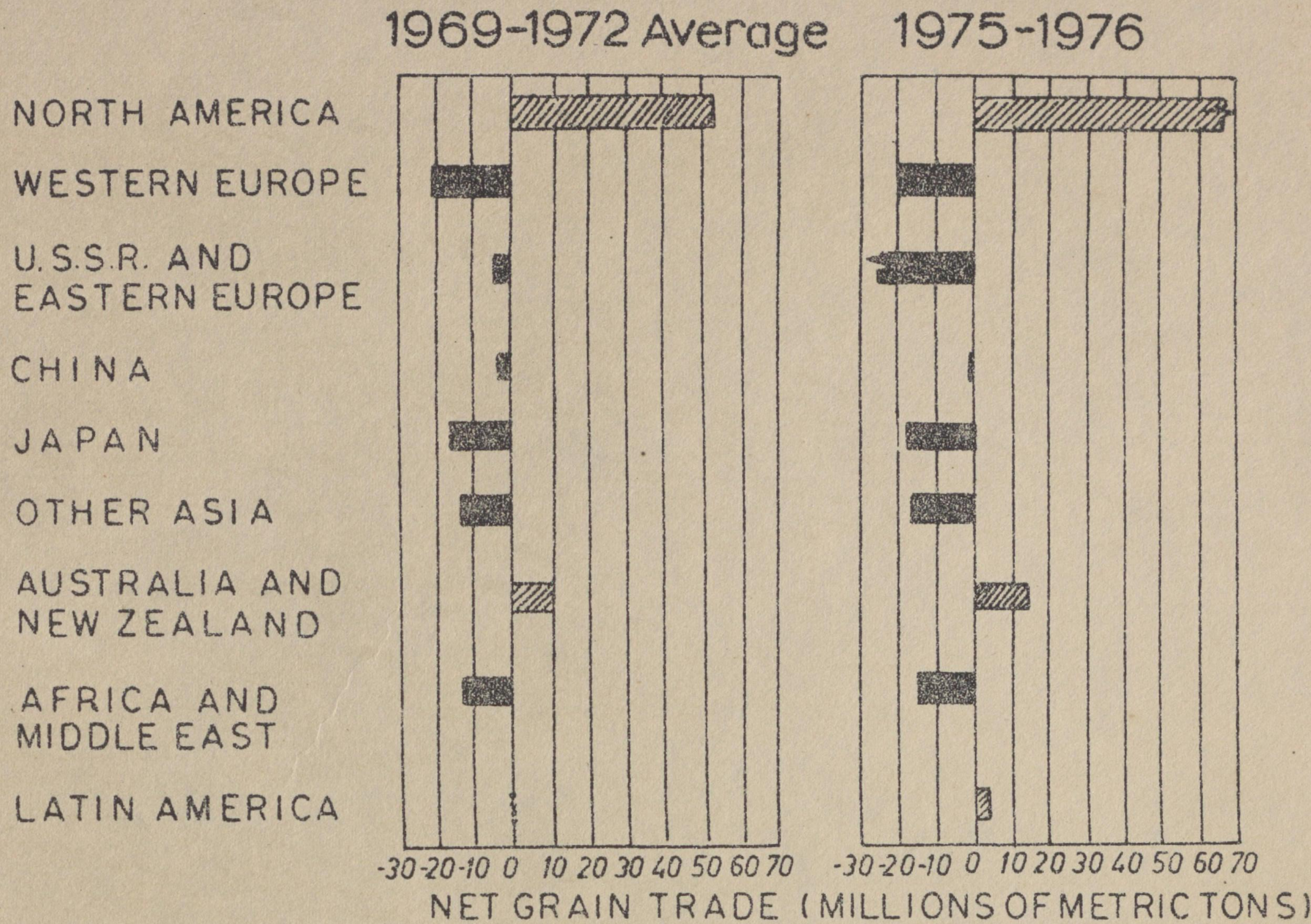

Figure 4 World's increasing dependence on the grain exports of a few countries; U.S.A. and Canada supply most of the grain.
(Source: U.S. Department of Agriculture [18])

Recent progress in the application of science and technology in the optimum utilization of available soil, water, air, sunlight and biological resources has raised hopes for our agricultural future. Considerable advances have taken place in developing agricultural balance sheets based on an understanding of the production assets and liabilities of each area, and in adapting the architecture and growth rhythm of plants to suit specific agro-meteorological and management conditions. Similarly, integrated animal production systems involving genetic upgrading, better nutrition and health care, and improved processing and marketing have been developed. New vistas of production have also been opened up both in freshwater aquaculture and mariculture, in addition to capture fisheries. In the area of forestry, land management systems involving integrated approaches to sylviculture and agriculture (termed "agro-forestry") are emerging. Above all, developments in the area of post-harvest technology are helping to minimize storage losses and to prepare value-added products from all parts of plants and farm animals.

On the basis of a scientific understanding of the global agricultural assets and liabilities, efforts have been made from time to time to measure potential terrestrial and aquatic productivity. Obviously such studies suffer from the limitations imposed by several unpredictable constraints which can retard production. Nevertheless, they are useful for stimulating national and international action since they indicate developmental peaks which countries can try to scale with hope of success. Buringh and his associates /6, 7/ have published their estimates of the absolute maximum food production potential of the world and the impact of labour-oriented agriculture on food production. They have used data from soil maps and from recent research on weather and climate. After estimating the area of potential agricultural land in each region of the world with suitable adjustments for soil conditions and water deficiency, they have converted the climatic parameters into a single composite measure called "gross photosynthesis" (GP). They have used appropriate conversion factors to transform GP values into dry matter production and, finally, into grain equivalents. These calculations indicate a theoretical production potential of 49 830 million tonnes of grain equivalents per year. The greatest potential occurs in Asia, followed by South America and Africa (Table 1).

Taking into account the possibilities of irrigation and the limitations of crop production caused by local soil and climatic conditions the absolute maximum production, expressed in grain equivalents of a standard cereal crop, is computed as 49 830 million tonnes per year. Since the average production in recent years has been of the order of 1 300 million tonnes, the postulated production potential is nearly 40 times the present level of production. In other words, we are now exploiting only 2.5 per cent of the absolute maximum potential. It is of course not possible to use all the available land only for growing food crops. The maximum production from the approximately 65 per cent of the cultivated land now used for cereal crop production, could be 32 390 million tonnes or 30 times the present production. Buringh et al. /6/ further consider South America and Africa south of the Sahara as the most promising regions for future food production. They consider Australia to be the least promising. Buringh and van Heemst /7/ have also stressed the need for greater attention to productivity improvement and increased land use intensity rather than to reclaiming large areas of land which may have adverse ecological consequences.

Table 1

Totals of the production potential of continents and the world

	A	PAL	IPAL	MPDM	PIAL	IPALI	NPDMI	MPGE
S. America	1 780	616.5	333.6	25 224	17.9	340.7	25 710	11 106
Australia	860	225.7	74.2	5 297	5.3	76.1	5 462	2 358
Africa	3 030	761.2	306.5	24 162	19.7	317.5	25 115	10 845
Asia	4 390	1 083.4	433.5	24 966	314.1	581.6	33 058	14 281
N. America	2 420	628.6	320.0	15 443	37.1	337.5	16 374	7 072
Europe	1 050	398.7	233.1	8 289	75.9	247.1	9 653	4 168
Antarctica	1 310	0	0	0	0	0	0	0
Total	14 840	3 714.1	1 700.9	103 381	470.0	1 900.5	115 372	49 830

Legend:

A	Area of a broad soil region (10^6 ha)
PAL	Potential agricultural land (10^6 ha)
IPAL	Imaginary area of PAL with potential production without irrigation (10^6 ha)
MPDM	Maximum production of dry matter without irrigation (10^6 tonnes/year)
PIAL	Potentially irrigable agricultural land (10^6 ha)
IPALI	Imaginary area of PAL with potential production, including irrigation (10^6 ha)
MPDMI	Maximum production of dry matter including irrigation (10^6 tonnes/year)
MPGE	Minimum production of grain equivalents, including irrigation (10^6 tonnes/year)

It is obvious that the figures in Table 1 have to be regarded as highly generalized indicators of the potential for progress. Land will continue to go out of farming as the demand for land for homes, factories and communication increases. More and more soil will be used for brick making. On the other hand, an inexpensive system of solar desalination of water can open up new vistas in production in many coastal and arid areas, including the Australian hinterland. While there are unpredictable trends in the future of agriculture, recent scientific advances, popularly termed as the "Green Revolution" technology, have aroused an awareness of the vast untapped production reservoir existing in most farming systems even at current levels of technology. It is, hence, not surprising that at several international conferences, the view has been expressed that, given a proper blend of political will and professional skill, the problems of hunger and malnutrition can become problems of the past. The World Food Conference (WFC) held in Rome in 1974 even set 1984 as the deadline for achieving the objective of ensuring that no child, woman, or man goes to bed hungry, and that no human being's physical and mental potential is stunted by malnutrition. Nearly 40 per cent of the time set by WFC for accomplishing this goal has elapsed, but all available statistics show that the number of persons going to bed hungry may in fact be increasing /8, 9/. According to recent Food and Agriculture Organization (FAO) statistics /9/, a calorie gap of 230 000 million calories per day or the energy equivalent of 37 million tonnes of wheat per year exists in the most seriously affected (MSA) countries from the point of view of minimum nutritional requirements. It would hence be useful to analyse the current world food situation, trends in demand and supply, factors responsible for instability in production and the steps needed to achieve the WFC goal.

2. The current world food situation

Several international and national agencies, particularly the Food and Agriculture Organization of the United Nations, the International Food Policy Research Institute (IFPRI) and the US Department of Agriculture have been issuing from time to time reports on the world food situation /9, 10, 11/. Based on these documents, the situation on the food production front can be summarized as follows.

World production of cereal grains (about 1 200 million tonnes) needs to expand by about 25 million tonnes per year to meet rising demand, since population increases by about 75 million annually, and one tonne of grain feeds on an average three people. In 1972, however - for the first time in twenty years - world output actually declined by about 33 million tonnes because of adverse weather. (Since 1972, output has fluctuated - rising in 1973, declining in 1974 and rising again from 1975 onwards /7/.)

World food demand is expected to grow at a rate of about 2.4 per cent a year until 1985, while the production growth rate is expected to average about 2.5 per cent a year. In the developing countries, however, the anticipated increase in demand is 3.6 per cent. These projections are based on past trends and exclude serious crop failure, major changes in government policies or relative prices and qualitative improvement in diets.

