Man and His Food

R. H. Clark

"The Government has set up 4,500 camps ostensibly to provide emergency relief for some of the more than 5,000,000 who face starvation. Flesh clings to bones of the adult and child alike. The bodies of children 5 and 6 years old are shrunken. New born babies suck on milkless mother's breasts. The Government has placed armed guards to keep those inside from roaming the Capital's streets causing social unrest." Science Fiction? No, a report from Dacca, Globe and Mail, 21st of October, 1974.

BACKGROUND

Barry Commoner[1] has called the statement "everything in the environment is related to everything else" the first law of ecology. Food, the subject of this lecture, is indeed related to everything else and most importantly to population, energy resources, population density and location, land utilization, politics, pesticides, fertilizers, animal life, the oceans and the atmosphere. As a result, it is not surprising to find divided opinions on the future of Man's food supplies.

Food is Man's most critically important requirement for life. A failing supply of energy, materials or water can be counterbalanced by a reduction of the standard of living and by intensive recycling and greater utilization of materials. Man requires, however, a fixed daily quantity of food. For this reason the lack of food could form the first Malthusian check to population growth. Starvation and malnutrition already dominate the way of life for many in the underdeveloped, overpopulated countries.

[1] Barry Commoner, *Science and Survival* (New York: Viking, 1966).

To assist us in defining a food it is helpful to consider what is considered to be a balanced diet in North America. The recommended daily dietary allowances for the U.S.A. are partially abstracted in Table 1 from those issued by the Food and Nutrition Board, National Academy of Sciences/National Research Council. It should be noted that these allowances are designed for the maintenance of good nutrition for normally active helathy persons in a temperate climate. The calorific value of a food is a measure of its ability to provide the body with energy and maintain its temperature. Fats, starches and sugars form the main energy sources, but in a high protein diet, protein can also supply energy. Proteins provide for the replacement or growth of body tissues and cells, and although on this continent the intake exceeds the allowance, the amount actually required is relatively small, except during the growth period. A whole variety of minerals and vitamins are also necessary, many of which can now be provided in manufactured form. Even this table is subject to change. For example, the 'safe' levels of protein intake have now been revised in 1973 from 2 1/2 to 1/2 gm/kg body weight per day for adults and from 3 1/2 to 1 1/2 for children.

Unfortunately, Table 1 cannot be used to estimate the current food requirements for the global population. Allowances must be made for bodily activity, environmental temperature and humidity, age distribution, and physique of the individuals comprising a given population. In terms of predicting food demands, these factors complicate the estimation of future food requirements, since it is well known that higher nutritional standards improve the physique, extend life, and are important in the development of the mind, if available from the moment of conception. Thus it might be anticipated that if the nutritional standards in some countries are raised, the future nutritional demands will increase. In the future therefore, even more food may be required than indicated by the projections based on the expected increase in population.

These factors and the varying acceptabilities of certain foods complicate the assessment of the global food requirements and present supplies. They demand urgent consideration but they cannot be allowed to form an excuse for delaying action to meet the obvious food shortages which are experienced by two-thirds of the world's population and the needs of the 1 billion persons to be added during the next ten years.

THE FOOD CHAIN

Man is dependent upon the plant kingdom for his life. Georg Borgstrom[2] reminds us that "the Bible has given us a most depictive expression for this fundamental law of nature: 'All flesh is grass'". The conversion of carbon dioxide and water, by photosynthesis, to 'biomass' upon the land and in the sea creates the beginning of a food chain which provides all the food for mankind.

TABLE 1: RECOMMENDED DAILY DIETARY ALLOWANCES FOR THE U.S.A.

Family members	Food energy, Calories	Protein, Grams	Calcium, Grams	Iron, Mg.	Vitamin A, I.U.	B vitamins: Thiamine, Mg.	B vitamins: Riboflavin, Mg.	B vitamins: Niacin, Mg.	Vitamin C (Ascorbic acid) Mg.	Vitamin D, I.U.
Children up to 12 yrs:										
2-6 months (13 lbs)	(1)	(2)	0.6	5	1500	0.4	0.5	6	30	400
7-12 months (20 lbs)	(1)	(2)	0.8	7	1500	0.5	0.8	7	30	400
1-3 years (27 pounds, 34 inches tall)	1300	40	1.0	7	2000	0.7	1.0	8	35	400
4-6 years (40 pounds, 43 inches tall)	1700	50	1.0	8	2500	0.9	1.3	11	50	400
7-8 years (60 pounds, 51 inches tall)	2100	60	1.0	10	3500	1.1	1.5	14	60	400
10-12 years (70 pounds, 57 inches tall)	2500	70	1.2	12	4500	1.3	1.8	17	75	400
Girls:										
13-15 years (108 lbs, 63 inches tall)	2000	80	1.3	15	5000	1.3	2.0	17	80	400
16-19 years (120 lbs, 64 inches tall)	2400	75	1.3	15	5000	1.2	1.9	16	80	400
Boys:										
13-15 years (108 lbs, 64 inches tall)	3100	85	1.4	15	5000	1.6	2.1	21	90	400
16-19 years (139 lbs, 69 inches tall)	3600	100	1.4	15	5000	1.8	2.5	25	100	400
Women: (128 pounds, 64 inches tall):										
25 years	2300	58	0.8	12	5000	1.2	1.5	17	70	
45 years	2200	58	0.8	12	5000	1.1	1.5	17	70	
65 years	1800	58	0.8	12	5000	1.0	1.5	17	70	
Pregnancy (latter half)	+300	+20	1.5	15	6000	1.3	2.0	+3	100	400
Lactation	+1000	+40	2.0	15	8000	1.7	2.5	+2	150	400
Men: (154 pounds, 69 inches tall):										
25 years	3200	70	0.8	10	5000	1.6	1.8	21	75	
45 years	3000	70	0.8	10	5000	1.5	1.8	20	75	
65 years	2550	70	0.8	10	5000	1.3	1.8	18	75	

Any changes which affect this initial process will inevitably affect us whether we consider ourselves to be herbivores or carnivores in the future. No options are open to us if we make such profound changes in the climate, the composition of the oceans or the nature of the land surface that this basic process fails.

Biologists are swift to remind us that all living creatures depend upon this source of life and that the complex interrelationships of living matter are in turn essential to mankind. We should briefly note, therefore, but remember, that when we consider food for man we should also consider the food requirements for other species.

Georg Borgstrom suggests therefore that the total biomass should be evaluated in conjunction with the human population when estimating food requirements. In this context, as will be noted from Figure 1, man is a small proportion of the biomass in terms of population equivalents, with only the domesticated animals included in the estimate.

The primary source of our food and impact of our greater food demands upon other living systems cannot be neglected. Disruption or a breakage of an individual food chain has inevitable and possibly disastrous consequences for man and other living species.

A previous lecture on population indicates that greatly expanded supplies will be required to support a growing population. Some authorities conclude, however, that if all the potentially arable land were cultivated to the European level of productivity the earth could only support the present population at the European dietary level. What then are the prospects for finding more food for the hungry and those yet unborn? Can new sources be developed without an ecological breakdown? These are the questions which need answers. Co-ordinated research and studies of exceptional breadth and depth are needed in this vital complex field. At the best this paper can only indicate possible trends and solutions.

