WORLD FOOD RESOURCES:AN OVERVIEW

BY

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ABSTRACT

Of the world's 4,000 million people, at least 500 million exist on the razor edge of survival. More than 1500 million lack access to adequate medical care. Extrapolations of population growth and subsistence food production among the less developed countries (LDCs), though widely variable, indicate total deficits of 145 million tonnes of grain by 1990. These projections anticipate little if any improvement in present nutritional standards among the world's least privileged people. These melancholy facts carry with them important economic and political considerations for nations such as Australia and Canada which produce grain in surplus to indigenous need.

They also carry a stern message for the political leaders of the LDCs and their supporters who place swords above ploughshares and guns higher than butter in national economic priorities. Scientists probably bear as great a responsibility as politicians for the world-wide failure to ensure a universally adequate food supply for all mankind. All too frequently scientists appear more concerned with the pursuit of what is ingenious rather than what is useful, economically desirable and socially acceptable.

Even in areas where land appears as the primary constraint, productivity per unit area can be significantly increased by: high-yielding crops; multiple cropping; the integration of animals and forestry with crops; the better use of marginal lands for pastures and fuel; of increased fish production through aquaculture and mariculture and the employment of industrial wastes and agricultural by-products for animal feed and fuel; the development of more

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efficient postharvest systems of preservation, processing and distribution; and, rural industrialization to conserve and raise the value of the products of agriculture, and to provide rural employment and to discourage migration to urban centres.

It is sad that political man appears to learn little from historical experience. Despite the tragic consequences of the continuous sacrifice of prime agricultural land to urban demand, first among the early civilizations of the Mediterranean, later in Europe, North Americans appear totally dedicated to the subjection of agriculture and their most productive lands, to the selfish demands of an urbanized society.

The prospect for an adequate food supply for all mankind need not to be bleak, but inevitably it will be so if politicians fail to assign a higher priority to agriculture and if scientists in all parts of the world are not more dedicated to serving mankind than serving science.

FOOD AND POPULATION

The best available statistics indicate that at the end of 1970, the less developed countries (LDCs) were inhabited by about 1.7 billion (1,000 x 10^6) people. Throughout the decade of the 1970s, LDC populations increased overall at about 3% per year from which trend one may extrapolate an LDC population of roughly 2.2 billion people by the mid-1980s. During the decade of the 1980s, it is estimated that the world population will increase by nearly 2.8 billion. Though these are crude averages, and the rate of population increase will vary noticeably among different countries, there are more than 30 countries whose population growth rates are expected to continue to exceed 3% per year. Most of the high population growth countries are to be found in Latin America, the Middle East and in Africa with a relatively smaller number in Southeast Asia.

The 1960s saw a significant increase in per capita food production throughout the world, particularly in Asia, Latin America and the Near East and based on overall statistics, food production in the LDCs kept slightly ahead of population growth throughout the 1970s.

The average for all developing countries suggests that over the past 25 years, food production per capita has been increasing at about 0.5% per year. These averages are, however, inherently misleading and conceal wide variations among the LDCs.

During the 1970s in both developing and developed economies, food increase per capita tended to decline; only Asian countries appear to have produced more per capita in the 1970s than in the 1960s. Among the poorest of the least developed countries, particularly those in Africa, the rate of population increase during the past decade significantly outstripped increase in food production, as is illustrated in Table 1.

In 1975 the difference between demand and supply in cereal grain equivalents in the LDCs was about 40 million tonnes. Based upon the careful and thoughtful estimates of the International Food Policy Research Institute (IFPRI), by 1990 the shortfall will lie somewhere between 100 and 150 million tonnes, that is between 2.5 and 3.5 times the deficiency in 1975. The deficiencies for several countries in 1975 and as projected in 1990 are shown in Table 2.

Also based upon IFPRI extrapolations, Table 3 presents data showing the annual growth rates in cereal crop production needed to meet 1990 demands (a) at the same per capita consumption level of 1975, and (b) at 110% of energy requirements in 1990. The data in Tables 2 and 3 illustrate the emphasis and priorities that must be given to food and agricultural research and development in both food surplus and food deficient countries as far into the future as one can visualize.

PROGRESS DURING THE PAST TWO DECADES

The 1960s were illustrative of progress that can be made in countries whose governments recognize agriculture as of prime importance and highest priority. Such countries are India and the Philippines, the former in recent times having been able to set aside more than 20 million tonnes of cereal grains as a strategic store and the latter having graduated from the status of a major importer to relative self-sufficiency. In both countries a significant improvement in productivity was largely attributable to the adoption of high-yielding, semi-dwarf cultivars of cereal grains.

Wheat, maize and rice illustrate how significant increases in yield (weight of grain per unit area of land per year) may be realized through imaginative applied research. Between 1965 and 1975, while the population of the LDCs increased by 30%, their total production of wheat increased by 50% and maize by 40%, while rice production approximately kept pace with the rate of population increase. It will also be illustrated later that in one of the most highly intensively cropped areas of the world, the rice producing region of South and Southeast Asia, multiple cropping with rice as the main crop can serve further to increase total food crop production.

Broadly speaking, the means by which to increase per capita food availability and to achieve self-sufficiency in food production fall into three categories:

1. Higher levels of productivity per unit of land;
2. Expand the area of land under cultivation; and
3. Attain greater efficiency in food conservation and distribution.