Since demand in the developing countries continues to grow faster than production, the deficit of cereals is expected to increase from an average of 16 million tonnes per year from 1969 through 1972 to around 85 million tonnes per year by 1985. This prospect is made all the more awesome by the fact that the average cost per tonne of cereals has more than doubled in the last few years.

In 1972, even before the oil-price rise and the related fertilizer-price increase, world cereal prices rose steeply. In spite of good 1973 harvests, prices reached even higher levels by early 1974. Although these increases were offset to some extent by greater earnings from exports, the profits were unevenly shared; the countries that suffered the most gained the least.

Before World War II, Asia, Africa and Latin America, as regions, were net exporters of foodgrains. During the period 1934-38, an average of 12 million tonnes of cereal grains used to be exported from these regions. However, largely due to a rapid increase in population size, these regions became importers of food. The annual imports were of the order of 5 million tonnes during 1948-52. This figure became 19 million tonnes in 1960, 36 million tonnes in 1966, 47 million tonnes in 1973 and 60 million tonnes in 1975.

As a result of these developments, increased numbers of people, now totalling an estimated 25 to 30 per cent of the population in Africa and South Asia, suffer from malnutrition or undernutrition. Malnutrition appears to affect around 460 million people in the developing world, and this is a conservative estimate. Even in countries with a substantial grain reserve, like India, inadequate purchasing power arising from unemployment and under-employment results in undernutrition among the economically handicapped sections of the community. In several MSA countries, emergency situations arising from national calamities like flood and drought aggravate problems of unemployment and undulations in production. Hence, direct State intervention in organizing food and health relief operations often become necessary. Guidelines are now available for organizing such relief measures effectively /12/.

3. The challenge for the future

As for the future, the following projections were made by the International Food Policy Research Institute (IFPRI) in December, 1977 /10/.

> "Longer term food prospects in food deficit countries with developing market economies remain unfavourable, despite good crops during the last two years. Under the conditions assumed in this study, production of staple food crops in these countries would fall short of meeting demand in 1990 by 120-145 million tonnes. This is over three times the shortfall over 37 million tonnes in the relatively good production year.
>
> The core of the food problem is the low income food deficit countries in which the per capita GNP in 1973 was less then $300. These countries have almost two-thirds of the total population of the developing market economies (DMEs). Their food deficit is projected to rise from 12 million tonnes in 1975 to 70-85 million by 1990. Just to maintain consumption at the 1975 per capita level would require 35 million tonnes more than the projected production."

The most recent comprehensive survey on the world food problem is by FAO /9/. The Survey clearly brings out that there is a widening gap in per capita food production between the developed and developing countries (Figure 5). Data on the average annual rates of growth of food production in relation to population are given in Table 2.

In its agricultural commodity projections for 1970-1980, FAO had concluded that world production of cereals is likely to exceed projected demand in 1980 by a margin of 62 million tonnes. However, the study also concluded that in 1980 there could be no substantial reduction in the absolute numbers of people suffering from undernutrition /9/. The projections of USDA /11/ also suggest that the world is capable of producing enough grain at reasonable prices to meet the demands of a largely cereal diet in the developing world. Why should food grain surplus and hunger co-exist? This question is most relevant to the most seriously affected (MSA) countries, which account for about 50 per cent of the total population of the developing world, and show a steady decline of per capita availability of food and the dependence by a majority of the population on agriculture for employment and income.

The Fourth World Food Survey /9/ indicates that in MSA countries there is need for a minimum growth rate of 4 per cent per annum in food production between 1974 and 1990, in order to provide 2 500 calories per head per day. This would call for a doubling of current growth rates in food output in MSA countries.

Table 2

Percentage annual growth of population and food production

Region	Population		Food Production			
			Total		Per capita	
	1961-70	1971-76	1961-70	1970-76	1961-70	1970-76
All developed countries	1.0	0.9	2.4	2.3	1.4	1.4
All developing countries	2.3	2.3	3.1	2.7	0.7	0.3
World	1.9	1.9	2.7	2.4	0.8	0.5

4. Aquatic production

Before considering how this challenge can be met, it would be useful to consider the trends in aquatic productivity, since with growing pressure of population on land, the fisherman and the sea will have to receive as much attention as the farmer and the soil. This will be particularly true for countries with a long coastline, since with the declaration of a 200 mile "Exclusive Economic Zone", the ocean surface available to them for scientific management and use may be substantial. For example, the area of the ocean space available to India under the "Exclusive Economic Zone" principle would be about 2 million km^2 as compared to the total land area of 3.28 million km^2.

According to the recent FAO projections issued in June, 1978 /13/, the current position with regard to world fisheries production and consumption is as follows.

Since 1971 the rate of growth of world fisheries production has declined sharply. In the fifties it grew at almost 7 per cent per annum, in the sixties at a little under 6 per cent but in the seventies the rate of increase has fallen to less than 1 per cent. The principal cause of this decline has been the collapse of a number of important fisheries exploited largely for the production of fish meal and oil. Among these, the most important has been the southeast Pacific anchoveta fishery which in 1976 yielded some 4 million tonnes compared with 12 million tonnes in 1970, but other fisheries, e.g., the Atlanto-Scandian herring, of less absolute size have shown similar proportional declines. Total landings of fish for reduction delivered to fishmeal plants which reached a peak of 26.5 million tonnes in 1970 had by 1973 declined to 18.5 million tonnes and although production has since recovered, it is well short of the 1970 level.

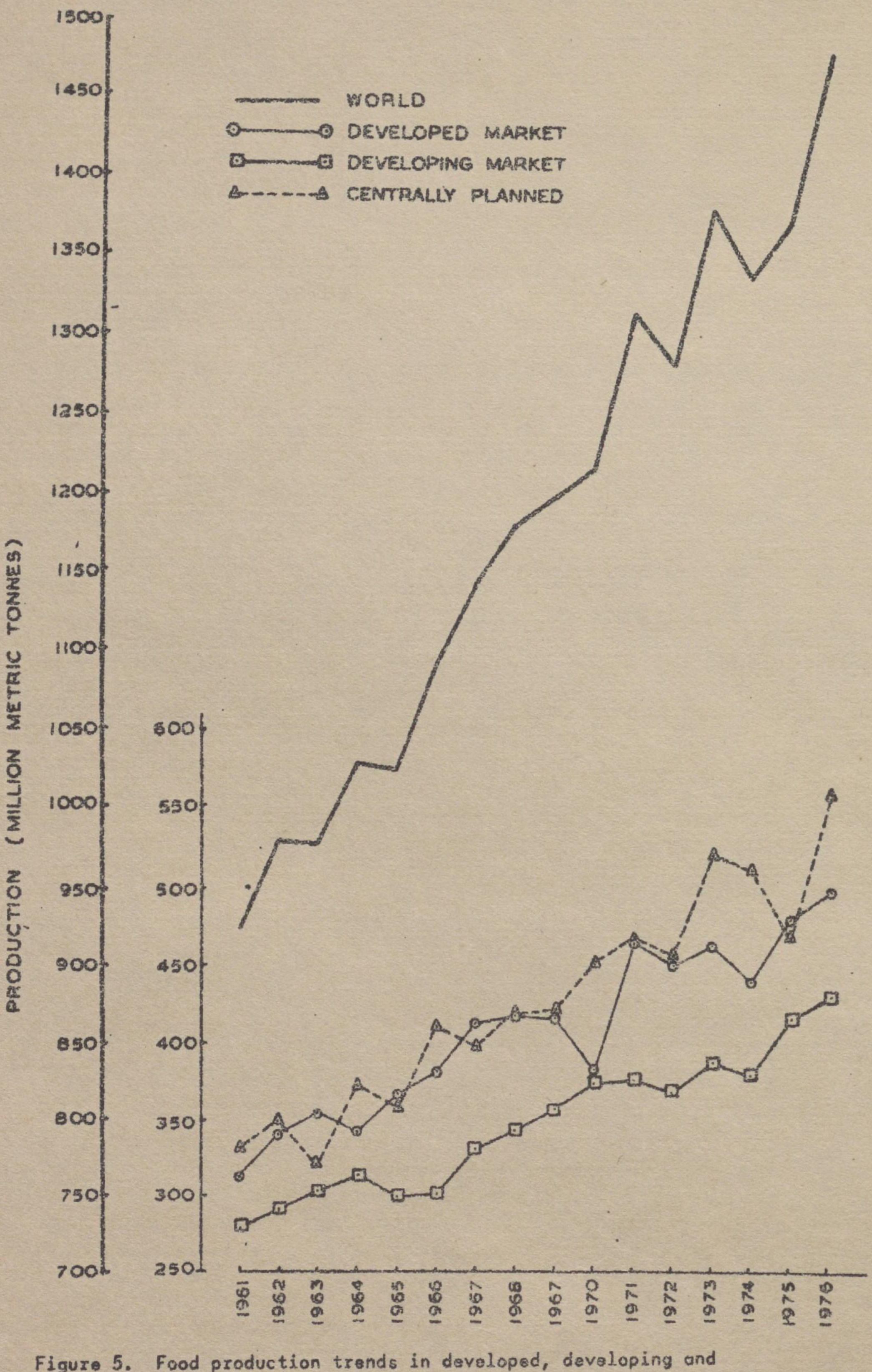

Figure 5. Food production trends in developed, developing and centrally planned countries. Source: FAO Production Year Books 1972 to 1976.

Landings of food fish destined for direct human consumption have by contrast continued to increase throughout the seventies, but even here the rate of growth at 2.5 per cent per annum has declined from that achieved in the 1960s. The basic cause of this decline, as in the case of the reduction fisheries, is the growing number of stocks becoming fully exploited and the rapidly shrinking opportunities for the diversion of fishing effort to new species or areas. Thus in many developed countries where technological innovation led early to the heavy exploitation of stocks in adjacent waters (e.g., the North Atlantic) there has been little or no increase in food fish production. Growth has come mainly from Japan and the U.S.S.R. (and other eastern European countries) which have increasingly had to rely on long-distance operations. There has also been steady growth in the developing countries, both from long-distance operations and from local resources often exploited by less intensive methods than employed in northern temperate waters.