CURRENT FOOD SUPPLIES

Data for the production and consumption of food for the selection of countries considered in the analysis of the population statistics are reported in Table 2. The dependence of some nations for their food supplies upon the export of manufactured goods will be noted. The importance of national independence for food, at the present time, may also be inferred. For example, it can be deduced that India cannot rely upon food imports to feed the future increase in its population even if India could afford to make these purchases. The quantity of cereals required would be equivalent to approximately 10 times the current production of Canada.

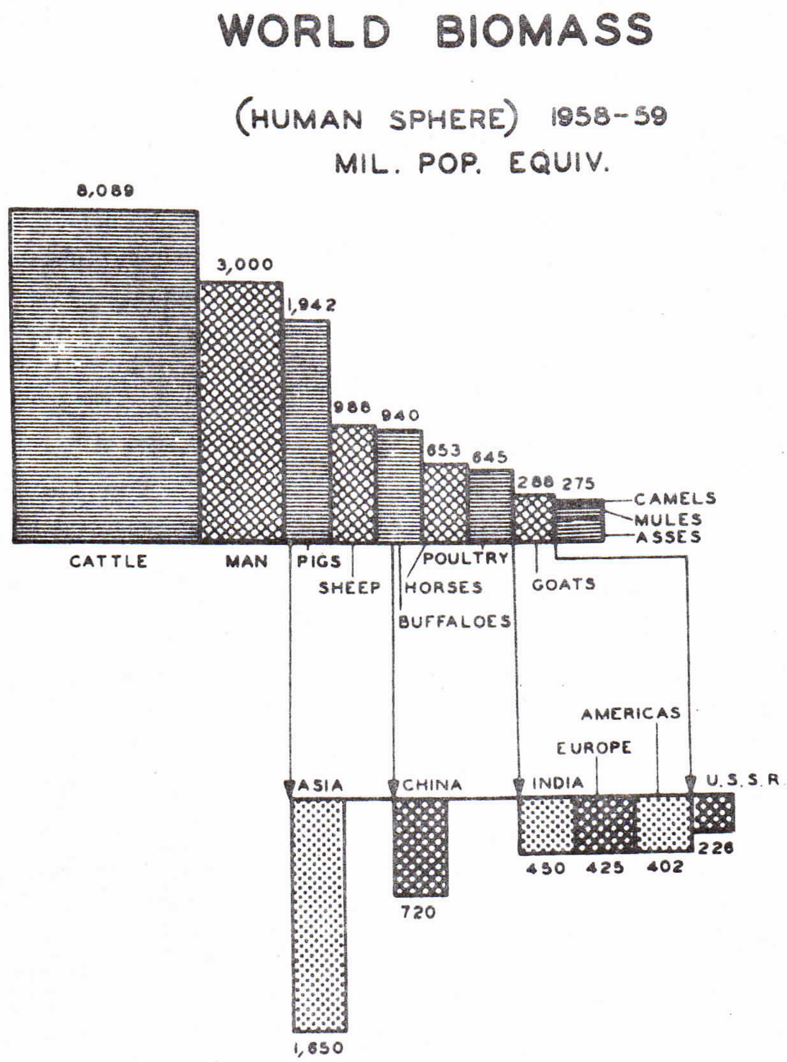


FIGURE 1. THE LIVING MASS WHICH DIRECTLY IS PART OF THE HUMAN BIOSPHERE. BESIDES MAN ARE THE VARIOUS LIVESTOCK CATECORIES REQUIRED FOR TRACTION AND OTHER WORK BUT LARGELY FOR THE RAISING OF ANIMAL PRODUCTS (MILK, MEAT, EGGS, ETC.). INDIRECTLY, MAN IS ENJOYING THE SUPPORT OF A FAR GREATER BIOMASS, REPRESENTED BY THE LENGTHY BIOCHAINS OF OCEANS AND FRESH WATERS, TERRESTRIAL WILDLIFE, AS WELL AS SOIL ORGANISMS AND A WEALTH OF MICRO-ORGANISMS. (Reproduced from Georg Borgstrom, 1967, with permission).

From the information given in Table 2, the relationship between calories and proteins consumed per capita has been plotted in Figure 2. A relatively good correlation is observed with the richer countries exhibiting a higher intake of both calories and proteins. The data indicate, however, that the populations of the richer countries eat a greater proportion of proteins, probably as meat, whereas those in the poorer countries are more dependent upon proteins contained in cereals.

If energy consumption per capita is used as an indication of wealth it is clear from Figure 3 that the cereal consumption declines with affluence but also decreases with extreme poverty. The consumption of food calories also increases with affluence as shown in Figure 4.

The importance of national income is also emphasized by the remarkable correlations reproduced in the U.N. Food and Agricultural Organization publication, *The State of Food and Agriculture, 1955*. Without wealth, food production is limited and its importation is restricted. For this reason less than 10 percent of the world's food supplies are exchanged on the international market. The productivity and requirements of individual nations are therefore of dominant concern.

Figure 5, illustrates the variation of land available and its utilization for a number of countries. It will be noted that countries having at least one acre of cultivatable land per capita are not necessarily stimulated to use the land as efficiently as those below this level. The most remarkable comparisons are to be found in the effective use of land by those nations with a high population density, particularly emphasized by the contrast between Japan and India. There might appear to be great scope for counterbalancing the increased demand for food by the introduction of more intensive cultivation methods. This conclusion is reinforced by consideration of the comparative rice yields per acre. A sixfold variation in yield is observed with many of the densely populated countries reporting a yield on only one-fourth the yield in Spain or Australia.

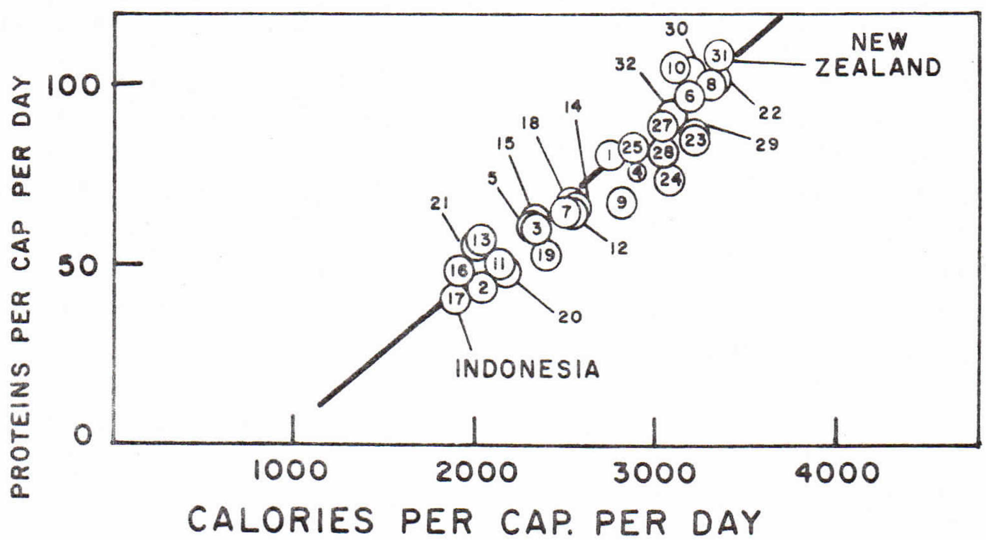


FIGURE 2. THE RELATIONSHIP BETWEEN CALORIES AND PROTEIN CONSUMED PER CAPITA. (Based on United Nations data).