TABLE 1

FOOD PRODUCTION PER CAPITA - ANNUAL RATE OF CHANGE (%)

	1961-70	1970-78
AFRICA	0	- 1.3
ASIA AND FAR EAST	0.2	0.5
LATIN AMERICA	0.7	0.6
NEAR EAST	0.5	0.4
ALL DEVELOPING COUNTRIES	0.4	0.2
POOREST DEVELOPING COUNTRIES (less than $200 per capita)	0.1	- 0.1
DEVELOPED COUNTRIES	2.4	2.2

TABLE 2

FOOD GRAIN (CEREAL EQUIVALENT) DEFICITS IN THE LDCs

	ACTUAL 1975		PROJECTED 1990	
	TONNES X 10^6	% OF CONSUMPTION	TONNES X 10^6	% OF CONSUMPTION
INDIA	1.4	1	20.0	11
BANGLADESH	1.0	7	7.0	32
INDONESIA	2.1	8	7.0	16
EGYPT	3.7	35	4.9	32
SAHEL	0.4	9	3.4	45

TABLE 3

ANNUAL GROWTH RATES IN CROP PRODUCTION TO MEET 1990 DEMAND

	PER CAPITA LEVEL AT 1975	AT 110% OF ENERGY REQUIREMENT
ASIA	3.1	4.3
N. AFRICA/M. EAST	4.2	5.0
AFRICA (SUB SAHARA)	3.2	4.6
L. AMERICA	3.9	4.1
ALL LDCs	3.4	4.4

HIGHER CROP YIELDS

By the mid-1970s, high-yielding wheat cultivars were being grown on roughly 44% of the total land given to wheat in developing countries, the resulting increase in production of some 24 million tonnes, if imported, would have cost the LDCs roughly U.S.$3 billion in foreign exchange.

Table 4 shows the proportions of wheat and rice growing areas now sown to high-yielding cultivars. As can be seen, this represents more than one-third of the wheat and rice producing areas of the LDCs, equivalent to about 55 million hectares of arable land. Seventy-five percent of the wheat areas of India, Pakistan, Bangladesh and Nepal are under high-yielding wheat and more than 70% of the rice areas of the Philippines, 30% of the rice areas of India, Indonesia, Malaysia, Pakistan and Korea also being given to high-yielding genotypes. The rice and wheat production in the LDCs have increased respectively by 2.4 and 4% annually since the introduction of these high-yielding crops in the mid-1960s.

TABLE 4

PROPORTIONS OF TOTAL AREA OF WHEAT AND RICE SOWN TO HIGH-YIELDING VARIETIES: 1976-77

	PERCENT		
	WHEAT	RICE	TOTAL
ASIA	72	30	41
NEAR EAST	17	4	17
AFRICA	23	3	7
LATIN AMERICA	41	13	31
TOTAL	44	27	35

The contribution which high-yielding cultivars can make to increases in productivity has been by no means exhausted. During the 10 years from the mid-1960s, when the higher yielding plant types of rice and wheat were introduced, average rice yields in the LDCs increased by 17% and total production by 27%; wheat yields increased by 24%, and annual production by 50%.

TABLE 5

PERFORMANCE OF 6 CEREALS IN DEVELOPING COUNTRIES

1961-65 COMPARED WITH 1971-75

CEREAL	ANNUAL AREA (million hectares)	(million hectares)	Increase (percent)	ANNUAL YIELD 1961-65 (kg/ha)	1971-75 (kg/ha)	Increase (percent)	ANNUAL PRODUCTION 1961-65 (million tonnes)	1971-75 (million tonnes)	Increase (percent)
Rice	85.8	93.0	8	1614	1884	17	138.5	175.4	27
Wheat	50.4	61.3	22	976	1211	24	49.2	74.3	50
Maize	44.8	53.4	19	1132	1313	16	50.7	70.1	38
All Cereals*	270.7	299.9	11	1098	1296	18	297.3	388.9	31

Source: FAO Production Yearbooks

*Includes cereals not listed

It appears that other food crops, which when compared with wheat, rice and maize have been relatively neglected by agricultural research scientists, are capable of even more spectacular yields when subjected to careful genetic selection combined with improved agronomic practices. The cereal grains of the semi-arid tropics (SAT) that include sorghum and the small seeded grains generally classified as millets, are planted to a greater total acreage throughout the world than is maize. Throughout semi-arid Africa and Asia the on-farm yields of these crops rarely exceed 500 kg/ha. Because of their superior photosynthetic efficiency as compared to wheat and rice, by careful genetic selection, breeding and agronomic management, yields in excess of 10 times the world average of sorghum and other dryland cereal crops are possible.

Cassava, which provides the main source of carbohydrate calories for perhaps 300 million people in developing countries yields on average about 5 to 10 tonnes of roots, equivalent to 1.5 to 3 tonnes of dry matter per hectare. In consequence of the research at the International Centre for Tropical Agriculture (CIAT) in Colombia, supported by more basic studies in Canada into the factors that control photosynthesis in the leaves and the efficiency of translocation of photosynthates to the root, it is now possible to achieve yields of between 30 and 50 tonnes of cassava roots per hectare.

Because in so many LDCs available arable land presents the primary constraint to increased productivity, research must of necessity focus upon achieving higher yields of edible matter per unit area of land per unit of time; a goal which has been and will continue to be achieved by seeking plant types with an inherent genetically controlled ability to produce higher yields combined with agronomic systems that exploit the high-yielding capabilities to fullest advantage.

The fact that greatest success has been achieved with wheat, maize and rice is attributable to the concentration of research effort that has been focused upon these crops respectively at the International Centre for Maize and Wheat Improvement (CIMMYT) in Mexico and at the International Rice Research Institute (IRRI) in the Philippines. Given equivalent attention, comparable successes could be achieved with other staple food crops. With the exception of soyabeans grown mainly for oil and animal feed in North America and groundnuts grown in the developing countries principally for export, edible oilseed crops have been largely neglected by agricultural research scientists in spite of the fact that the LDCs collectively import more than $100 million worth of vegetable oils annually. The protein of food legumes is nutritionally complementary to that of cereal grains, a combination of roughly two parts by weight of cereal with one part by weight of dried food legume providing an almost nutritionally perfect protein.