Much of the effort in the developing countries has, however, been directed toward export fisheries (tuna, shrimp, etc.) and thus supplies available for direct human consumption in these countries have risen less rapidly than production. In the sixties <u>per capita</u> intake in this group of countries as a whole rose by about half a kilogramme and in the first half of the seventies by a further 200 grammes. In the developed countries there has been a marked difference in the experience of eastern Europe and the U.S.S.R. where <u>per capita</u> consumption rose by some 9 kg in the sixties and a further 3 kg in the first half of the seventies, and the countries of western Europe and North America where consumption has stagnated. Of the other developed countries, only in Japan and Spain has there been any significant increase in <u>per capita</u> fish consumption in the past decade.

In contrast to the actual fish harvests, theoretical estimates of potential productivity at various trophic levels reveal a vast untapped production reservoir. For example, the total fish biomass for the world as a whole has been put at 640×10^6 tonnes, assuming that the harvest is taken at the second stage of carnivores with a 15 per cent ecological efficiency factor. The krill resources alone have been estimated to range between 750 and 1 350 million tonnes with an annual harvestable yield of 100 to 150 million tonnes from the Southern Ocean. Out of this, only about 20 000 tonnes are being harvested.

In addition to the potential for capturing additional quantities of fish through improved technology, there is vast scope for culture fisheries both in inland and coastal waters. Modern fish farming techniques are as exciting as recent developments in crop or animal husbandry. By appropriate integrated strategies of capture fisheries, the availability of fish products both for human and animal consumption can be increased considerably.

5. <u>Impact of the plant-animal-man food chain on world food needs</u>

According to FAO statistics /9/, animal products contributed about one-third of the <u>per capita</u> calorie supply and more than half of the protein in the diet of the population of developed countries. The share of animal products in the diet of the consumers of developed countries is still rising (Table 3).

Table 3

Percent contribution of various food groups in daily calorie supply, per capita basis (per cent)

Regions	Vegetable products				Animal products			
	Cereals		Total		Milk		Total	
	1961-63	1972-74	1961-63	1972-74	1961-63	1972-74	1961-63	1972-74
Developing Market Economies								
MSA countries	64.6	65.8	93.9	93.8	3.1	3.2	6.1	6.2
Non-MSA countries	50.5	51.6	89.6	89.7	2.9	2.8	10.4	10.3
Developed countries								
Developed Market Economies	31.0	26.4	67.9	66.6	9.0	8.6	32.1	33.4
World	50.2	49.4	82.7	82.6	5.0	4.7	17.3	17.4

Source: FAO The Fourth Food Survey - 1977. Note: MSA = most seriously affected.

The plant-animal-food chain is also important among developing countries in Latin America, the Near East and parts of Africa. In contrast, this chain provided only about 6 per cent of total calories and 14 per cent of protein in the MSA countries. This is to be expected since grain consumed directly by people provides two to five times the calories it would if converted to livestock products and then consumed. In countries with high average meat consumption as in U.S.S.R. nearly 1 tonne of grain may be needed to feed one individual in a year in contrast to the global average of 1 tonne per three persons. In India, nearly 6 persons survive on one tonne of grain. Thus, although the plant-animal-man food chain may have some nutritional advantages (and also some disadvantages arising from over-consumption of fats), it is expensive in terms of total grain and energy needs (Figure 1).

Due to a positive correlation between affluence and the consumption of animal products, about 30 per cent of the world population in developed countries uses about two-thirds of the world grain supply. About 60 per cent of this quantity is used as livestock feed. In 1976, about 480 million tonnes of grains were fed to livestock. This quantity is more than the total food grain consumption by the human population of China and India taken together. In fact, the total amount of cereals used as human food in all developing countries was only 37 million tonnes more than the amount of 480 million tonnes of cereals used as animal feed in the world.

6. Trends in demand for food

The demand for food is influenced by factors such as population and income growth, the level and distribution of income and the proportion of income spent on food.

6.1 Population growth

The total world population was about 3.8 billion in 1973. The annual increase, at present, is about 70 million people, nearly double what is was in 1950.

Food demand as well as economic development are affected by the striking differences in the rate of population growth between the rich and poor nations. The population growth in the developed countries has declined to about 0.9 per cent annually. In contrast the population in the less developed economies is expanding at a rate of more than 2.5 per cent. At present, 70 per cent of the world's population live in the developing countries. These countries account for 86 per cent of the increase in world population. In 1960, the developing countries had about twice the population of the developed countries but because of rapid population growth they will have three times as much by 1985. The rate of growth in population will hence be a major determinant in finding an equilibrium between demand-supply equations in food output.

6.2 Income and demand for food

As income rises, the consumer buys more food, but a smaller proportion of income is spent on food. However, income is rising throughout the world at different rates. As a result of population and income growth, world demand for food grains increased at a little less than the rate of expansion in food production for several years prior to 1972. In rich nations, the growth in demand was due, mainly, to the growth in incomes, and the demand for grain was relatively higher because of low prices during the latter part of the 1960s. A rapid growth in income also generated demand for livestock products particularly in developed countries. In the developing countries, population expansion is the major factor for increasing demand for grain.

Income elasticities expressed as the ratio of the percentage increase in consumption of a given food to a percentage change in income for a few selected countries and the world as a whole are given in Table 4.

Table 4

Income elasticities for selected food

Food	India	Brazil	Japan	US	World
Wheat	.50	.40	.10	-.30	-.24
Rice	.40	.20	-.10	.20	.23
Maize	-.10	-.30	-.50	-.10	.10
Meat	1.17	.48	.79	.24	.32
Total Food	.43	.19	.13	-.01	.10

A smaller proportion of the food budget is allocated to cereals by the consumers of developed nations. The income elasticities of livestock product are relatively higher. This is an indication of the growing indirect consumption of grains to which a reference has been made earlier.

The future demand for food for a large part of the world's population will continue to be a problem of grain's availability and its price. The likely world demand for cereals as suggested by Aziz is given in Table 5.

Table 5

World demand for cereals 1970 actuals, 1980 and 2000 projected

	1970			1980			2000	(metric tonnes)	
	Food	Feed	Total*	Food	Feed	Total*	Food	Feed	Total*
Wheat	215.7	69.4	332.5	253.2	93.7	403.7	368.8	152.6	601.3
Coarse Grain	142.8	384.4	566.0	172.3	465.8	733.7	252.8	780.1	1186.6
Rice	270.0	4.6	310.0	346.7	8.2	400.1	543.5	20.6	633.0

* Total includes other uses also.

6.3 Availability of food

The Fourth World Food Survey of the Food and Agriculture Organization observed that the average quantity of calories available on a per capita basis for the years 1961-63 through 1972-74 in the developed countries was high throughout the period. This was 23 to 31 per cent more than the actual requirements. For the developing countries, it had also risen, but from a lower base, and was inadequate in relation to requirements. However, the trends in these countries were dissimilar. The increase in the availability was only marginal in the 1970s in the Near East and Latin America and a decline occurred in Africa and the Far East /9/. The situation is unfavourable in the MSA countries where the calorie supplies on a per person basis were reduced in 1970-74 to a level of 2 030 from 2 040 in 1961-63. On the other hand in the non-MSA developing countries there was an increase of 7 per cent /9/.

The World Food Survey further indicates that the availability of protein witnessed a relatively larger gap in the developed and developing countries. In the developing regions as a whole, the per capita supply of protein was only 58 per cent of that in the developed world. Moreover, this proportion remained more or less unchanged during the entire period. The lowest level was noted for the Far East and the highest in Latin America and the Near East.

The supply of protein in MSA countries was 11 per cent less than that in non-MSA countries 1972-74. The developed nations had greater availability of proteins of animal origin, while the level of plant protein was similar in both groups of nations. However, the proportion of animal protein in the case of developed countries showed a rising trend whereas in the case of poor countries it remained stationary at one fifth (Table 6). In the case of availability of fats, it was reported that the developed countries had more than three times more fat compared to developing countries in 1961-63. This ratio rose to three and half times in 1972-74.

Table 6

Per capita daily food supply in terms of protein (Grams)

Region	Total Protein		Animal Protein	
	1961-63	1972-74	1961-63	1972-74
Developed Countries	90	95	48	56
Developing Countries	53	57	11	12
World	65	69	22	24
MSA Countries	53	51	7	7

6.4 Composition of food supplies on a per capita basis

Food supplies in the developing world, in general, are inadequate in relation to energy requirements. The composition of diet also reflects the lack of diversity. According to the Fourth World Food Survey of the FAO, cereals contributed about half of the total calorie intake on a *per capita* basis in the world. During 1961-63, an average person in the developed countries had 36 per cent cereals in his diet. On the other hand, cereals provided about two thirds of the calories in the MSA developing countries.

The Food Survey further indicates that "maximum reliance on cereals as a source of dietary energy was in Far East and the Near East regions; and the minimum in Latin America. During the period under review, the importance of cereals as a major component of diet was steadily declining in the developed countries partly due to the growing share of meat. On the other hand, dependence in the Far East on the cereals as a source of calorie supplies rose slightly between 1961-63 and 1972-74, mainly due to shrinkage in the availability of pulses, nuts and seeds" /9/.

It is now widely accepted that in areas where a cereal is a staple, under-nutrition may be the primary cause of malnutrition /14/. In contrast, in areas where cassava or sweet potato is the staple, inadequacy of proteins in the diet may be a serious problem. It is in such areas that Kwashiorkor in children is widely noticed. In cereal based diets, Marasmus arising from calorie deprivation is relatively more common.

7. Achieving equality in distribution

As pointed out earlier, there are wide disparities in the consumption of both plant and animal products in the developed and developing countries. Also, there are considerable differences in the quality and quantity of food consumed within each developing country, based on the extent of prevalence of economic and ethnic disparities. Inadequate purchasing power rather than non-availability of food in the market may be the primary cause of undernutrition even in many MSA countries. Hence, reducing the degree of inequality in food distribution should receive as much attention as accelerating food production. An important requirement in this context is a strategy for generating more opportunities for gainful employment in rural areas.

7.1 Unemployment as a key factor in under- and malnutrition

Economists estimate that for every 1 per cent growth in the labour force, a 3 per cent rate of economic growth is required to generate jobs. With current technology, countries experiencing a 3 per cent rate of population growth therefore require a 9 per cent rate of economic growth just to maintain employment at its current level. A much higher growth rate will be needed to achieve full employment. Unfortunately, economic growth rates have been falling during the seventies /15/. Since agriculture is the major source of employment in many developing countries, agricultural policies will have to aim at creating more jobs and income in addition to more food.