TABLE 2: IMPORTANT FOOD STATISTICS FOR SELECTED COUNTRIES

(from *United Nations Statistical Yearbook 1974*)

(a) Available Food Supplies (in thousands of metric tons) with Percentage of Supplies Produced shown in brackets

Reference No.	Region or Country	Wheat and Rye	Rice	Potatoes	Meat
	AFRICA				
1	Egypt	3,463(44)	974(174)	478(124)	364(92)
2	Ghana	65(-)	70(44)	3,766(100)	49(65)
3	Nigeria	213(9)	229(100)	27,801(100)	672(100)
4	S. Africa	1,107(76)	71(8)	439(100)	832(104)
5	Liberia	4(-)	153(71)	353(100)	10(80)
	N. AMERICA				
6	Canada	4,324(422)	42(-)	2,394(105)	2,047(101)
7	Cuba	886(-)	325(16)	717(92)	291(96)
8	U.S.A.	21,825(176)	1,024(293)	14,478(106)	22,787(99)
	S. AMERICA				
9	Brazil	4,122(44)	5,003(102)	34,733(101)	3,215(105)
10	Argentina	4,102(140)	84(238)	3,072(102)	2,922(127)
11	Columbia	150(36)	218(100)	1,626(100)	273(101)
12	Chile	1,721(73)	85(59)	666(98)	389(95)
	ASIA				
13	China	31,351(82)	57,678(101)	116,895(100)	12,963(100)
14	Taiwan	594(2)	2,196(106)	4,060(100)	395(102)
15	Hong Kong	111(-)	355(3)	88(19)	149(67)
16	India	22,560(89)	39,414(100)	9,631(100)	-
17	Indonesia	417(-)	13,257(93)	12,182(102)	452(100)
18	Japan	5,207(9)	11,041(104)	6,361(97)	1,831(89)
19	Pakistan	7,753(87)	13,913(101)	2,007(100)	460(100)
20	Viet Nam(s)	147(-)	6,032(91)	2,159(100)	428(100)
21	Saudi Arabia	342(42)	120(2)	11(10)	59(97)
	EUROPE				
22	France	10,055(147)	163(40)	8,724(103)	4,685(92)
23	Germany W.	10,087(87)	109(-)	17,892(84)	4,881(87)
24	Germany E.	4,478(75)	50(-)	13,047(98)	1,071(94)
25	Portugal	1,001(70)	126(107)	1,209(101)	285(95)
26	Spain	4,605(108)	203(139)	4,834(99)	1,346(91)
27	Italy	10,381(93)	299(149)	4,319(92)	2,645(78)
28	Sweden	952(125)	12(-)	1,329(112)	426(105)
29	U.K.	9,437(45)	123(-)	7,631(95)	4,200(68)
	OCEANIA				
30	Australia	2,380(443)	34(459)	777(102)	1,410(158)
31	New Zealand	362(79)	4(-)	283(105)	310(338)
32	U.S.S.R.	82,384(112)	671(57)	90,057(100)	8,918(99)

TABLE 2: (cont'd)

(b) Food Consumption (per capita per day)

Reference No.	Region or Country	Cereals (g)	Meat (g)	Milk (g)	Calories	Protein (g)	% Animal Protein	Energy (Kg Coal Equiv.)
	AFRICA							
1	Egypt	565	32	135	2,770	80	7	.772
2	Ghana	191	16	13	2,070	43	3	.526
3	Nigeria	283	28	17	2,290	60	7	.162
4	S. Africa	443	113	222	2,730	77	19	7.93
5	Liberia	343	33	22	2,290	41	4	1.00
	N. AMERICA							
6	Canada	183	257	619	3,200	97	46	25.5
7	Cuba	297	111	216	2,500	63	16	3.15
8	U.S.A.	176	310	689	3,300	99	40	30.81
	S. AMERICA							
9	Brazil	272	84	195	2,820	67	14	1.37
10	Argentina	250	335	338	3,160	105	35	4.85
11	Columbia	175	91	301	2,140	50	20	1.75
12	Chile	321	108	231	2,560	66	21	4.15
	ASIA							
13	China	387	47	9	2,050	57	9	1.54
14	Taiwan	459	75	20	2,620	68	15	-
15	Hong Kong	323	111	52	2,370	65	21	2.85
16	India	384	4	116	1,990	49	5	.51
17	Indonesia	344	10	5	1,920	43	2	.34
18	Japan	352	48	137	2,470	77	15	8.95
19	Pakistan	496	11	208	2,410	55	11	.26
20	Viet Nam(s)	486	27	13	2,200	49	7	.45
21	Saudi Arabia	412	32	94	2,080	56	8	2.71
	EUROPE							
22	France	219	256	630	3,270	103	41	10.76
23	Germany W.	189	220	567	3,180	83	43	14.31
24	Germany E.	270	171	316	3,040	76	37	-
25	Portugal	329	95	183	2,920	82	19	2.21
26	Spain	305	112	297	2,770	80	21	4.42
27	Italy	353	136	394	3,020	88	21	7.35
28	Sweden	168	142	721	2,850	80	42	16.68
29	U.K.	200	209	592	3,170	87	43	15.09
	OCEANIA							
30	Australia	216	294	646	3,220	106	41	14.68
31	New Zealand	212	305	740	3,380	108	50	8.04
32	U.S.S.R.	428	106	476	3,180	92	21	12.42

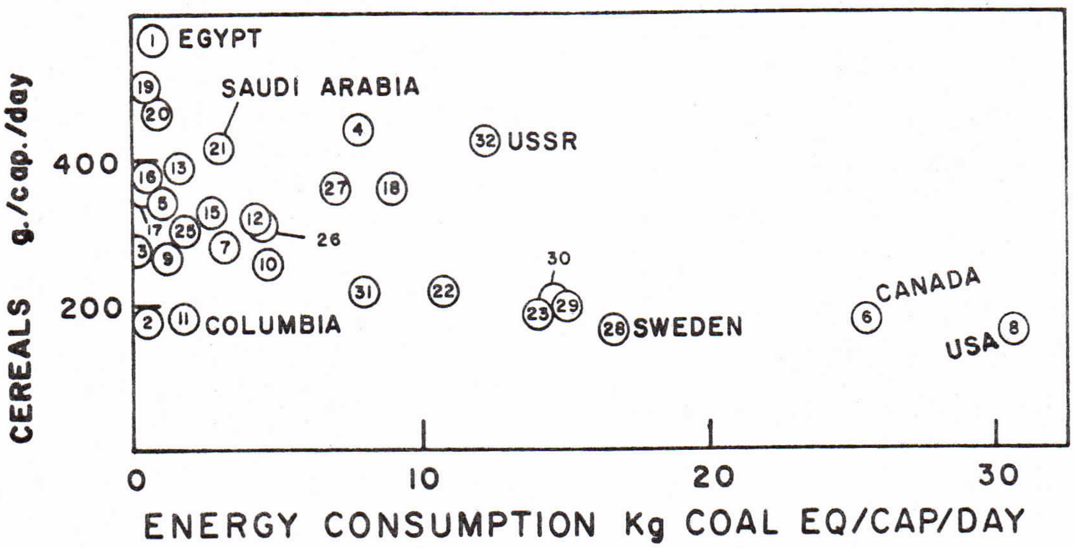


FIGURE 3. THE RELATIONSHIP BETWEEN ENERGY CONSUMPTION (AN INDICATION OF WEALTH) AND CEREAL CONSUMPTION. (Based on United Nations data.)