Because of their low yields relative to wheat and rice, the acreage under food legumes in Asia has been falling and rather than the nutritionally desirable ratio of two of cereal to one of legume, the legume crop of Asia is only about one-tenth that of cereal production throughout Asia. In addition to the many legume breeding projects that seek to increase yields in the LDCs above the average of about 0.5 tonnes per hectare, a great deal more fundamental research is needed to better comprehend the biochemical and physiological mechanisms in legumes that influence the symbiotic fixation of nitrogen and the translocation of the products of photosynthesis to the edible seeds. In general, a very high proportion of photosynthetic energy is absorbed in legumes in the conversion of atmospheric nitrogen first to ammonia then to amino acids and protein. If the total energy demand of fixing nitrogen could be reduced, a significant increase in legume yields might be facilitated.

Indicative of the world's relative neglect of its potential food sources, it is worth mentioning that whereas about 80,000 different edible plant species are known, barely 50 are cultivated to any significant extent. In fact, almost 90% of the world's food harvest is supplied by only 12 plant species. Consequently, the opportunity by which to expand the world's diet in quantity and variety from plant sources has been barely imagined let alone exploited.

In addition to seeking higher yielding plant types, several complementary approaches deserve attention and encouragement. High-yielding plant types are generally characterized by a relatively higher ratio of edible seed to non-edible vegetable material. A complementary approach is to seek genotypes that mature more rapidly than their established relatives. The time to maturity of most traditional rice types is at least 120 days. At IRRI scientists have identified cultivars that mature in less than 100 days thus permitting two or even three crops of rice to be grown upon the same piece of land every year. Although these sequential multiple rice cropping systems present a new and complex generation of economic and technological difficulties, they clearly offer a remarkable opportunity for increased annual production per unit of land. Similarly, sorghum breeders in West Africa have selected lines that mature in less than 90 days and are therefore better able to take advantage of a short rainy season than their established relatives that require in excess of 120 days to mature.

The advent of the rapidly maturing crop types has made possible an increase in total edible dry matter production per year through increased cropping intensity. This family of technologies has come to be known as multiple cropping in which several food crops are grown either (a) simultaneously, non-competitively or in mutual symbiosis; (b) successively, when one crop is planted after the other is harvested; or, (c) sequentially in which one or more crops are planted while the first is still growing. Multiple cropping which provides more than one harvest of the same or different crops from the same piece of land in one calendar year, is by no means a new agricultural phenomenon. Multiple cropping technologies have been practised in China and many Asian countries for as long as historical records are available. Theophrastes, a pupil of Aristotle, records in his "History of Plants" how Babylonian farmers during the second millenium, on land irrigated from the Euphrates, harvested two crops of wheat followed by pasture crops for their domesticated animals. It is probable that Egyptian farmers in the third and second millenia practised multiple cropping on land watered from a remarkable network of irrigation canals and dykes.

GREATER LAND USE

All other things being equal, probably the most critical factor relevant to the population and food equation in the LDCs is the number of persons to be fed from each unit area of farmland. During 1975, the needs of approximately 3 people in developing countries were supplied from each hectare of cropland. By simple extrapolation of an estimated population increase of about 3% per year, in 1985 each hectare cultivated in 1975 in the LDCs will need to support 4 persons and by the end of the century between 5 and 6 persons. But these crude averages do not reveal the dramatic differences to be found among developing countries. Table 6 illustrates in sharp contrast possible justification for cautious optimism on the one hand and near despair on the other when the state of different LDCs is compared.

In 1975, 60 million Mexicans relied upon 28 million hectares of arable land, equivalent to about 2 persons per hectare. At the same time, 37 million Egyptians depended upon 3 million arable hectares, equivalent to 13 persons per hectare. Based upon the above assumptions, by 1985 an arable hectare will need to support 3 Mexicans and 16 Egyptians respectively and by 2000 AD the number of Mexicans will increase to 5 and of Egyptians to 22 per arable hectare. As is mentioned later, the International Development Research Centre is cooperating with

TABLE 6

POPULATION PER ARABLE HECTARE IN SELECTED COUNTRIES, 1975, 1985 AND 2000 A.D.

ASSUMING NO CHANGE IN POPULATION GROWTH RATE

	Arable hectares (millions)	Population 1975 (millions)	Population per arable hectare 1975 (persons)	Annual Rate of natural increase 1965-75	Population 1985 (millions)	Population per arable hectare 1985 (persons)	Population 2000 A.D. (millions)	Population per arable hectare 2000 A.D. (persons)
Mexico	28	60	2	3.5%	85	3	136	5
Korea	24	34	14	2.0%	41	17	54	22
India	167	608	4	2.0%	741	5	983	6
China	129	823	6	1.7%	974	7.5	1241	10
Kenya	1.8	13	7	3.3%	18	10	28	15
Tanzania	6.1	15	2.5	2.8%	20	3.5	30	5
Egypt	2.9	37	13	2.3%	46	16	63	22
All LDCs	670	1900	3	2.5%	2400	3.5	3343	5

Sources:

Arable hectares from FAO Production Yearbook. Arable hectares includes land used for both annual and permanent crops.

Population levels and rate of natural increase from "Population Growth 1965-75" published by Population Reference Bureau, Washington, D.C.

Ratio of man to land extrapolated.

several agencies in Egypt to reclaim parts of the desert for agricultural production.