Looking at the developing nations as a whole, the International Labour Organization (ILO) estimates that 24.7 per cent of the total labour force was either unemployed or underemployed in 1970. The comparable figure for 1980 is expected to rise to 29.5 per cent. Yet, the labour force in the less developed nations is projected by the ILO to expand by 91 per cent between 1970 and the end of the century, nearly doubling within the span of a single generation. The labour force in the more developed regions is expected to increase by only 33 per cent during this period (Table 7).

Table 7

Projected growth in world labour force, 1970-2000*

	1970 (millions)	2000 (millions)	Additional jobs required (millions)	Change 1970-2000 (per cent)
More developed nations	488	649	161	+33
Less developed nations	1 011	1 933	922	+91

* Source: ILO (cited in reference /15/)

Further aggravating the problem, the number of persons requiring non-agricultural employment in developing economies will increase from 342 million in 1970 to a projected 1 091 million in the year 2000, a staggering increase of 219 per cent in one generation. Few, if any, developing countries have the kind of investment capital needed to generate new jobs at such a fast pace. Thus, a massive effort is needed to generate jobs both in the agricultural and non-agricultural sectors. The vast dimensions of this problem and the lack of adequate resources for the effective utilization of the available manpower necessitate the development of employment generation policies based on the scientific utilization of local resources. Without such an approach it will be difficult to initiate self-replicating and self-propelling systems of rural development.

Depending on the extent and quality of unemployment, technologies appropriate to the socio-economic conditions of each country should be developed and disseminated. A good example of appropriate technology under conditions of rural unemployment and underemployment is the development of hybrid cotton in India based on seed produced by hand emasculation and pollination. A one-hectare hybrid seed production unit in cotton may provide jobs for 80 women for 100 days. Creation of opportunities for gainful employment of women is particularly important since rural women tend to remain underpaid or unpaid for most of the jobs they currently perform.

7.2 Impact analysis

In view of the linkages among poverty, unemployment and hunger, there is need for subjecting all developmental projects to impact analyses from the ecological, economic, employment and nutritional viewpoints. The criteria used for measuring the likely social impact of a new technology must include employment. It is also essential that the impact analysis is designed to measure the implications of new projects on the economic and nutritional well-being of women and children, if the goal of ensuring their physical and mental potential is not to be frustrated by malnutrition. An impact analysis of this kind can help to correct distortions in priorities which may arise if human needs are overlooked. For example, supplies of fish available for direct human consumption in several MSA countries have remained practically stagnant, while exports of fish products have grown.

8. Risk and uncertainty in food production

The three major factors which influence variations in yield and food production are weather, pest epidemics and public policies.

8.1 Impact of weather on terrestrial and aquatic productivity

According to an analysis of the U.S. Department of Agriculture /11/, there is a positive correlation between the effects of weather in one place and those in another. An analysis of yield trends and variations in 25 regions covering the world's major grain producing areas indicates that when grain yields decline because of adverse weather in one part of the world, the chances are better than even that they will be lower in many other parts of the world too. Unfavourable weather conditions played a dominant role in causing major declines in food production in 1964-66 and 1972-74. Conversely, good weather tends to be experienced also at the same time in many parts of the world. However, the analysis did not reveal the existence of weather cycles or trends during 1950 to 1973.

8.2 Variation in yield caused by weather factors

An analysis of variation in grain yield in several parts of the world during 1950-73, showed that the weather in one year out of three could be expected to produce a deviation greater than 21 million tonnes from trend production in the 25 regions studied (Table 8).

Table 8

Changes in grain production due to weather in
25 major world grain producing regions
(data from reference /11/)

Grain	Without covariation (1) (million metric tons)	With covariation (2) (million metric tons)	Per cent difference
Wheat	11.59	13.28	+15
Rice	4.58	4.81	+5
Corn	5.68	6.24	+10
Barley	5.13	5.42	+6
Oats	1.95	2.23	+14
Sorghum-millet	2.06	2.23	+8
Rye	0.91	1.03	+13
Coarse grains (incl. rye)	8.22	10.04	+22
All grains (incl. rice)	14.74	21.08	+43

(1) Assumes that yield fluctuations are not related

(2) Includes interrelation between yield fluctuations

There has been considerable interest in recent years on climate in relation to production, in view of reported changes in climatic trends. Several scenarios have been constructed. A recent study organized by the National Defense University of the United States, for example, considered five different possibilities including largely global cooling, moderate global warming, large global warming /16/.

The derived climate scenarios manifest a broad range of perceptions about possible temperature trends to the end of this century, but suggest as most likely a climate resembling the average for the past 30 years. Collectively, the respondents tended to anticipate a slight global warming rather than a cooling. More specifically, their assessments pointed towards only one chance in five that changes in average global temperatures will fall outside the range of -0.3 deg C to +0.6 deg C, although any temperature change was generally perceived as being amplified in the higher latitudes of both hemispheres. The respondents also gave fairly strong credence to a 20- to 22-year cycle of drought in the High Plains of the United States but did not agree on its causes.

The question of temperature change was also discussed in detail at a Conference held in Bellagio in Italy in June, 1975. The following conclusions were drawn /17/.

(a) Climate variability, region by region and from year to year in particular regions, is and will continue to be great, resulting in substantial variability in crop yields in the face of increasing global food needs and short supplies.

(b) There is some cause to believe, although it is far from certain, that climatic variability in the remaining years of this century will be even greater than during the 1940-1970 period.

The implications of the undulations in food production caused by climate have been examined at several international conferences. More recently, the climate-food output relationships have assumed importance in relation to the grain reserves necessary for building global and national security systems /18, 19/. Walters /18/ has stressed the need for utilizing the surplus wheat of some 40 to 50 million tonnes available during 1977-78 for building a grain reserve, either an insurance reserve of 20 to 30 million tonnes or a major stabilization reserve of 50 to 60 million tonnes. While the building of such grain reserves at the global, regional and national levels is exceedingly important for off-setting the shortages caused by weather aberrations, it is also essential that steps are taken to insulate agricultural fortunes from the vagaries of climate to the extent possible. The following are some of the major steps needed for this purpose.

8.3 Expanding the area under assured irrigation

Wherever possible, steps for increasing the area under assured irrigation should receive the highest priority. This is particularly important in the tropics and sub-tropics where (a) the rainfall distribution is often skewed, (b) the evapotranspiration rates may be high throughout the year and (c) the period of maximum insolation often coincides with the period of minimum precipitation. Without assured water supply, fertilizer application becomes risky and yields tend to remain low. In rice, which is the second major crop of the world, there is in Asia a strong positive correlation between the proportion of area under irrigation and average yield (Figure 6). In India, studies by the India Meteorological Department reveal that variation in climate resulting in drought, floods, high evapotranspiration, etc., may account for more than half the variation in the yield of crops. Also it is not just total rainfall but rainfall during critical stages in the growth of the plant such as the grain development phase that influences the ultimate yield. The stabilizing influence of irrigation was brought out by Chowdhury and Rao /20/, who studied the effect of climate change on wheat yield in the States of Punjab and Haryana of India over a 50-year period (1911 to 1960). Rainfall and mean daily temperature from December to February were examined in relation to the mean yield of wheat. There was a striking correspondence between rainfall and yield till about 1940. After 1940, the rainfall showed a falling trend but the wheat yield went up. This was attributed to the increase in the area under irrigation (Figure 7).

CORRELATION OF INTENSIFICATION OF FARMING AND YIELD OF RICE

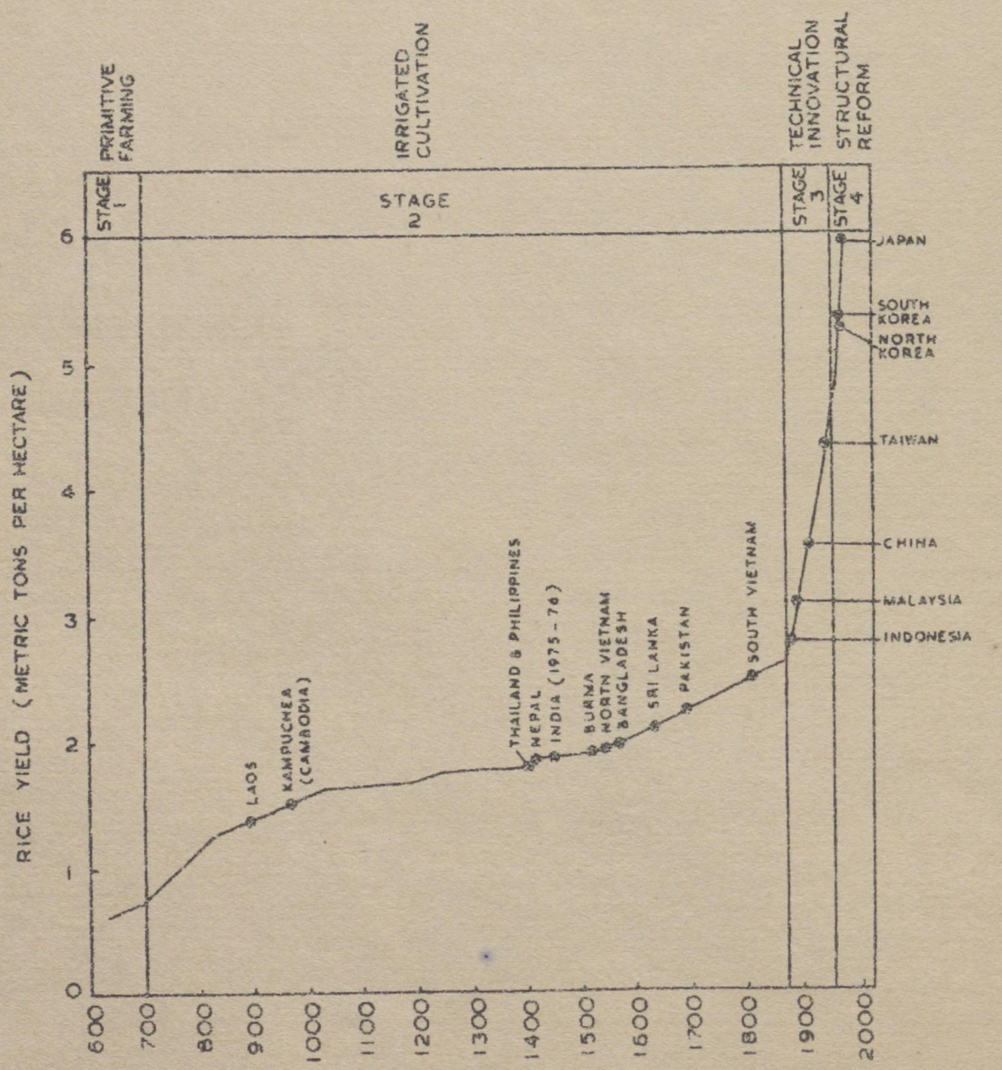

Figure 6. Yield of rice in different countries in Asia in relation to the historic progression in rice yield in Japan. (Source: Asian Agricultural Survey, Asian Development Bank, 1969, p. 520 "Development Strategy on Irrigation and Drainage", by K. Takase and T. Kano.