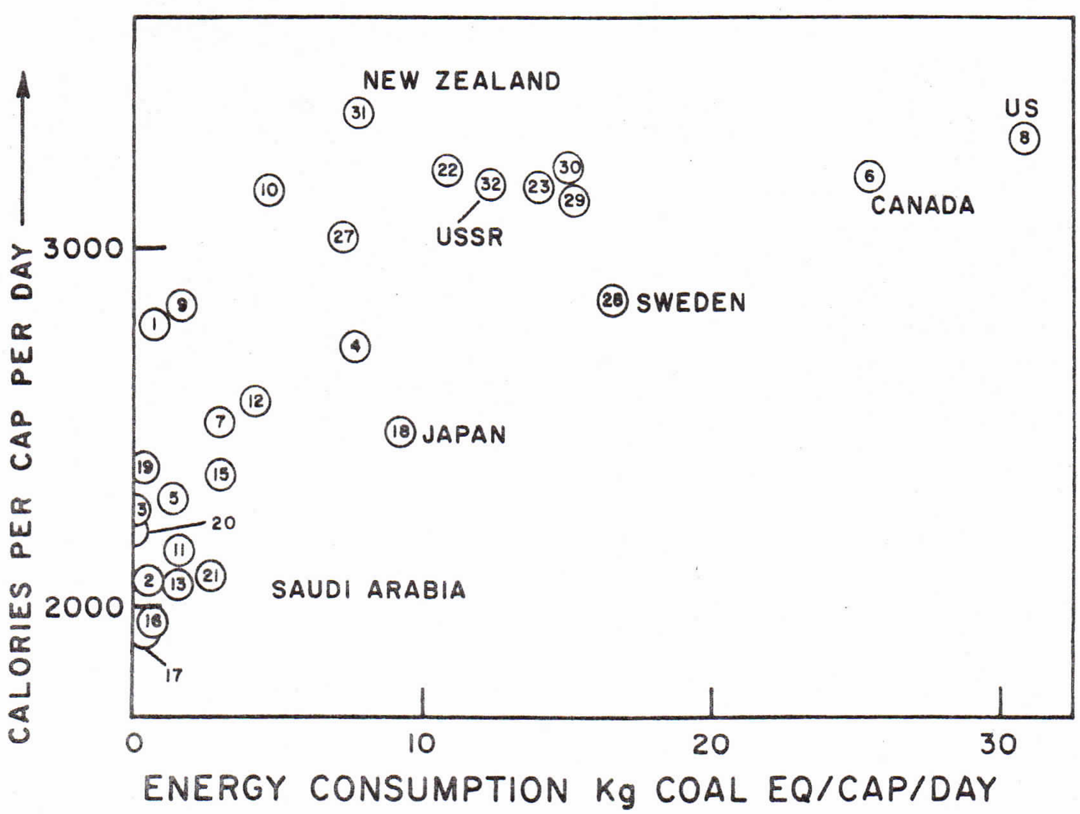


FIGURE 4. THE RELATINNSHIP BETWEEN ENERGY CONSUMPTION (AN INDICATION OF WEALTH) AND CONSUMPTION OF FOOD CALORIES. (Based on United Nations data.)

One should be aware, however, of the shortcomings of this simple analysis. Climate has a profound affect on growth rate irrespective of the rainfall and soil quality. A variation of night temperature by itself can cause a fourfold change in growth for some plants. The length of the day is also of fundamental significance in assessing the productivity of land. A complete analysis of the levels of productivity in relation to the maximum feasible productivity is required for individual areas, but the necessary information was not available to the author and may not in fact exist.

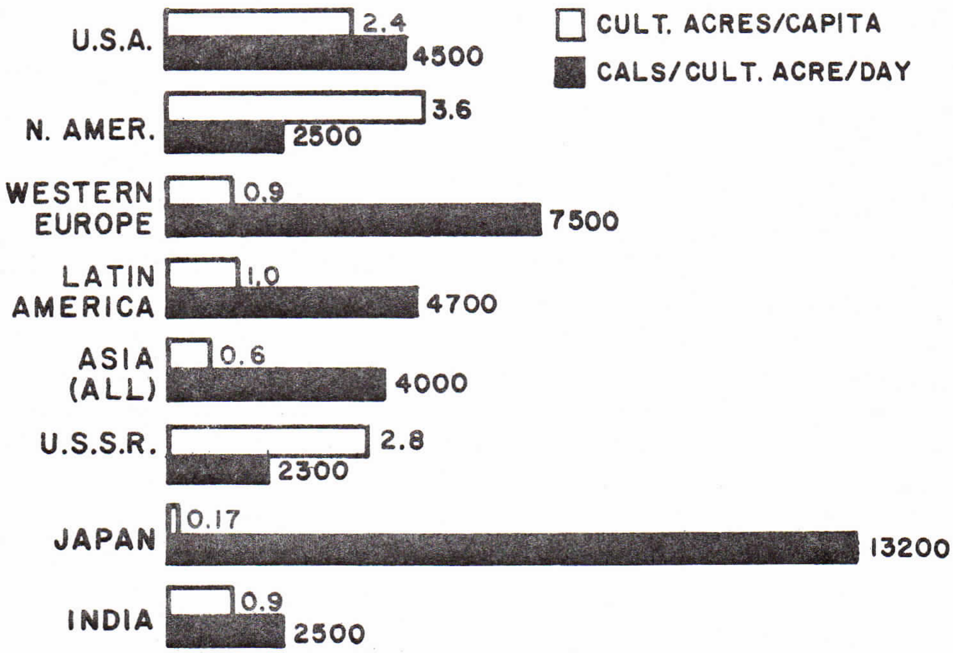


FIGURE 5. AGRICULTURAL LANDS AND PRODUCTION

Increased productivity requires capital however, for irrigation projects, artificial fertilizers and farm machinery. The unequal distribution of the world's income, agricultural production, land and population is such that the richest countries tend to have the least population, the most agricultural land, and the highest agricultural production, or can import their food. The opposite circumstances are found for nations in which there is a need for a greatly increased food supply.

To a large measure this imbalance results from chance historical events rather than from fundamental differences in the attitudes, intelligence and work of the respective populations. This imbalance is difficult to adjust. Wtih an inadequate nutritional standard a population becomes indifferent to problems, and less active both physically and mentally. Without energy, ambition and knowledge, however, the nutritional standards will not be improved. Extensive long-term, external assistance would appear to be the only means to break this negative feedback loop which, in conjunction with population increases, tends to steadily reduce the nutritional standards of the poorer countries.