Unless an unforeseen effective constraint is applied to population increase in the LDCs, production levels of such staple foods as cereal grains, food legumes and root crops must be significantly expanded. If the increases necessary are to be achieved solely by higher yields, then cereal grain yields in the LDCs, which during 1975 averaged 1.3 tonnes per hectare, must be increased to 1.7 tonnes and to 2.2 tonnes by 1985 and 2000 AD respectively. These crude linear extrapolations take no account of variations in population increase nor in above average consumption demands by those segments of LDC populations whose disposible income may rise above national averages.

In spite of the self-evident need to increase the area of land under cultivation, relatively few governments throughout the world appear dedicated to this purpose. The UN Conference on Desertification drew attention to the consequences of inadequate land management systems and the deterioration of the chemical, microbiological and physical properties of tropical soils through destruction of natural forests and overgrazing. Though they should know better, the developed countries of North America and Europe offer an unfortunate example to developing countries by the manner in which they permit much of their best agricultural land to be destroyed by the bulldozers and cement mixers of the urban developers. Since the Industrial Revolution, Britain and other European countries have encouraged urban growth at the expense of good farmland. In France, it is estimated that about 60,000 hectares of agricultural land are lost annually to urban and industrial proliferation. Similarly, in California and other parts of the United States, large areas of highly productive agricultural and horticultural land have been sacrificed to industrial development.

To the outside observer it might appear that Canada, with the second biggest land mass of any nation in the world, possesses more than enough land to satisfy the needs of its 25 million people. But, of Canada's total land area of about 1 billion hectares, less than 12% is classed as land with agricultural potential and barely half of the agricultural land is categorized as "prime class" arable land suitable for the sustained production of field crops. The greatest rate of urban growth in Canada is found in three of the nation's most fertile areas: south central Ontario, the St. Lawrence lowlands of Quebec, and the lower mainland of British Columbia. Over the past decade, 75% of the Canadian land taken out of farming was prime farmland and 80% of this prime land was destroyed in Ontario which possesses more than half of all the nation's prime agricultural land. It has been forecast that if the trend continues in the future, in less than 40 years there will be no prime land left in Ontario.

The result of this land depredation is plain for all to see. Thirty years ago Canada produced roughly the same weight of fruit and vegetables as the nation consumed. Now, Canadians import 60% of their fruit and about 37% of the vegetables we eat. It is my earnest hope that Australia is one nation in the world that treasures its most productive agricultural land as its most valuable asset.

Table 7 presents an approximate classification of the world's land area and records the estimated yield of biomass for each region classified. Past depredations and the ever growing and barely sustainable demands upon land call urgently for research to bring under food or fodder crops, land which previously was considered unsuitable because of a hostile climate, adverse soil conditions and low fertility, inadequate rainfall or other unfavourable conditions. Many and varied efforts are now being made to extend areas of food crop and animal production into what may be termed marginal lands. The plant breeder and agronomist are seeking plant types more tolerant of adverse conditions including: rice cultivars that can be directly seeded onto dry uplands where continuous irrigation is impossible or uneconomic; rice that is tolerant of high salinity and other adverse soil components; and, floating rice that grows fast enough to keep its head above water when heavy rains cause flooding.

Research is being devoted to sorghum and several of the minor millets which display exceptional tolerance to continuous and/or intermittent drought, and to a greater understanding of the biological and physiological mechanisms that facilitate drought tolerance; to relatively neglected food crops such as quinoa, a staple of the Amerindians which in addition to being highly nutritious displays an adapted tolerance to the harsh conditions of the High-Andes where many of the poorest people of Latin America survive.

Canada has invested significantly in the development of the intergeneric cereal hybrid "triticale" which combines the high yield and desirable technological characters of its wheat parent together with the ruggedness and superior amino acid composition of its rye parent. For more than a century wheat x rye hybrids remained as botanical curiosities until the combined efforts of scientists at CIMMYT and the University of Manitoba demonstrated that the inferior seed quality and mule-like infertility of wheat x rye hybrids could be overcome. From a sizeable population breeding and selection program there emerged a promiscuous outcross that exhibited an inheritable fertility. The range of fertile hybrids was increased by embryo culture followed by colchicine treatment

TABLE 7

EARTH'S ANNUAL PRODUCTION OF PRIMARY PHOTOSYNTHETIC BIOMASS

	AREA %	DRY MATTER/YEAR %
CONTINENTS	29.2	64.6
FORESTS	9.8	41.6
WOODLAND	1.4	2.7
SCRUB (INCL. TUNDRA)	5.1	1.5
GRASSLAND	4.7	9.7
DESERT (DRY & ICE)	4.7	0
CULTIVATED LAND	2.7	5.9
FRESHWATER	0.8	3.2
OCEANS	70.8	35.4
TOTAL EARTH	100	100
TOTAL AREA	510 M km^2	155 billion tonnes dry matter/year

of the resultant seedlings. Most first generation triticale seedlings possess only a single set of each of wheat and rye chromosomes. The two single chromosome sets cannot pair for the purpose of sexual reproduction and therefore they generate no progeny. If colchicine, an alkaloid derived from the autumn crocus, is applied to the seedlings, the chromosomes are induced to double and the resulting twin sets of chromosomes can pair thus enabling the hybrid to reproduce itself.

The superiority of triticale over wheat under adverse conditions has been demonstrated in the highlands of Ethiopia, in northern India where triticale has been grown at altitudes of between 1800 and 3000 metres, in the highlands of East Africa where, because of its resistance to stripe and stem rust triticale gave double the yields of established wheats last year, and in Latin America where the hybrid demonstrates significant tolerance to light, sandy, acid and high aluminum soils. It now remains for the cereal chemists and the food technologists to demonstrate that triticale can be used successfully in both traditional and adapted cereal foods.