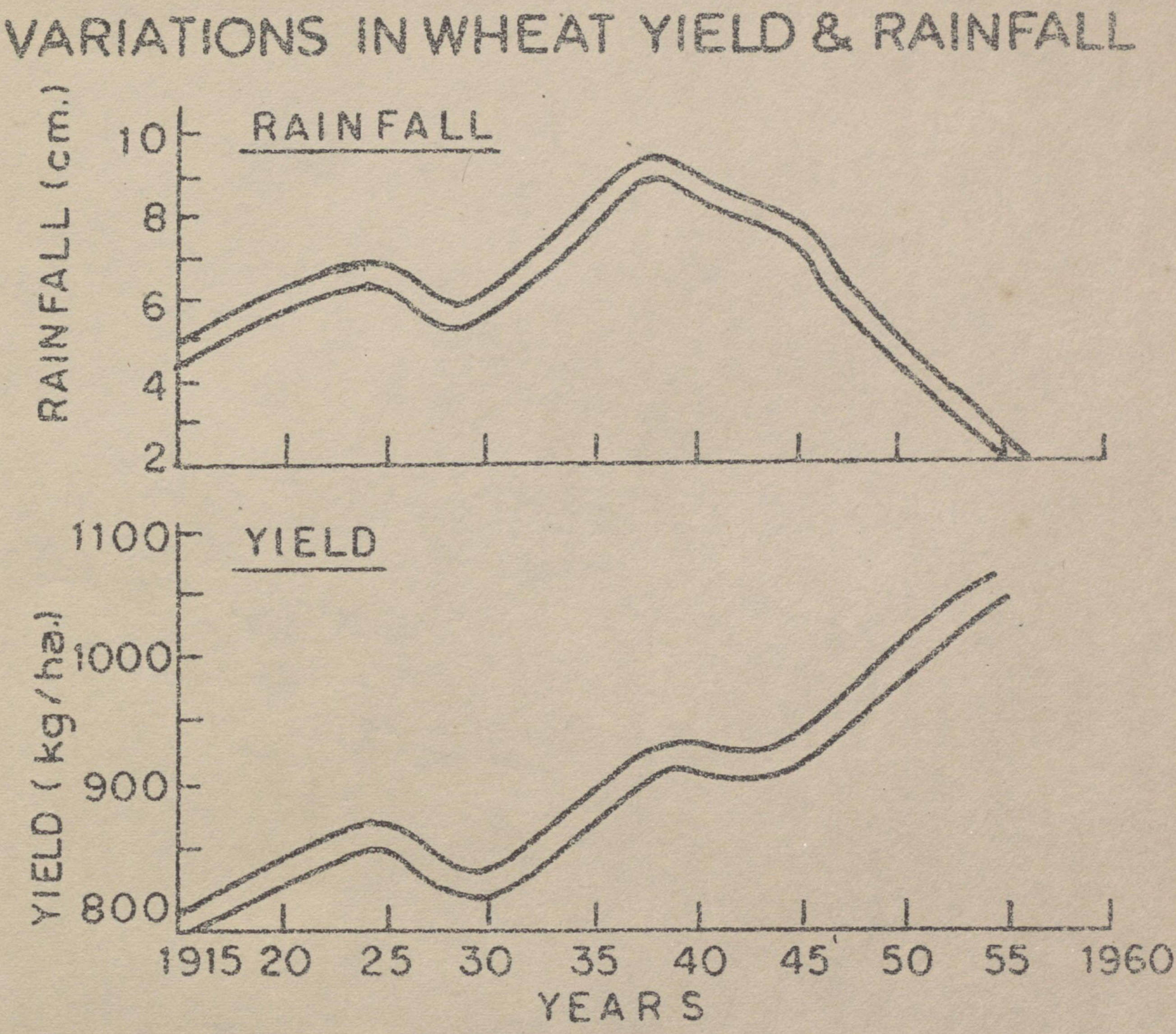

Figure 7. Relationship between rainfall and wheat yield in northwest India showing the impact of irrigation on enhancing and stabilizing yield /19/.

The availability of a large irrigated area also makes the initiation of additional production programmes in such areas in years of drought or floods possible. Such compensatory programmes in irrigated areas could form an important part of the strategy for minimizing the adverse impact of aberrant weather. The U.S. Department of Agriculture has computed the production needed to build adequate stocks in "good" years to maintain consumption in "bad" years /19/. This study also reveals that the largest potential for yield increases is in coarse grain, particularly corn and sorghum.

8.4 Minimizing fluctuations in production in rain-fed and semi-arid areas

The technological approach to imparting greater stability to production in rain-fed and semi-arid areas involves above all measures to conserve the available moisture under a given set of weather variables. By studying the rainfall pattern in detail, including the probable date of commencement of the sowing rain and the likely inter-spell duration between two rains, it is possible to develop more stable cropping systems taking into account the moisture-holding capacity of the soil and the evapotranspiration data /21, 22/. It is also possible to develop contingency plans and alternative cropping strategies to suit different weather probabilities in areas prone to drought and floods. To implement the contingency plans it will be necessary to build seed reserves of the alternative crops. In areas characterized by wide annual fluctuations in rainfall pattern, it is desirable to make the seed reserves necessary for implementing alternative cropping strategies an integral part of the national seed production and storage system /23/.

If surplus water can be stored in the watersheds of rain-fed areas, a crop life-saving irrigation can be given if the rainfall stops abruptly at the time of grain development; other crop life-saving techniques are also now available /24/. While the solution both to excess and shortage of water is largely an engineering one, genetic approaches are possible through the development of varieties possessing greater resilience to environmental variables. Thus, Ganga Prasad Rao and co-workers /25/ have shown that early maturing hybrids and varieties of sorghum do better during both scanty and abundant rainfall years. Early seedling vigour, hybrid vigour for root growth and quick maturity are attributes which confer on the plant stability of performance in drought prone areas. The cropping strategy for flood-prone areas will have to rely heavily on making the flood-free season the major cropping season.

When meteorologists are able to develop reliable early warning systems of monsoon behaviour, it will be possible to refine further the contingency plans for different weather possibilities and implement them more effectively. Through an integrated approach to efficient water and soil conservation and management in each watershed area, crop planning based on both yield and stability characteristics, introduction of crop life-saving techniques when necessary, and preparedness for introducing alternative land use strategies according to weather conditions, it is now possible both to elevate and stabilize crop production to a greater extent than was considered possible some years ago.

8.5 Fluctuations in production arising from pest epidemics

Besides weather aberrations, the incidence of pest epidemics has been a major factor in causing instability and risk in crop production. Both weather conditions favourable to the pest as well as man-made causes like unscientific crop planning, cultivation of large areas with a single strain of a crop and improper or inadequate plant protection measures can result in widespread pest epidemics. The following are some of the major famines or food losses associated with pest epidemics in the past:

(a) The Irish famine of the 1840s due to the potato leaf blight epidemic;

(b) The wheatless days of 1917 in the U.S.A. due to stem rust epidemics;

(c) The Bengal famine in India in 1943 associated with the Helminthosporium brown spot disease of rice;

(d) The devastation of all Victoria-derived oats in the mid 1940s in the U.S.A. due to a fungus causing the Victoria blight disease;

(e) The southern corn blight epidemic caused by Helminthosporium maydis on all U.S.A. maize hybrids carrying the T-type cytoplasmic male sterility during 1970-71;

(f) The rapid shift from brown planthopper biotype 1 to biotype 2 during 1974 to 1976 when large areas in the Philippines and in Indonesia were planted to a few semi-dwarf strains of rice;

(g) Downy Mildew epidemic in pearl millet caused by Sclerosphora graminicola in India in 1973.

Whereas uniformity within a crop leads to genetic vulnerability, reinstating genetic diversity is one of the most effective means in providing protection against such vulnerability [26]. On the other hand, the sequential release of resistant varieties based on major gene-controlled vertical resistance could lead to the "boom and bust" cycles. Hence, an integrated pest management strategy will have to be developed for each major crop and agro-climatic region. Studies on the relationship between weather and pest epidemics and the establishment of pest survey and surveillance systems at the national and regional levels (as for example, the FAO-sponsored Locust Warning System) can help in taking timely action against pest epidemics. Varietal diversification, gene deployment and other pest containment strategies can be very effective in the control of important diseases like wheat rusts. Satellite photographs of cloud movements also provide a basis for predicting the zone of early establishment of stem rust of wheat in India [27].

Countries in the tropics and sub-tropics face more serious pest problems since there are crops and vegetation through the year serving as alternate hosts to many pests. Also, temperature, sunlight and moisture conditions promote continuous multiplication of pests without interruption, unlike in the temperate areas where the severe winter is a restraining factor. This will be evident from the following comparison of the magnitude of disease problems in the temperate and tropical regions.

Tropical countries will therefore have to devote considerable research and development attention to insulate crops from severe devastation by pests. For developing reliable disease forecasting procedures, the integration of meteorological data with field survey data is essential. Such an approach could lead to other beneficial results. For example, healthy seed potato is now being produced in the plains of North India as a result of the finding that during certain months of the year aphids, which serve as vectors of several virus diseases, are absent [28].

Table 9

Crop disease in temperate and tropical regions

Crop	Number of Diseases reported: Temperate zone	Tropics
Rice	54	500 to 600
Maize	85	125
Citrus	50	248
Tomato	32	278
Beans	52	250 to 280

8.6 The role of public policies in ensuring stability of production

In the ultimate analysis, farmers grow food or other crops to earn income, in addition to satisfying their home needs. Hence, except in countries where land use planning is controlled by the State, farmers' choices of crops are largely based on the net returns per hectare as well as the extent of risk involved. High yield potential-cum-low risk crops will hence receive much greater acceptance than high yield potential-cum-high risk crops. To sustain agricultural progress at a desired level, it is necessary to support a package of economically viable technology with appropriate packages of services and public policies. Though the production technology associated with dwarf and fertilizer-responsive varieties of wheat and rice itself does not possess built-in seeds of social discrimination, small farmers will be able to derive economic benefit from such technology only if their inherent handicaps in mobilizing the necessary inputs and in taking risks are removed through the provision of appropriate services including credit. The public policy package will have to include appropriate land reform measures, integrated input and output pricing policies and effective marketing, storage and distribution.