The land occupies approximately thirty percent of the world's surface. Excluding Antartica this amounts to 52.4 million square miles or 33.5 billion acres (52.4 x 640). Only about 4.25 billion acres, i.e. approximately 13 percent of the total earth's surface, is now under cultivation.

As a general rule, one acre of fertile land has been considered sufficient to supply the food requirements of a single individual. Thus the present area now under cultivation should be capable of supporting a population of 4.25 billion. Regrettably, with only a 3.8 billion population it is estimated that at present two-thirds of humanity is undernourished. **"France, Sweden and Denmark, with about one acre per capita, all achieve self-sufficiency. India and Pakistan, on the other hand, lie very close to the boundary between self-sufficiency and dependency with 0.8 acres per capita. China, with 0.5 acres, is a chronic food importer, while England, with 0.4 acres per capita, despite high yields and intensive farming must import significant amounts. In contrast, the U.S.A. has 2.9, Australia 4.0 and Canada 6.5 acres per capita, enabling all three countries to export** large quantities of food"[3]. Georg Borgstrom demonstrates, however, that cultivatable acres per capita is a poor guide to the intensity of demand. The total biomass, in population equivalents, should be used in place of population. If this is done a very different picture emerges in some cases, as illustrated by the comparison between India and China (see Figure 6).

[3]**Philip Wagner, *Environment and Man* (Norton, 1971).**

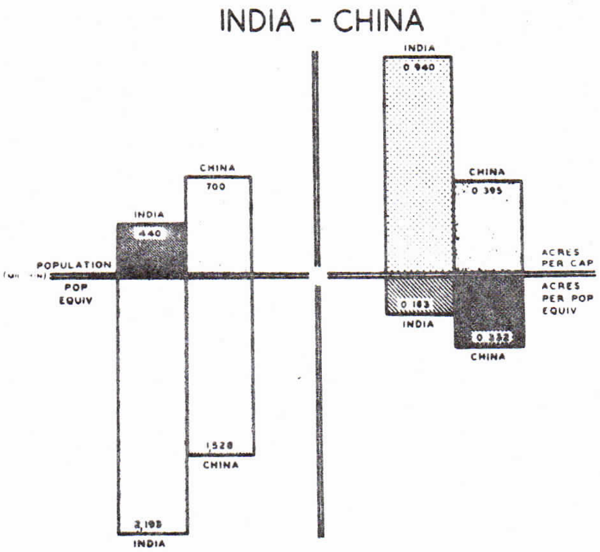


FIGURE 6. COMPARING AGRICULTURAL SOIL RESOURCES OF CHINA AND INDIA IN RELATION TO POPULATION. CONVENTIONALLY, CHINA IS CONSIDERED TO BE IN A LESS FAVORABLE POSITION AS TO TILLED LAND AVAILABLE PER INHABITANT (see top part of diagram, above horizontal center line). WHEN THE FEEDING BURDEN REPRESENTED BY THE LIVING MASS OF THE LIVESTOCK, IN POPULATION EQUIVALENTS, IS TAKEN INTO ACCOUNT THEIR RELATIVE STATUS IS REVERSED (see lower section of diagram). (After Borgstrom, 1967.)

CURRENT ATTITUDES

It would appear that the current problem is largely generated by poor farming techniques, maldistribution of food supplies, population outstripping the local food resources and by national policies which in extreme cases financially discourage farm production. Thus it might be claimed that with international goodwill, appropriate education and the revision of attitudes, the current world population could be supported at a satisfactory standard of sustenance. It is interesting to note two viewpoints on why this happy state has not been attained.

The Marxist viewpoint in 1966 on this matter is clearly expressed by I. Adabashev[4]. After denouncing Malthus' "vicious theories" attributing the poverty of the proletariat to the inevitable laws of nature rather than to capitalist exploitation, he describes population control as a "barbarian way to salvation which is rejected by an indignant mankind". He adds that "people are well aware that hunger is a concomitant of Capitalism" and that "the best way to save the situation is to end capitalism with all possible dispatch".

The President's Science Advisory Committee Panel on World Food Supply reported in contrast that

> *"The situation as the Panel now views it after nearly a year of study, is that hunger and malnutrition are not primary 'diseases' of the last half of the 20th Century. Rather, along with the so-called population explosion they are symptoms of a deeper malady - the lagging economic development of Latin America, Asia and Africa in which nearly two-thirds of the people of the earth now live."*

This abstract does not fairly summarize the P.S.A.C. 1200-page report entitled *The World Food Problem*, but it correctly portrays the economic bias of American thinking on this subject.

Both countries are viewing the same situation, some aspects of which are vividly depicted by the following excerpt from an old Eli Lilly Company Newsletter, updated by the inclusion of 1975 figures:

> *"If all the people in the world could be reduced proportionately into a theoretical town of 1000 people, the picture would look something like this: In this town there would be 60 Americans and Canadians with the remainder of the world represented by 940 persons; the 60 Americans and Canadians would have half the income of the entire town with the other 940 dividing the other half. About 300 of these would be practicing Communitsts with others under Communist domination. White people would total 250 with 750 being non-white.*

[4] I. Abadashev, *Global Engineering* (Moscow: Progress Publishers, 1966).

> *The 60 Americans and Canadians would have 15 times as many possessions per person and produce or buy 5 times as much pood per person as all the rest. Since many of the 940 non-North Americans in the town would be hungry most of the time it would create ill feelings toward the 60 Americans and Canadians who would appear to be enormously rich and fed to the point of sheer disbelief by the great majority of the townsfolk. On their part the Americans and Canadians would donate less than 3/4 of one percent of their income to help the town's poor."*

The differing U.S.A. and Communist viewpoints, previously noted, are understandable upon examining this simplified model. It should be remembered, however, that this hypothetical town does not truly depict the dynamic, politically unstable, dispersed world community in which vast disparities of natural resources and educational and industrial standards are enhanced by the generally higher population growth rates of the underprivileged. By the year 2000, the relative affluence of the Americans in this hypothetical town may even increase further, as their numbers, as a percentage of total population, decrease.

The critical problems of the underdeveloped countries are magnified by the fact that contrary to Malthusian doctrine many of these countries have the highest population growth rates in the world. Even in this brief review it will be recognized that the technology and techniques are available to assist these nations but the current efforts will have to be greatly expanded immediately to avert an impending human disaster of frightening magnitude. If this is not accomplished the more fortunate nations will in James Bonner's words, "begin to regard the starving population of the underdeveloped nations as a race or species apart, people totally different from us, as indeed they will be. 'They are just animals' we will say and 'a serious reservoir of disease'. The inevitable culmination of the two cultures will be that one culture will devour the other."

In the last few years much has been written on the achievements of the "Green Revolution". It has been claimed that agricultural productivity can be, and has been, significantly increased by technological and economic means in the underdeveloped countries involving the introduction of high-yield hybrid varieties of crops, the extension of the use of fertilizers, pesticides and irrigation, and mechanisation of the agricultural processes.