A serious effort is being made to bring into production more than 850 million hectares of forest and savanna land in tropical Latin America. The soils covering most of this area consist of oxisols, ultisols and andosols which are generally acidic with a pH below 5.5

and are low in available phosphorus. For the most part, it is uneconomic to import chemically manufactured superphosphates but at many locations in the region rock phosphates occur naturally. Research supported by IDRC in cooperation with the International Fertilizer Development Centre (IFDC) and CIAT has demonstrated that by simple concentration of the phosphate present, by fine grinding with or without partial acidulation or fusion with magnesium, the natural rock phosphates when applied to acid soils increase yields of food crops, forage grasses and pasture legumes.

Table 6 demonstrates the extreme population pressure upon arable land in Egypt, a country that was practising highly productive settled agriculture while the ancestors of most Europeans and North Americans were primitive stone age people. The position is now so grave that the Egyptian government has nowhere to look but to the reclamation of the desert. IDRC is cooperating with the American University in Cairo, three other Egyptian universities, and several government departments in an attempt to restore fertility to desert soils through the combined approach of controlled irrigation, the establishment of drought tolerant pasture legumes, protected by extensive tree barriers, pastures which first will be used to graze sheep and later, as the top soil develops, cultivated in rotation with cereals and other food crops.

ANIMAL PRODUCTION

Some commentators on the state of world nutrition tend to ignore or even to derogate the value of farm animals in food production systems. Their opposition is usually based upon the calculation that approximately 7 calories of input are required to generate 1 calorie of output when cereal grains are fed to livestock (see Table 8). Opponents of animal production tend to overlook what is well known to Australia: that carefully selected mixtures of forage grasses and pasture legumes can both survive and sustain animals on marginal land areas unconducive to the production of cereal grains or other food crops. During seasons of low rainfall when pastures are less abundant, animals can be fed hay or silage supplemented by a wide variety of agricultural and industrial by-products unsuited for direct human feeding.

IDRC is supporting a rapidly growing network of animal production projects in Asia, the Near East, Africa, the Caribbean and Latin America in which animals are raised on pasture land unsuitable for crop production with diets supplemented by such agricultural by-products as coffee pulp, processed hay and other lignocellulosic materials, cassava and other leaves, oilseed meals and microbially enriched carbohydrate sources, none of which can be fed directly to human beings.

TABLE 8

ANIMAL FEED CONVERSION

(Calories of input/Calories of output)

BEEF		16:1
PORK		6:1
TURKEY		4:1
EGGS		3:1
BROILERS		3:1
	AVERAGE	7:1

Source: USDA, Economic Research Service

WATER MANAGEMENT

It would require a dissertation many times the length of this presentation adequately to deal with the critical importance of efficient water management in intensive cropping and other land management systems. Despoliation and depredation of the land resource over many generations is paralleled in seriousness only by mankind's appalling mismanagement and unsatisfactory use of the world's water resources. It is indeed sad to contemplate the millions of litres of irrigation water delivered to farmers' fields, of which only a small proportion provides benefit to growing crops and the excess of which causes salination and other damage to once fertile soils. There is an urgent need throughout developing countries for greater investment of talent and money to gain a more comprehensive understanding of plant-soil-water interactions and to develop and exploit more efficient agricultural water management systems.

AQUACULTURE AND MARICULTURE

One of the most exciting opportunities for more productive management of inland and coastal waters is to be found in aquaculture and mariculture: the farming of village ponds, natural and man-made lakes, rivers and irrigation canals; and the cultivation of oysters, mussels, and other shellfish and finfish in estuarine and coastal waters.

Though fish farming has been practised for many centuries in China and much of Asia, a major constraint to increased fish production throughout Asian countries is to be found in the shortage of fish seed caused in part by the fact that the females of some important fish species do not readily lay their eggs when in captivity. Oviposition may be induced by injections of crude gonadotrophins extracted from the pituitaries of Pacific salmon and other fish.

One such is the milkfish (Chanos chanos), a main source of dietary protein for many poor people in the Philippines and other countries of Southeast Asia. With support from IDRC, in 1977 the Southeast Asian Fisheries Development Centre (SEAFDEC) for the first time on record, induced spawning in a female milkfish by a gonadotrophin injection. It is hoped that through the further development and wider adoption of this technique the supply of fish seed and fingerlings to Asian fish farmers can be greatly increased.

In many countries aquaculture consists of monoculture, the raising of a single species in natural ponds or enclosures. The productivity of monoculture systems is limited by the availability of the food required by each species cultured. Indian scientists, from their research centre at Barrackpore have developed polyculture systems that can yield up to 10 times the quantity of fish produced in ponds stocked with a single species. By introducing up to six non-competitive species of carp supported by pond fertilization and supplementary feeds, it is possible to harvest up to 9 tonnes of fish per hectare of pond surface per year. Such systems of polyculture are gradually being adopted by village communities in Orissa, West Bengal and other Indian States.

In their natural habitat oysters, mussels, and other bivalves, following their limited period of motility as juveniles, attach themselves to mangrove roots and other natural submarine surfaces. Because they tend to become overcrowded, their food supply is limited and consequently their growth is stunted. Whereas it takes from three to five years to produce an oyster of marketable size in the temperate ocean waters around Canada, in Sabah and Sierra Leone oysters can be grown in raft culture to a marketable size of an average meat weight of 9 g within 9 months. These oysters are roughly four times the size and develop in one-fifth the growing period of the naturally occurring overcrowded wild mangrove oysters.

In Singapore in the open coastal waters around Changi a quarter of a tonne of mussels are cultivated below each square metre of raft in a six month period, which by extrapolation is roughly equivalent to 90 tonnes of protein per hectare of surface water. In comparison, a satisfactory crop of soyabeans will produce about 0.9 tonne of protein per hectare per year.