Price incentives can stimulate rapid advances in production, as happened in Japan in the case of rice. However, unduly high grain prices will defeat the very purpose for which more food is produced, namely to feed the hungry. Hence, other compensatory benefits may have to be given to small farmers so as to enhance their income without making prices unreasonable to the consumer. Also, it will be desirable to develop an agricultural credit insurance system, which can protect farmers from weather risks such as hailstorms, typhoons, floods and drought. For developing an effective credit insurance programme for different farming systems, there will be need for joint research between meteorologists and agricultural scientists.

8.7 Constraints analysis

Another important contribution Governments can make to help farmers to realise full economic benefits from the untapped production reservoir which exists even at current levels of technology in the major farming systems, is to sponsor multi-disciplinary analyses of the constraints responsible for the gap between potential and actual yields. Some of the major groups of constraints which determine the size of gap are indicated in Figure 8. The relative importance of each component will vary from area to area and suitable weightages can be developed on the basis of a careful study. A study of this kind carried out by the International Rice Research Institute in several Asian countries has revealed the important constraints to high yields in rice /29/. Meteorologists, agronomists, economists and statisticians should undertake similar joint studies in all major farming systems. Recent estimates of the ultimate potential for increase of land area for agricultural use are summarized in Table 10. The data are from the World Bank report on Agricultural Land Settlement published in 1978 and summarized in Ceres /30/.

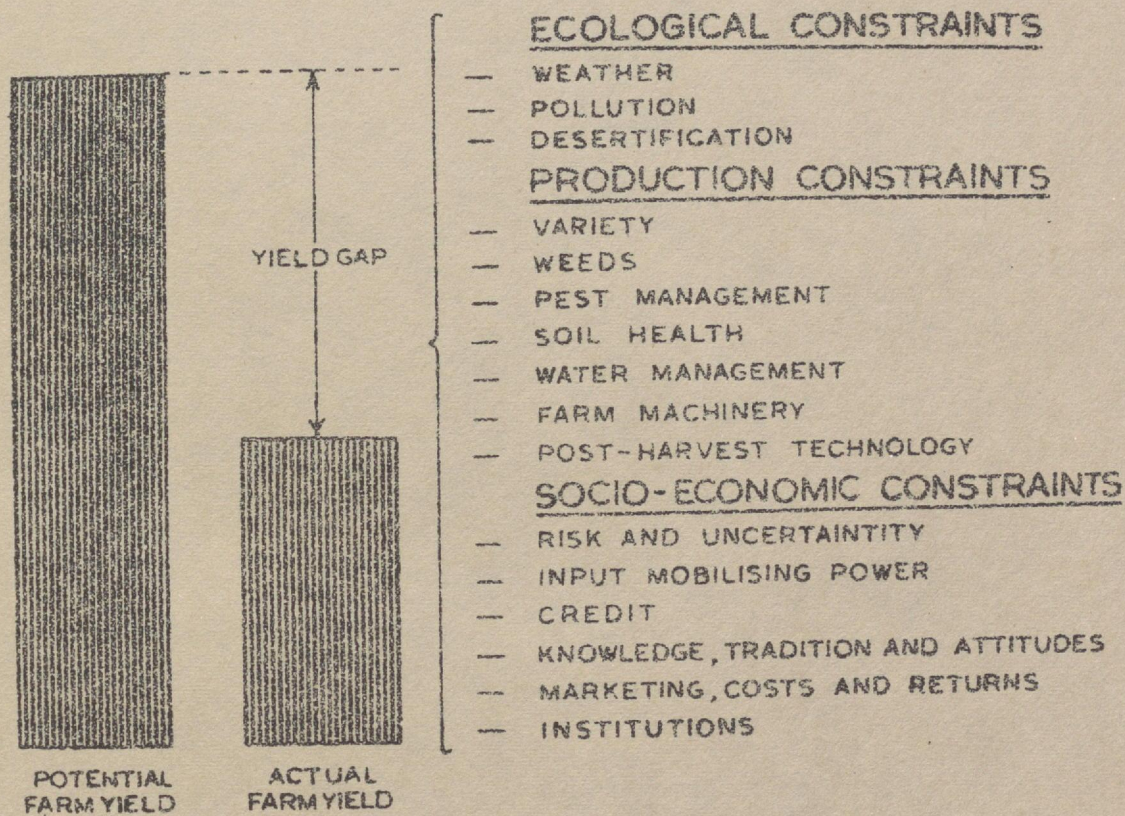

Figure 8. Major constraints causing a gap between potential and actual farm yield at current levels of technology in field crops.

Table 10

Potential for increase of land area for agricultural purposes (in '000 hectares)

Region	Land under agriculture in 1976	Estimated potential for increase	Percentage of world total potential for increase
North America	232 097)		
Western Europe	96 184)		
Eastern Europe and USSR	278 574)	181 43	18.04
Oceania	46 019)		
Africa	185 610	280 390	29.92
Latin America	143 568	442 432	44.06
Near East	81 062	30 938	3.08
Asian Centrally Planned countries	141 266	62 734	6.25
Far East	266 329	5 671	0.56

It will be observed from the data in Table 10 that some of the densely populated regions of the world like the Far East have very little scope for increasing the area under cultivation. Hence the only pathway of agricultural advance open to them is productivity improvement. For achieving this, data from constraints analysis will be very useful. Similarly, in areas with great potential for bringing more land under cultivation, as Latin America and Africa, an analysis of constraints and consequences (particularly from the ecological standpoint) will be helpful to the policy makers in arriving at priorities in investment.

8.8 Effect of climate on aquatic productivity

It is well known that the success of fish catch in any particular year depends on the effective recruitment during the previous seasons through proper spawning and survival of the young. The influence of climate on the breeding of many fishes in the tropics is seen from the spurt of spawning activity and a general increase in the number of fish eggs in the marine plankton soon after the first outbreak of the rains. Such intensive spawning associated with climatic changes is even more pronounced in freshwater fishes whose spawn occur in abundance during the floods. There is, however, need for intensive research on the relative role of different environmental parameters in determining the size of fish stocks if reliable systems of forecasting are to be developed. The quantitative relationship between temperature and fish yield also needs to be elucidated under different environmental conditions. Interrelated systems like the Peruvian anchovy and El Niño and the oil sardine and the monsoons in the Indian Ocean provide opportunities for multi-disciplinary research. (See also overview paper by Cushing.)

Besides research on the methodology for early warning and yield-forecasting services, it is necessary that more detailed knowledge is developed on the management of both ocean and freshwater resources. The scientific management of aquatic resources based on principles of ecology and economics is as important in fisheries as the scientific management of soil, water and air resources in crop and animal husbandry. If this is not done, aquatic desertification leading to the destruction or diminution of the biological potential of water caused by pollution, over-fishing and other man-made processes can occur.

9. Global food production: challenges and opportunities

9.1 Challenges

The relentless growth in population, particularly in poor nations, following rapid advances in preventive and curative medicine in recent years (Figure 9) poses the greatest challenge not only for producing the needed quantity and quality of food for the existing and expanding population, but also for generating the economic growth rate essential for full employment. Agricultural growth will have hence to be viewed not merely in terms of the production of certain quantitites of food but also in terms of employment and income generation in the rural areas.

Another major challenge is the preservation of the renewable nature of our renewable resources. This can be done only if the entire community in each country co-operates in ensuring that there is no depreciation in basic agricultural assets. Unfortunately, this awareness is yet to become widespread.

A third major challenge is in the area of energy supply and management in agriculture and aquaculture. Technologies will have to be developed and promoted which involve organic recycling principles and integrated approaches to pest management and nutrient supply. When solar power becomes economically attractive, new vistas in production can be opened up by combining the use of solar energy for a variety of purposes during the production and post-harvest phases with techniques like no-tillage or minimum-tillage and other methods of minimizing the energy input needs.

A fourth area of considerable significance is the development of crop-livestock integrated production systems. While livestock production has assumed importance in rich countries to meet the dietary preferences of people, the integration of animal husbandry with agriculture has become essential in many MSA countries since this is the only immediately feasible method of enhancing the income of small farmers and reducing under-employment among landless labour. How can this situation be reconciled with the much higher energy needs of the plant-animal-man food chain to which a reference was made earlier? Obviously, technologies of livestock management based on a complementary relationship between animal and man need to be developed. Mixed farming has always been a way of life with farmers in many developing countries. The ruminating animal is ideal for such a symbiotic production system, since all cellulosic material which cannot be digested by man can be suitably fortified and converted into nutritious animal food. Crop-livestock-fish integrated production systems offer even greater opportunities for achieving high energy input-output ratios /31/.

A fifth area of immediate relevance to the food problem is the initiation by governments of appropriate programmes for deriving benefit from the untapped yield reservoir existing at current levels of technology. This will call for massive efforts in education, organization of relevant services based on constraints analysis and above all, in introducing public policy measures which would stimulate both production and consumption.