In parallel with other revolutions, the "Green Revolution" has not been painless and has given rise to other problems. The peasant class in the underdeveloped countries in many instances has not been able to adapt to the changing agricultural methods and there is a tendency, as previously witnessed in the Western world, for the population to migrate from the rural to the city areas. There is evidence that increased food productivity at a local level has tended to increase the birth rate, which if widespread could negate the benefits of the revolution. The ecological effects of multi-cropping and increased use of fertilizers also need further serious consideration. For example, it has been reported that in some cases the workers have been unable to properly harvest the second crop since they have suffered from a protein deficiency, caused by the disappearance of fish which bred in the flooded areas between the annual cropping periods and which formed their staple protein diet. Even more serious are the reports that the so-called miracle grains are tasteless and unpalatable, thereby reducing their acceptance. Some authors also believe that the increased productivity in the late 1960's might be largely ascribed to favourable natural events and point out that the cost of the revolution in terms of fertilizers, water and equipment is too high a price to pay for what might prove to be marginal benefits.

It is, however, too early to judge whether the green revolution will succeed, but these are the signs that it has failed to meet the expectations of its proponents. Perhaps it would be wiser to seek a green evolution, instead of a revolution, and thus permit the multitude of factors affecting food production and utilization to be given further thought.

To summarize the current situation and attitudes one might conclude that the solution to the present problem resides not so much in the realms of science and technology as in the fields of politics and economics. Once again it could be that the world is looking for a technical answer where none can exist. The food crisis now being experienced by the underdeveloped countries can be overcome by making international and national social and economic decisions. The technology and resources are adequate to support the world's current population.

FOOD FOR THE FUTURE

Unfortunately the world will not stand still for us to solve the current problems, and these problems intensify with time. If the world population nearly doubles by the year 2010 and continues to increase at an exponential rate, the "future" is of immediate concern and methods of greatly increasing our food resources will need to be urgently explored. We must make provision now, for example, for the approximately one million persons being added to India's population each month.

Consideration of the future possibilities for increased food production has been too long in coming. There are four approaches which could be employed either individually or simultaneously: more land might be converted for agricultural use; increased productivity might be obtained from present agricultural areas; man might be encouraged to change his diet; and finally new foods might be devised. The details and limitations of each approach are summarized under the following headings:

(1) The Cultivation of New Land

As previously mentioned, approximately 13 percent of the land is cultivated at this time, comprising some 4.25 billion acres. Some optimistically believe that this could be raised to 6 billion acres, with a further 8 billion utilized for grazing. The remainder of the earth, constituting approximately one half of the total, is tundra, desert, mountainous or ice-covered, and offers very limited opportunity for food production even allowing for the most favourable predictions of future innovations.

The current land requirement is approximately 1 acre of cultivated land per person with a further acre for grazing land. Thus, on this basis the world might be expected to support approximately 6 billion people or about the population now predicted for the year 2,000. However, there are immense difficulties involved in preparing this additional potentially cultivatable land. If it were not so this land would already be under cultivation in many parts of the world.

To develop this new land, new techniques are required for preparing the soil, supplying nutrients, and creating new strains of plants. Supplementary water, supplied either by standard irrigation methods or by innovative techniques, will be needed in many areas.

The greatest demand for the development of new areas will be for water. Proponents of water desalination and irrigation of the desert lands in tropical regions claim that by year-round, scientifically managed cropping, much can be achieved. The case for optimism is well presented by G. Young[1] He reports the data for water consumption by various crops shown in Table 3. Quite rightly, he emphasizes the large water requirements of rice and reports a recent experiment in which the water requirement was reduced to 107 gallons per pound using a periodic watering technique.

For a large farm using desalinated water he estimates that the capital costs will be $950 per acre and operating costs $75 per acre excluding the cost of desalinated water. The costs of growing grain would

TABLE 3: WATER CONSUMPTION BY VARIOUS CROPS (after G. Young, 1970).

Crop	Yield, 10^3 lb/acre	Food Value, 10^2 Cal/lb	Water Use	
			Gal/lb	Gal/2500 Cals
Wheat	6.0	14.8 (9.7)	91	153
Rice:				
India	1.36	16.5 (1.81)	1800	2720
Japan	4.8	16.5 (8.6)	900	1360
Australia	5.35	16.5 (9.7)	530	800
Potato	48	2.79 (14.6)	9.0	80
Tomato	60	0.95 (6.25)	8.6	226
Orange	44	1.31 (6.32)	33	630

NOTE: Figures in parenthesis are the number of people supportable per acre at a caloric intake of 2,500 cals. per day.

then be as given in Figure 7. As an additional advantage it is claimed that the large desalination plants could be constructed to provide power in addition to water.

Such projects may in fact extend the degree and intensity of land utilization but the capital and operating costs together with the heavy demand for energy may well defer their introduction.

Each area of potentially cultivatable land has special requirements. Water, fertilizers and machinery will be required to bring these new acres under cultivation. Limitations in these resources and finances lead most authorities to conclude that any increase achieved by bringing new land under cultivation will not match the increase in population. It is unlikely therefore that the demands of a doubled population in thirty years can be met solely by increasing the percentage of cultivated land.

(2) Better Utilization of Existing Cultivated Land

Figure 8 shows the relative sizes an ear of corn produced today compared to its counterpart of 4000 years ago. Man has now learned how to improve the major crop plants and farm animals to almost the same dramatic degree.

For example, the International Rice Research Institute developed the 1R8 strain in 5 years that has now increased rice production in one instance from 710 to 10,000 pounds per acre, a 14-fold increase, in areas where it can be intensively cultivated. In the few years since its development it has been planted on 20 million acres in Turkey, India, Pakistan and the Phillipines. However, as previously noted, fertilizers and

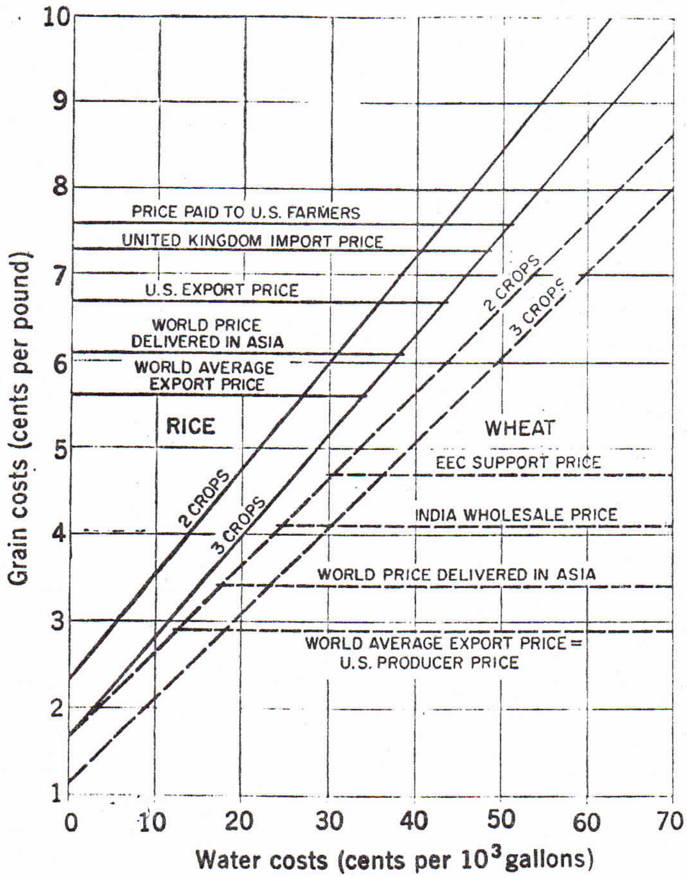


FIGURE 7. THE COSTS OF GROWING GRAIN. (From Gale Young, 1970, Fig. 1, p.342, with permission. Copyright 1970 by the American Association for the Advancement of Science).

water are required, however, which are not in over-abundant supply in the underdeveloped nations for the continuity and development of these projects.