Another technique, capable of world-wide adoption in many fresh, brackish and marine waters, is known as cageculture. In cage and enclosure systems the cultivated fish are contained inside submerged cages constructed of knotless net or other open work materials through which water flows freely, thus providing the captive fish with a continuous supply of oxygen and a means of removing waste products. The enclosures may be located over natural sources of algae or other acceptable food materials, or the fish may be provided with other suitable food sources. IDRC is encouraging the investigation and adoption of cage and other enclosure systems in natural and man-made lakes, rivers, irrigation and drainage canals, and in various coastal waters. For example, off the coast of Singapore research on groupers reared in floating cages has made possible the production of 400 tonnes of fish per hectare per year.

Nevertheless, fresh water species are cultured on a much larger scale than are brackish or marine species. Fish seed for fresh water farming is generally obtained from captive brood stock whereas coastal mariculture depends mainly on the collection of seed from the wild. Almost all systems of aquaculture are at a state of knowledge about equivalent to that which was reached by poultry breeders 30 or 40 years ago. Consequently, the range and diversity of research needed on virtually all aspects of fish breeding and rearing appears formidable.

Research is required into the frequency and duration of maturation and spawning in captive fish and how these may be influenced by photoperiod and environmental temperatures. More needs to be known about the nutritional and environmental requirements of brood stock. Techniques are necessary for the standardization and large scale, long term, cryogenic storage of gametes. As mentioned earlier, maturation, ovulation and spawning can be induced by injections of mammalian and piscine gonadotrophins, alone or together with steroid hormones. But the standardization of optimum doses and techniques of injection are yet to be determined for most of the major cultivable species.

The successful rearing of the vulnerable larvae after hatching remains the most difficult phase of seed production. Relatively little is known about the nutritional requirements and optimum environments to ensure satisfactory survival and growth during the early life of almost all cultivated aquatic creatures.

Probably the greatest constraint to the rapid development of aquaculture and mariculture is the relatively few scientists interested and trained to conduct research into the many fascinating aspects of the subject. Unquestionably, aquaculture and mariculture deserve much more attention than they have received. In general, fish are more efficient converters of feed to body flesh than are land animals since fish do not waste energy maintaining body heat, their body temperature being conditioned by the surrounding water. Furthermore, many fish are able to use food sources unsuitable even for domestic animals. As described above, in polyculture systems a variety of species, each with a different feeding habit, can live in common collective symbiosis and use most efficiently the different sources of feed available in a limited volume of water.

In analogy with multiple cropping systems, the purpose of polyculture research is to determine the optimum combination of species, stocking densities, supplementary feeding and water fertilization, together with the management system best suited to the conditions that prevail.

AGROFORESTRY

In North America it seems to be expected of every commentator upon the state of world food supplies that a significant proportion of the presentation will be devoted to energy and the conversion of carbohydrate and other forms of biomass to methane, ethanol and other combustible materials. In a world in which the growth of demand for edible cereal grains is outpacing the rate of increase in grain production and in which 500 million people, more than half of them children under five years of age, are malnourished, it appears wicked for the governments of the major cereal producing nations to contemplate the conversion of their surpluses to ethanol in order to satisfy the appetites of their automobiles. Considering the fact that demand for wheat among all the developing countries has increased by more than 60% over the last decade, it does not appear economically, let alone morally, justifiable for such wheat surplus nations as Australia and Canada to dedicate their grain surpluses to filling gasoline tanks.

Australian scientists are to be commended upon their research on the nitrogen fixing properties and other important aspects of the drought tolerant Casuarina; for the remarkable progress made in the development of Leucaena as a source of high density wood, animal feed and crop fertilizer; and to the recent research on trees such as the Hevea and Euphorbia that are capable of producing combustible hydrocarbons and species that are capable of generating hydrogen. The latter appears a far more rational approach to the provision of supplementary combustible fuel than the fermentation of cereal carbohydrates.

It is often overlooked by citizens of the developed economies that probably more than one-third of the world's population depend almost entirely upon wood to cook their food and to heat their homes. For this reason, IDRC is supporting a network of social forestry projects most of them in the SAT of Africa, each project dedicated to the greater production and more efficient utilization of forest products in association with settled agriculture.

At the current rate of deforestation in the developing world, equivalent to about 11 million hectares per year, nearly half the area of the United Kingdom, the present forest inventory of the world will be halved by the end of the century. Table 7 illustrates the comparative superiority of forests as generators of biomass and, therefore, the very serious material loss that results from the wanton destruction of the natural forest.

Agroforestry, the controlled management of combinations of trees with other crops and farm animals, offers many opportunities for increased food and fuel for humans, feed for animals, fertilizer for growing crops, together with a more rational management and conservation of the natural environment.

Deep tree roots act as nutrient pumps, the falling leaves restoring nitrogen and other essential elements to the top soil. In the SAT trees protect the crops from searing winds and the top soil from inundation by blowing sand. Leguminous and some non-leguminous tree species, in association with soil bacteria, fix atmospheric nitrogen enabling the leaves, pods and other vegetative materials to provide nutritious feed and fodder, together with shade for farm animals, in addition to the wood available for fuel and building materials.

Roughly 36 million sq km of tropical land are subjected to shifting cultivation, a process in which the natural forest cover is first destroyed by slashing and burning, following which crops are grown until the soil nutrients become virtually exhausted, a period which usually lasts no more than 3 years, following which the shifting cultivators move on to continue the depredation of the natural forest.

Several donor agencies have combined to create a new international organization, the International Council for Research in Agroforestry (ICRAF) to explore how tree species can be employed more efficiently in farming systems, and to find ways by which areas subjected to shifting cultivation may be conserved by more scientific systems of land management, tree and crop cultivation. Unquestionably agroforestry embraces a vast and complex field of research and will call for the integrated efforts of many scientific disciplines. Nonetheless, the need to combine tree crops with food crops and animals in farming systems is essential if most efficient land management is to be achieved.