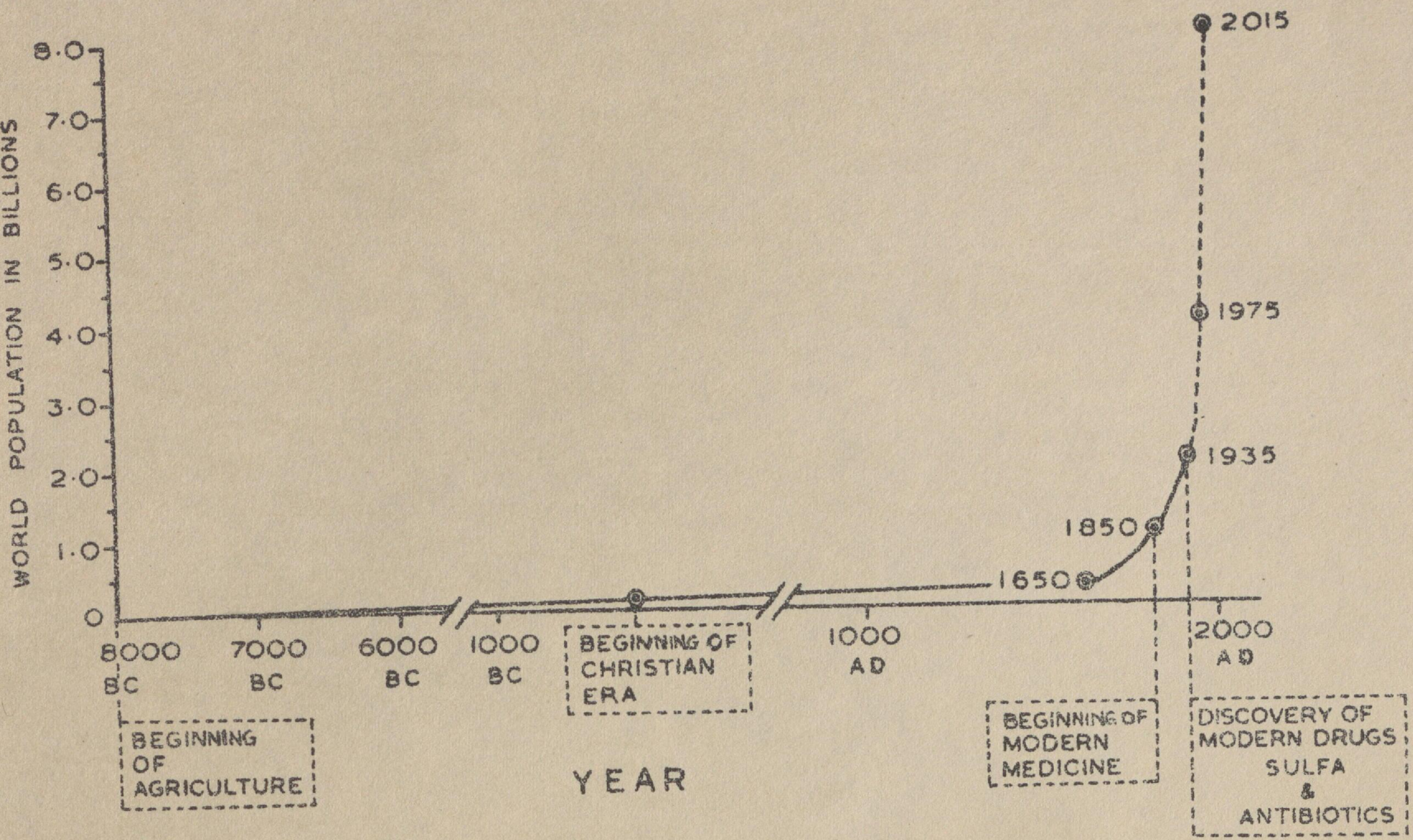

Figure 9. Trends in population growth

Finally, governments will have to grapple with the challenge of distribution. As would be evident from the data presented earlier, the world food production is sufficient to feed the millions who are malnourished today provided there is equitable distribution. The deadline of 1984 set by the World Food Conference for ensuring that no human being goes to bed hungry can be advanced even to 1979, if a new age of humanism can be superimposed on the era of science and technology. Unless this happens, global action to meet man's need for food, energy and other basics may not be forthcoming. Until all global planning for the future and all development of technology are subjected to the one test prescribed by Mahatma Gandhi, "Will this benefit the poorest men?", it is unlikely that an international food security system will come into existence (Figure 10). The prevailing condition where with every rise in Gross National Product, the poorest nations and income groups within nations suffer more due to the increased demand for food by wealthier nations and wealthier groups within nations can be altered only by public policies designed to bring about equitable distribution /32/. How can each nation proceed to build a national food security system which can insulate the people of the country from hunger arising from weather-induced crop failures and/or inadequate purchasing power?

9.2 Opportunities

While available projections of population, per capita income and demand for food on the one hand and production and marketable surplus of food on the other, reveal a possible global food gap of about 45 million tonnes by 1985, the encouraging sign is the growing awareness among developing countries that agriculture needs and deserves over-riding priority. National, regional and global efforts in agricultural research and development are growing. The Consultative Group on International Agricultural Research sponsored by FAO, UNDP and IBRD and supported by many nations, banks and foundations is financing a global grid of research centres designed to advance the pace of technology development in major food crop and livestock production systems in developing countries. Analysis of gaps and constraints in major crop production systems in several MSA countries has shown that while the gap between potential and actual farm yields is high, the constraints can be remedied fairly speedily. Global weather monitoring programmes sponsored by WMO are also making rapid progress and agro-meteorology is emerging as a major science. Yield forecasting techniques are being perfected. Weather satellites and remote sensing techniques have added a new dimension to research in this area. Hence, reliable early warning systems of likely food shortage can be developed if there is adequate international co-operation. The time is therefore appropriate for governments to launch a programme to build strong national food security systems. Once national food security systems are developed, it will be relatively easy to build an international food security system.

9.3 Components of a national food security system

The following are some of the major components of an effective national food security system:

(a) Ecological security;

(b) Technological security;

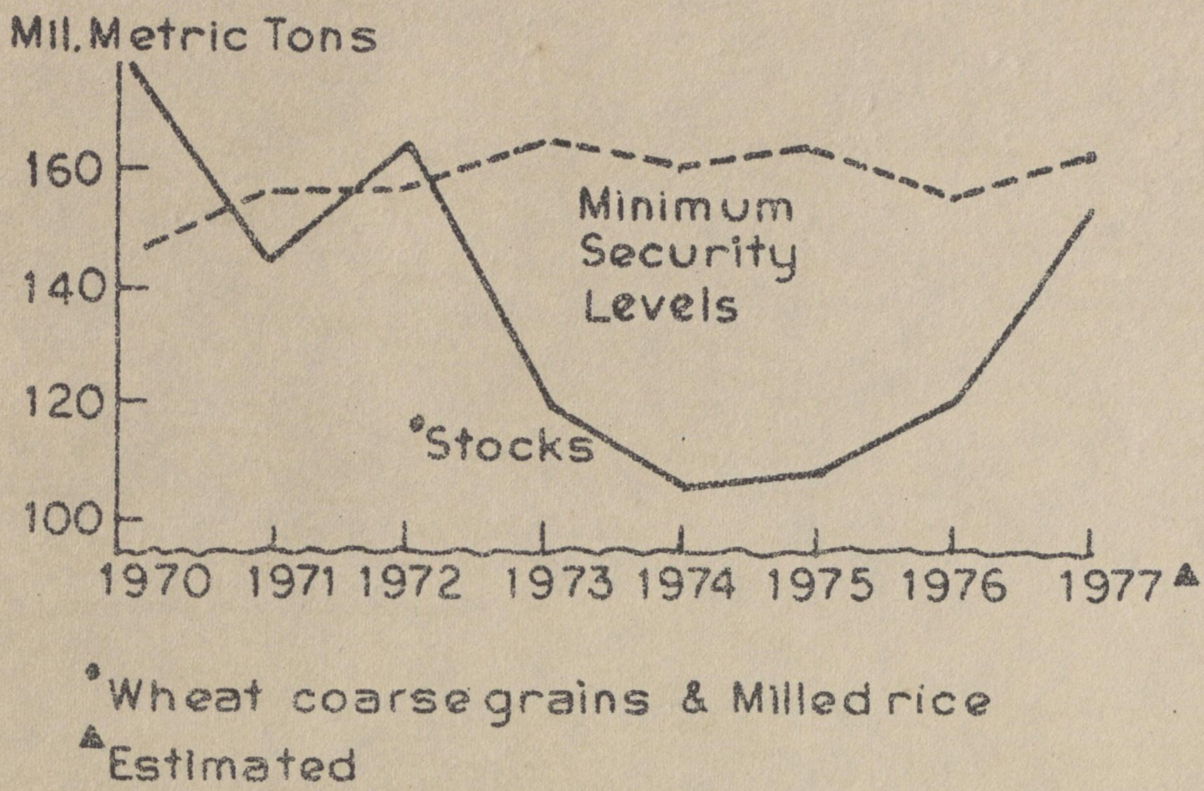

Figure 10. World carry-over stocks and minimum security levels (excluding U.S.S.R. and People's Republic of China) /18/.

(c) Building up food reserves;

(d) Social security.

9.3.1 Ecological security

If the ecological infrastructure necessary for sustained agricultural advance is not preserved and strengthened, desertification processes will damage both agriculture and aquaculture. Nothing should be done which will cause unfavourable changes in the macro- and micro-environment. To achieve this, there is need for a national movement in every country for promoting economic ecology /33/. Economic ecology, unlike strictly conservation ecology, is intended to maximize the economic benefits from a given ecological milieu and to minimize the risks and hazards characteristic of that environment. Guidelines for achieving ecological security along with agricultural progress will have to be drawn up by an inter-disciplinary team of scientists for each area.

9.3.2 Technological security

Technology development should be tailored to specific ecological, economic and social conditions. It should be ensured that the technology does not possess built-in seeds of social discrimination. The major aim of technology in countries with very little scope for bringing additional land under cultivation should be to increase continuously the economic yield per hectare of land or water surface without detriment to the long term production potential of soil and water. Also, productivity improvement has to be brought about without increasing heavily the consumption of non-renewable forms of energy. The improvement of yield should not also be at the cost of stability of production. Where the probability for weather-induced instability in yield due to causes like flood and drought is high, alternative cropping strategies and crop life-saving techniques should be developed to suit different weather models. Post-harvest technology should receive as much attention as production technology so that both the farmer and the consumer derive full benefit from the products marketed.

An area of technological security which has yet to receive adequate attention is the introduction of a systems approach in R and D efforts. The following are a few of the major farming systems which need attention particularly in countries where land is a limiting factor in expanding production:

(a) Multiple cropping systems in irrigated areas

It is possible to take 3 to 4 crops in the same plot of land in a year in the tropics and sub-tropics with photo-insensitive and quick maturing varieties of different crops. It is, however, necessary to pay adequate attention to the maintenance of soil health and fertility, prevention of pest build-up and grain drying and storage. Instances of liver ailments arising from aflatoxins in the grains of varieties which mature before the rains stop are growing.

(b) Rain-fed farming

Research programmes in semi-arid areas should lay stress on water and soil conservation and scientific land use planning. Detailed knowledge should be gathered on the likely date of commencement of sowing rains, inter-spell duration, evapotranspiration and moisture holding capacity of the soil.