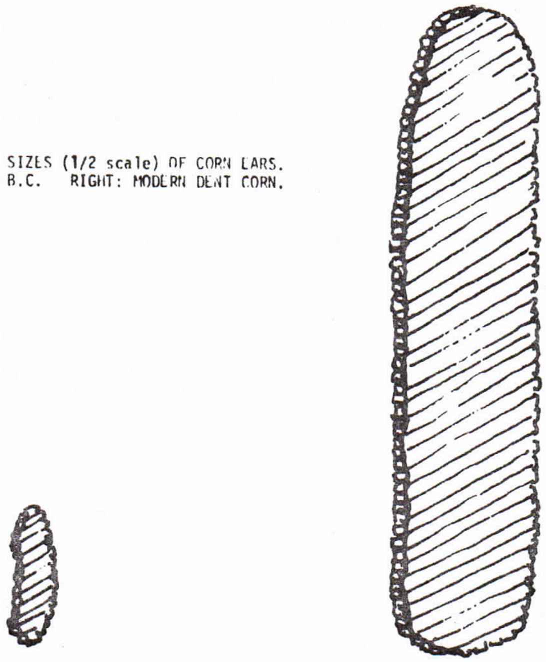
Triticale, a cross between wheat and rye, developed by the University of Manitoba, is another example of the creation of a new species. It provides a greater yield, is hardier and has a higher protein content than either rye or wheat.

Similar strides have been made in the selective breeding of livestock and in their intensive rearing. The result has been earlier maturation times and greater protein, food or milk production with less waste of feed materials.

Those who criticize the use of artificial fertilizers, herbicides or pesticides should realize that the necessary tremendous increases in food production required in the last two decades have been made possible by these means. Development of these materials will continue to increase the degree of land utilization. Those responsible for their development and use are now aware of the possibilities of unwanted side effects and the possibility of their eventual assimilation by living organisms, and new products and techniques are being explored. The use of biological techniques for pest control and the possible creation of leguminous new species may in the end supersede the more brutal chemical approach.

Man is learning to live with nature rather than attempting to impose his own conditions. As a further example, wild game, an unexploited source of protein, is found to be more efficient at grazing and production of protein than many domesticated species. The possibility of using a larger percentage of the grazing land by farming wild game is now being considered.

FIGURE 8. COMPARATIVE SIZES (1/2 scale) OF CORN EARS. BELOW: 2000 B.C. RIGHT: MODERN DENT CORN.



Serious attention is now being given to reducing the losses of food, not only in the growing operations but during storage and distribution. These losses are significant, and range from approximately 10 to over 50%, depending upon the type of food and the storage and distribution system. Losses caused by natural catastrophes have been regarded as unavoidable, but even in this case reductions in lost capacity may be partially avoided by better management and utilization of technology. To a great extent, however, a program to reduce these losses requires capital and operating expenses which might be currently beyond the means of the underdeveloped nations. Losses incurred at the consumer level by either extravagance or neglect would appear to be more significant in the developed countries, but if the food supplies are considered a global resource such losses would seem to be inexcusable. The elimination of losses in global food production presents a challenge, but it would seem to be worthy of special consideration. The return on the investment may prove to be far greater than that obtained in developing new cultivatable areas.

Many authors, in analysing the possibility of increasing the productivity of existing agricultural land, have concluded that since only the U.S.A. has managed to obtain an annual 2 percent growth in agricultural production, little hope of significant advances can be expected on a world basis. This would appear to be an overly pessimistic conclusion if only for the reason that many countries have only just begun to change their farming and food handling methods which have been traditional for centuries. It is quite possible that the existing cultivated lands will, by increased productivity and reduced losses, support twice the present world's population. There is, however, an upper limit to the amount of food which can be grown on these cultivated lands. The first restriction will be imposed by the quantity of water and fertilizers available, which in turn will depend on the state of the world's energy resources.

(3) The Effect of Dietary Change

About 50,000 pounds of phytoplankton are required to produce 1 pound of cod fish, or a whole acre of land must be devoted to providing a pound of steak protein per week. Both cod fish and steak are desirable foods, and as previously noted the more affluent nations tend to favour such high protein foods, many of which are at the end of the food chain.

These food habits are illustrated by the fact that to provide high protein foods approximately 11,000 calories of food are produced in the U.S.A. per capita, most of which is used to feed animals, whereas in Japan with a low animal protein diet the total food production is almost equal to the food consumption per capita.

Table 4 lists the production of protein per acre by different methods of land management. It is obvious from this table that in terms of protein production the productivity of land could be increased over 30 times if protein extracted from alfalfa was considered to be an acceptable substitute for beef protein. Changes in diet, particularly those involving a switch to foods at the beginning of the food chain, could allow the world to support a far greater population. For example, it is probably possible to harvest 100 million tons per year of fish on a continual basis from the sea, i.e. only approximately 1 pound per person per week for everyone on earth. With present techniques approximately fifty percent of the catch is available for human consumption, thus reducing this figure to 1/2 pound. If, however, we developed the taste for and means for harvesting zooplankton, for example, each person on earth could choose to eat at least 50 pounds per week, or it alone could supply the protein necessary for ten times the present population of the earth!

TABLE 4: PRODUCTION OF PROTEIN PER ACRE BY DIFFERENT METHODS OF LAND MANAGEMENT. (After H. Brown, *The Next Hundred Years*, Viking, 1957, P. 71)

Method of Management	Method of Recovering Protein	Edible Protein, lbs/acre/year
Planted to Forage Grain Fed to Steers	As Beef	43(1.2)
Planted to Forage Silage Fed to Cows	As Milk	77(2.1)
Planted to Soybeans	As Soybeans	450(12.33)
Planted to Alfalfa Average U.S.	As Extracted Protein	600(16.4)
Planted to Alfalfa	As Extracted Protein	1500(41.1)

NOTE: Figures in parenthesis are the numbers of people supportable per acre at a protein intake of 0.1 lbs. per person per day.

Care is needed in evaluating alternative protein sources since one or more of the essential amino acids (lysine, methionine, phenyl-alanine, tryptophan, leucine, isoleucine, threonine and valine) may not be present in adequate quantity. Thus the protein content of different foods cannot be precisely equated. Nevertheless, it is clear that a change of diet, involving a greater use of vegetables and foods at the beginning of the food chain, would allow for a significantly greater food supply.