POSTPRODUCTION SYSTEMS

It is estimated that the world produces sufficient grain to provide at least 3,000 calories per day for every man, woman and child alive. Additional calories and nutrients exist in the sizeable quantities of fruits, vegetables, fish and other animal products harvested. Since 2700 calories a day is probably sufficient to sustain a moderately active adult, millions suffer malnutrition because existing systems are inadequate to distribute uniformly the food sources available from the regions and seasons of abundance to those of scarcity.

Inadequacy of postharvest distribution systems is not confined solely to the transfer of surplus grain crops from Australia, Canada and the United States, though such transfers to developing countries, on both economic and concessional terms, will be required long into the foreseeable future. Inadequate postharvest systems exist among regions, countries, among zones within countries, among communities, families, and even within families. Wide seasonal variations are also apparent in many developing nations. For example, in the Sahelian zone of Africa the period from December to mid-March, which immediately follows the harvest, is a time of relative abundance. But between April and July food supplies tend to dwindle until August and September when serious dietary deficiencies are to be found among those rural people who do not maintain an adequate store or who lack the disposible income to buy from grain traders.

A recent study carried out in the Thiès region of Senegal indicates that where adequate during December, dietary caloric levels may fall to 27% below recommended intakes during August and September.

The unsatisfactory state of nutrient distribution among LDCs may be attributed to economic, social, logistic and technological causes, all of which tend to vary in kind and/or degree among different communities. There are two contributing causes that are often overlooked. The first is the need to consider each post-production (or postharvest) system in its entirety; the second results from an unwarranted optimism in the transferrability of technology. Scientific principles are universally applicable; many technologies are not. Biologically based technologies, whether they relate to the cultivation of edible plants or to the transformation, preservation and distribution of plant or animal products, are greatly influenced by their surrounding physical, social and economic environments. Consequently, it is generally difficult and often impossible to transfer postproduction technologies and food transformation systems from developed countries, with temperate climates and access to advanced technologies, to the less developed countries of the semi-arid and humid tropics.

Postproduction systems need to be studied comprehensively and in their entirety and their component technologies must be developed where they are to be used and in close cooperation with those who are to use and benefit from them. Consequently, analogous to cropping and farming systems research, postproduction systems research must begin with a thorough examination and understanding of the systems that exist, however primitive they may appear to be. Only by comprehending what already exists, technically, economically and socially can one hope to devise and implement improved systems and component technologies.

The subject of postproduction research and development has been dealt with more comprehensively in several of the publications listed in the bibliography. Suffice it to say that in addition to the basic scholarships of which each is composed, there is a demonstrable need for systems analysts, mathematicians and socio-economists to study and seek to improve in an orderly manner the many post-production systems that exist throughout the less developed countries of the world.

A review of present research activity suggests that greater concern be addressed to a better understanding of the technological and nutritional properties of the principal cereals, food legumes and oilseeds of the developing countries. Though high yield potential must remain the main priority for plant breeders, high yield should be combined with such other desirable properties as grain types that can be satisfactorily processed industrially or domestically; that do not require long cooking; that are free from nutritional inhibitors that cannot be eliminated or neutralized by available processing technologies.

It has been demonstrated in Canada and elsewhere that in addition to the traditional technologies by which they are processed, cereal grains such as maize, sorghum and the millets can be combined with wheat to produce satisfactory fermented bread provided the traditional breadmaking technology is significantly modified.

The acceptability of and demand for food legumes can also be markedly increased by modified processing technologies. Clearly the future calls for a closer integration of interest and effort between plant scientists on the one hand and food scientists and technologists on the other.

A greater research effort needs to be dedicated to the preservation and distribution of fish in tropical countries where refrigeration is generally unavailable and uneconomic. The ultimate promise and potential of aquaculture and mariculture will not be realized until effective and economic systems of fish preservation and distribution are developed and adopted. The applied research needed must be undertaken where the fish are harvested, starting with a thorough study of the climatological, social and economic conditions that prevail. At all stages the research needs to be pursued and the results applied in close cooperation with the fishing community that is eventually destined to make use of whatever technologies are forthcoming.

RESEARCH MANAGEMENT

One of the most urgent needs throughout the universe of food and agricultural science and technology is for the training and development of managers of applied research; people who recognize that applied research is by definition research for human benefit; persons who have acquired a capacity of broader and deeper comprehension and attitude of mind than is generally provided by conventional BSc, MSc and PhD courses. It is not unusual to encounter the belief that managers, like marriages, are created in heaven and that competent scientists automatically metamorphose into competent research managers. This concept I believe is demonstrably fallacious. Competent scientists do not necessarily become effective research managers. Nonetheless, research scientists who display a potential for management can significantly improve their research management capability when given appropriate training.

CONCLUSION

As the recent Brandt Commission report points out "Many (poor countries) face growing food deficits and possibly mass starvation.... The 1980s could witness even greater catastrophies than the 1930s." It is evident from the relevant information available that the next quarter-century could be a period of immense human suffering; serious poverty and malnutrition among the majority being sharply contrasted with an abundant excess and misuse of agricultural resources by the privileged minority. If we are not to witness one of mankind's most appalling tragedies it will require a significant shift in priorities by almost all nations of the world. Governments of the LDCs must quickly come to recognize that ploughshares are more important than swords and that farmers deserve a higher stratum in the social hierarchy than at present they enjoy.

The economically developed nations must come to the realization that prime agricultural land is their most valuable possession and that food and agricultural industries must rank first in their economic order.

Australia has a unique role to play in that it is one of the few economically, scientifically, and technologically advanced countries that enjoy a tropical climate. Australia is therefore able to undertake both fundamental and applied research on agricultural, aquacultural, maricultural and silvicultural systems of direct and immediate interest to many developing countries. This is a situation unique among the world's economically privileged nations.