(c) Orchards and garden land cropping

In the case of fruit trees, plantation crops and forest trees, it is possible to design an efficient 3-dimensional canopy involving both the horizontal and vertical spaces. An efficient canopy should promote co-operation among the crops grown together. Thus, in such areas the efficiency of farming will have to be measured by the effectiveness with which the air space is used in addition to soil and water. Since multi-level or 3-dimensional cropping is likely to assume increasing importance when the pressure of population on land increases (the situation being analogous to the spread of sky-scrapers in city architecture), intensive research on the micro-environment in 3-dimensional canopies is necessary. Coconut, cocoa and pineapple form a good co-operative combination from the point of view of efficient utilization of sunlight, water and nutrient in several tropical areas.

(d) Mixed and inter-cropping

In such systems, some of the factors promoting efficiency and stability of production are:

(i) efficient interception of sunlight;

(ii) ability to tap nutrients from different depths of the soil profile;

(iii) non-overlapping pest sensitivity; and

(iv) introduction of legumes for promoting biological nitrogen fixation.

(e) Kitchen gardening

This can take the form of growing vegetables and fruits, backyard poultry farming and home fish gardening. When designed properly, a very high return of food calories for every calorie of cultural energy invested can be obtained, thus making substantial contributions to the improvement of nutrition.

(f) Agro-forestry

In addition to promoting commercial, social and other forms of forestry, there is need for more research on inter-cropping in forest canopies. Agro-forestry is a sustainable management system for land which increases overall production, combines agricultural crops, forest plants and animals simultaneously or sequentially.

(g) Mixed farming

Mixed farming systems may involve crop-livestock, crop-fish, livestock-fish and crop-livestock-fish integrated production systems. These can be of great value to farmers with small land holdings for maximizing income and employment.

Plant and animal breeders should adopt a cafeteria approach in the selection of genetypes of crops and farm animals for the different farming systems referred to above. Production agronomists also should adopt a cafeteria approach in developing technologies suited for farmers with varying input-mobilizing capacity. Meteorologists should measure the impact of different weather parameters on the entire system and not just on components of it if their data are to be of use in designing more efficient systems. Farming System Meteorology will involve much greater attention to the micro-environment in crop canopies and to the matching of sequential use of land with weather conditions which are conducive to the optimum performance of the crops and animals farmed either concurrently or consecutively.

9.3.3 Building up food reserves

Every MSA country should try to build a grain reserve which can help it to meet the anticipated shortfall in a bad year as well as to run an effective public distribution system. Countries which are not normally self-sufficient in their food requirements will obviously have to maintain adequate stocks by imports so that in years when the production is adversely affected by weather in the traditional food exporting countries, prices are not allowed to rise abnormally. Every country will have to devise an appropriate grain reserve policy based on ecological, economic, logistic and other considerations. The reserve may not be only of cereals but may include millet, grain legumes, oilseeds and other crops depending on needs and availability. Such a buffer stock operation can also help to ensure that prices of farm produce do not fall below an economic level. In addition to maintaining a basic reserve and sufficient operational stocks, it will be prudent to always keep in readiness plans for increasing the production from irrigated areas during years characterized by widespread drought. Thus, an integrated grain reserve policy and a programme for the efficient use of the reserve in production potential during emergencies on the basis of early warning from crop-weather watch groups should help to launch every country on the path of self-reliance in food.

9.3.4 Social security

A mismatch between the ability to grow food and the ability to purchase and consume it on the part of large numbers of people could lead to a situation where a country may have large grain reserves but many children, women and men may still go to bed hungry. Hence, social security measures which ensure that everyone has his daily bread are important. Depending on social conditions, such measures could take the form of "Food for Work", employment guarantees, minimum wage, etc. Social security measures should not be based on dole and patronage concepts but should aim at providing opportunities for earning a minimum wage. Under conditions of sudden disasters, relief and nutritional intervention programmes will be essential /12/. Social security measures should not only cover consumers but farmers also. Through integrated pricing policies, farmers should not only be assured a fair price for their produce but also articles of daily consumption in rural areas at a fair price. Small farmers will also have to be insulated against risks arising from aberrant weather through an appropriate insurance system.

10. Conclusions

Future developments in solar energy utilization, genetic engineering and weather forecasting and modification could open up altogether new vistas of terrestrial and aquatic productivity. However, while working and waiting for such breakthroughs, no time should be lost in building dependable and effective national and international food security systems based on known knowledge and technology. Given appropriate political decisions and resource back-up, this task can be accomplished by 1984, the target year set by the World Food Conference held in Rome in 1974 for banishing hunger from the Earth. The finite resources of the "Spaceship Earth" (to quote Buckminster Fuller) can provide food, clothing and shelter for all provided the resources are conserved and utilized by all countries in a manner that will generate synergy and symbiosis /34/. This will call for a highly co-operative interaction between those who serve science and those who move society as well as among both scientists belonging to different disciplines and social leaders belonging to different political ideologies.

REFERENCES

/1/ UN CONFERENCE ON DESERTIFICATION. (1977). Desertification - its causes and consequences. Edited by the Secretariat of the UN Conference on Desertification, Pergamon Press 448 pp.

/2/ LOWDERMILK, W.C. (1953). Conquest of the land through seven thousand years. Agriculture Information Bulletin No. 99, U.S. Dept. of Agric., 30 pp.

/3/ BROWN, L.R. (1978). The twenty-ninth day - A World Watch Institute Book, W.W. Norton and Company, Inc., New York, 363 pp.

/4/ ECKHOLM, E.P. (1976). Losing ground - Environmental stress and world food prospects - World Watch Institute, W.W. Norton and Company, Inc., 223 pp.

/5/ PIMENTAL, D. and KRUMMEL, J. (1977). America's agricultural future. Ecologist VII, pp. 254-261.

/6/ BURINGH, P., VEN HEEMST, H.D. and STARING, G.J. (1975). Computation of the absolute maximum food production of the world. Dept. of Tropical Soil Science, Agricultural University, Wageningen, 55 pp.

/7/ BURINGH, P. and VEN HEEMST, H.D. (1977). An estimation of World Food Production based on labour-orientated agriculture. Centre for World Food Market Research, Wageningen, 46 pp.

/8/ UNITED NATIONS WORLD FOOD CONFERENCE. (1974). The world food problem - proposals for national and international action. 237 pp.

/9/ FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. (1977). The fourth food survey. 128 pp.

/10/ INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE. (1977). Food needs of developing countries, projections of production and consumption to 1990. Washington, 157 pp.

/11/ UNITED STATES DEPARTMENT OF AGRICULTURE. (1975). The world food situation and prospects to 1985 - Foreign Agricultural Economic Report No. 98, Washington, 90 pp.

/12/ PROTEIN-CALORIE ADVISORY GROUP OF THE UNITED NATIONS SYSTEM. (1977). A guide to food and health relief operations for disasters. 206 pp.

/13/ FOOD AND AGRICULTURE ORGANIZATION. (1978). Fishery products: Supply, demand and trade projections. Rome, 10 pp.

/14/ SUKHATMA, P.V. (1977). Incidence of undernutrition in India. 2nd Jour. Agric. Econ. 32, pp. 1-7.

/15/ BROWN, L.R., McGRATH, P.L. and STOKES, B. (1976). Twenty-two dimensions of the population problem. World Watch, Paper 5, 83 pp.

/16/ NATIONAL DEFENSE UNIVERSITY. (1978). Climate change to the year 2000, Washington, 109 pp.

/17/ THE ROCKEFELLER FOUNDATION. (1976). Bellagio Conference on climate change, food production, and interstate conflict, 71 pp.

/18/ WALTERS, H.E. (1978). International food security; the issues and the alternatives - International food policy issues. U.S. Department of Agriculture. Foreign Agricultural Economic Report No. 143, pp. 91-99.

/19/ U.S. DEPARTMENT OF AGRICULTURE. (1978). Alternative features for world food in 1985. Volume 1, World Gol. Model Analytical Report. U.S. Dept. of Agriculture, Foreign Agricultural Economic Report, No. 146, 137 pp.

[20] CHOWDHURY, A. and APPA RAO, G. (1976). Climatic changes and the wheat yield in northwestern parts in India. Climatological Note 19, Symposium on recent climatic change and the food problem. (4-8 October 1976). 42 pp.

[21] RAMAN, C.R.V. (1975). A new approach to rainfall climatology over Maharashtra State for agricultural planning. Science Today, July, Bombay.

[22] INDIAN COUNCIL OF AGRICULTURAL RESEARCH. (1977). Crop planning in drought and flood prone areas. 27 pp.

[23] SWAMINATHAN, M.S. (1972). Can we face a widespread drought again without food imports? Rajendra Prasad Memorial Lecture of Indian Society of Agril. Statistics, India, 25 pp.

[24] INDIAN COUNCIL OF AGRICULTURAL RESEARCH. (1976). Crop life-saving research - ICAR-IDRC Seminar Proceedings, published by Indian Council of Agricultural Research, New Delhi, 130 pp.

[25] RAO, N.G.P., SUBBA RAO, S. and VIDYASAGAR RAO, K. (1975). Rainfall fluctuations and crop yields, Current Science, 44: 19: pp. 694-697.

[26] NATIONAL ACADEMY OF SCIENCES. (1972). Genetic vulnerability of major crops. National Academy of Sciences, Washington, U.S.A. 307 pp.

[27] NAGARAJAN, S. and HARDEV SINGH. (1976). Preliminary studies on forecasting wheat stem rust appearance. Agril. Meteorol. 17: pp. 281-289.

[28] PUSHKARNATH. (1976). Potato in sub-tropics. Orient Longman, New Delhi, 289 pp.

[29] THE INTERNATIONAL RICE RESEARCH INSTITUTE. (1977). Constraints to high yields on Asian rice farms - an interim report., Manila, 235 pp.

[30] WORLD BANK REPORT. (1978). Report on Agricultural Land Settlement, summarized in Ceres, 64: pp. 14 and 15.

[31] SWAMINATHAN, M.S. (1977). Indian Agriculture at the cross-roads, Indian Journal of Ag. Econ. XXXII, pp. 1-34.

[32] RUSH, H., MARSBRAND, P. and GRIBBIN, J. (1978). World futures: Growth with redistribution? Food policy, May. 1978: pp. 114-126.

[33] SWAMINATHAN, M.S. (1973). Agriculture on spaceship earth, Coromandel Lecture No. 3., New Delhi, 31 pp.

[34] BUCKMINSTER FULLER, R. (1975). Synergetics, Macmillam Publishing Co., Inc., 876 pp.