If I appear to have painted an excessively gloomy picture, it is perhaps because my philosophy is influenced by Sir Francis Bacon's dictum that: "If we start with certainties, we shall end with doubts; but if we begin with doubts and work patiently we shall end with certainties." Francis Bacon also wrote: "A wise man creates more opportunities than he finds."

Based upon the history of our recent past, we have reason to doubt that all will be for the best in the best of all future worlds. But if we begin with reasonable doubts, and humane concern is allowed to take precedence over restricted self-interest, patient effort can ensure the certainty of an adequate diet for all the world's people.

BIBLIOGRAPHY

1. Agricultural Research Organization, 1977. Supporting Papers: World Food and Nutrition Study, Vol. 5, Study Team 14, National Academy of Sciences, Washington, D.C., U.S.A.
2. Agriculture Canada, 1977. Orientation of Canadian Agriculture. A Task Force Report, Vol. 1, Part A, Canadian Department of Agriculture, Ottawa, Canada.
3. Agriculture, Food and Nutrition Sciences Division: The First Five Years, 1977. International Development Research Centre, IDRC-089e, Ottawa, Canada.
4. Arndt, T.M., Dalrymple, D.G. and Ruttan, V.W., (eds.) 1977. Resource Allocation and Productivity in National and International Agricultural Research, University of Minnesota Press, Minneapolis, U.S.A.
5. Borlaug, N.E., 1972. The Green Revolution, Peace and Humanity. Speech delivered upon receipt of the 1970 Nobel Peace Prize, CIMMYT Reprint and Translation Series No. 3, Mexico.
6. Boyce, J.K. and Evenson, R.E., 1975. National and International Agricultural Research and Extension Programs, Agricultural Development Council Inc., New York, U.S.A.
7. Brown, L.R., 1970. Seeds of Change. The Green Revolution and Development in the 1970's, Praeger Publishers Inc., New York, U.S.A.
8. Changes in Rice Farming in Selected Areas of Asia, 1975. The International Rice Research Institute, Manila, Philippines.
9. CIMMYT Review, 1978. International Maize and Wheat Improvement Centre, Mexico.
10. Dalrymple, D.G. 1974. The Green Revolution: Past and Prospects, Foreign Development Division, USDA and Office of Policy Development and Analysis, USAID, Washington, D.C., U.S.A.
11. Hopper, W.D., 1976. Food Production in India: a perspective, International Development Research Centre, IDRC-066e, Ottawa, Canada.
12. Hulse, J.H., 1977. Research Management, in "Agricultural Research Management, Vol. II. Southeast Asian Regional Centre for Graduate Study and Research in Agriculture (SEARCA), College, Laguna, Philippines.
13. Hulse, J.H. and Laing, E.M. 1974. Nutritive Value of Triticale Protein, International Development Research Centre, IDRC-021e, Ottawa, Canada.
14. Hulse, J.H. and Spurgeon, D., 1974. Triticale, Scientific American, Vol. 231, No. 2, pp.72-80.

15. ICRISAT Annual Report, 1975-76. International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India.

16. Johl, S.D., 1975. Gains of the Green Revolution: How They Have Been Shared in Punjab, The Journal of Development Studies, Vol. 11, No. 3, pp. 178-189.

17. Kappagoda, N., 1978. The Cost of Foreign Aid to Developing Countries, International Development Research Centre, IDRC-TS12e, Ottawa, Canada.

18. Lee, K.T., 1977. Cooperation in Research in Food Technology in Southeast Asia, background paper prepared at the request of the Committee on the Needs of Developing Countries of the IUFoST.

19. Lee, K.T., 1977. Technical Assistance - Improved Relations Between Donors and Recipients, background paper prepared at the request of the Committee on the Needs of Developing Countries of the IUFoST.

20. Report of the Committee on the Needs of Developing Countries of the IUFoST, 1974-1978. Submitted for the Fifth International Congress of Food Science and Technology in Kyoto, Japan.

21. Report of the Second Meeting of the Committee on the Needs of Developing Countries of the IUFoST, 1977. Ottawa, Canada.

22. Report of the First Meeting of the Committee on the Needs of Developing Countries of the IUFoST, 1975. London, England.

23. Report of the Education and Training Committee of the IUFoST, 1974-1978. Submitted for the Fifth International Congress of Food Science and Technology in Kyoto, Japan.

24. Research Highlights, 1977. The International Rice Research Institute, Los Banos, Laguna, Philippines.

25. Russell, E.J., 1931. The Changing Outlook in Agriculture, British Association for the Advancement of Science, Centenary Meeting, London, England.

26. Ryan, J.G. and Asokan, M., 1977. Effect of Green Revolution in Wheat on Production of Pulses and Nutrients in India, Indian Journal of Agricultural Economics, Vol. 32, No. 3, pp. 8-15.

27. Sander, J., 1975. Hunger Can't Wait, International Mineral and Chemical Corporation, Illinois, U.S.A.

28. Science Statistics, 1978. Survey of Industrial Research and Development, Education, Science and Culture Division, Statistics Canada, Catalogue 13-003, Ottawa, Canada.

29. Spensley, P.C., Foda, O. and Rossin, M.C., 1977. Scientific, Technical and Other Professional Support for the Food Industry in Developing Countries - A Commentary on Needs and Institutional Arrangements to Meet Them, background paper prepared at the request of the Committee on the Needs of Developing Countries of the IUFoST.

30. Wortman, S. and Cummings, Jr. R.W., 1978. To Feed This World: The Challenge and the Strategy, The John Hopkins University Press, Baltimore, U.S.A.