However, even such 'obvious' actions should not be undertaken without considerable thought. The effect of harvesting zooplankton on a large scale, for example, would profoundly change the fish population to the extent that some species would become extinct and the world catch would be severely reduced. Georg Borgstrom (in *The Hungry Planet*) emphasizes that the sea is not a future source of limitless food, and that already with the oceans contributing "close to one-fifth of the global consumption of animal protein", the limit is being approached. International agreements on fish culture and harvesting would appear to be of vital and immediate importance and should certainly precede any large scale attempts to harvest zooplankton or fish at the beginning of the food chain.

In terms of caloric content there are many alternative methods for providing a daily intake of between 2,300 and 2,500 calories. This energy source for man is equivalent to approximately 600 grams of sugar and 300 grams of fat. It is conceivable that this reqirement could be supplied by the large scale conversion of cellulose to sugars and oil from rape seed, combined with cellulosic material as a filler and the rape seed residue, which contains approximately 50 percent protein, to support the protein requirement. Alternatively, as may be seen from Tables 3 and 4, the future diet could consist of approximately 1/5 lb. of potato and 1/3 lb. of soybean per day. With this basic diet augmented with vitamins and innert filler material each acre of land could support at least 6.5 people or a world population of 28.3 billion could be fed by merely using the acreage now under cultivation.

Food has been a source of pleasure to Man, but if in future it is merely regarded as body fuel then changes in diet would allow the world's population to be greatly expanded. Perhaps better estimates already exist for the ultimate world population which could be supported by a radical change without increasing productivity levels or the area farmed. It is clear, however, that considerable reserves are at Man's command, if we are prepared to accept food as a body fuel with little regard to its taste or appearance.

(4) Future Technology

From the preceding sections of this paper it might be concluded that new technology is required for a very broad spectrum of endeavours concerned with food production. Technology is needed to support the "Green Revolution" with its heavy demands for water, fertilizers and pesticides, and to ensure that food wastage in harvesting, distribution and storage is minimized. New technology will be required to implement scientific discoveries relating to the cultivation of hybrid plants, animal husbandry, and the controlled utilization of the oceans' resources. Traditional technology adapted to satisfactorily develop new cultivatable land, will also be necessary.

These functions for new technology are overshadowed, in the public's conception, by possibilities of a spectacular breakthrough in food production, for example, the development of a daily pill to supplant food, as it is currently defined. Although this pill concept belongs in the realm of science fiction, there have been spectacular developments.

One of the most exciting discoveries is the commercial potential of extracting proteins from microorganisms utilizing hydrocarbons as a nutrient source. It is estimated that the equivalent of all the animal protein needed today could be produced in this way from approximately 3 percent of the current oil production. Processes of this type are now in development scale operation. B.P., for example, have operating units at Grangemouth in England and Laverne in France, and the nutritional characteristics and utility of the products as an animal feed have been established.

There are technical and long-term problems associated with the production of proteins from petroleum products. To avoid toxic side products, a carefully fractionated hydrocarbon source is essential and purification steps must be included. Furthermore, in view of the already rapid depletion of the oil reserves and the high capital costs of the processes the long term viability is debatable.

For these reasons, other companies have concentrated upon developing more appealing foods from natural foods. For example, Courtaulds will soon test market a textured protein food named Kesp. It is manufactured from the field bean, vicia faba L, and is spun into a product which provides a meat-like texture, and which can be given a chicken or beef flavour. A number of other manufacturers are developing products from the Soybean. Soy flour contains 50 percent protein, markets for 20 to 25 cents per pound and has few deficiencies, except for methiamine as a protein source. It can be concentrated to provide 70 to 80 percent protein at a cost of 30 to 45 cents per pound. These valuable products are likely, therefore, to become important protein sources for the future. Currently they are being used in Canada as a 'level ingredient' (2%) in enriched breads, as a meat extender (10-30%) in products like 'burgers' and to a limited extent as meat analogues (100%) in spun flavoured products to simulate steaks. The use of cottonseed to produce a protein flour at 35 cents per pound, which is water soluble, is another alternative and one which cotton growing nations of the underdeveloped world could find to be important. The business world estimates there will be a rapid growth in these products, but it should also be noted that the average price is estimated to be 40 cents per pound for extruded vegetable protein and 90 cents per pound for the textured material.

Other food sources under active consideration are the food, agricultural and human wastes. For example, fish wastes can be converted into fish protein meal suitable for human consumption. A Canadian plant to treat whole fish was constructed in 1969 in Nova Scotia to produce fish protein without wastage at a cost of approximately 4 million dollars.

Unfortunately, although the product would supply the protein needs of 1/2 million persons, it did not meet the current market demands and the plant is now being dismantled and sold for scrap. Similar efforts to produce food from more obvious and objectionable wastes may suffer the same fate at this stage but their future potential should not be dismissed.

The utilization of wastes for animal feed has a long history but is being rapidly developed, and this may lead, eventually, to their utilization for human food production. The University of Guelph reports, for example, that chicken excrement can be treated and fed to ruminants or even fed to chickens and recycled up to seven times without any noticeable deterioration of growth or egg-laying capacity. The use of human wastes in this fashion is conceivable if not appealing. The growth and harvesting of bacteria for food grown on sewage wastes is already being investigated as an indirect method of employing human wastes.

Direct chemical synthesis of food materials from common organic sources is also a possibility. However, this potential source of food, together with other manufactured sources which requires heavy expenditures for equipment and demands upon the energy and material reources, are unlikely to be of major significance.

The introduction of synthetic and processed foods is currently restricted by the lack of market acceptability and government approval. Increased food prices and hunger may change this situation within the next decade. The purchase of canned dog food as a sandwich spread by some Canadian families may indicate that this change is imminent.

New technology is also being employed to increase food production from the sea and inland waters. To date, much of the effort has been expended in increasing the catch and in doing so, several species are now almost at the point of extinction in terms of commercial fishing. It is curious to realize that many centuries ago man resigned from being a hunter on the land to become a farmer but it is only within the last few years that mariculture has been considered as a sensible enterprise. Recent projects include the cultivation of salmon, shrimps, oysters, eels and the production of algae for shellfish stock feed.

These developments in technology create exciting and valuable challenges for the scientists and the engineers and also provide great comfort to the general public in the developed nations. For the underpriviledged, 71 percent of the world's population, many of these possibilities must appear to be unrealistically expensive and of little value in solving the problem of feeding their additional 67 million people this year. In summary, these countries which currently most need these new developments are unable to afford them, whereas those that can, should not require them.

NEW PROBLEMS

Decisions by nations and individuals are generally made by taking into account the lessons of history. There are, however, certain factors which have not been experienced before and which are likely to have profound effects on the world's food supply and its distribution. These factors which have only recently been recognized and are not yet completely understood are the changes in climate, the potential shortages of energy and materials and the economic repercussions of these shortages.

It was noted in a previous lecture that the global climate is changing. There has been a decrease of 0.3^{o}C in the earth's annual average temperature since 1940 and it is this apparently insignificant change which is thought to have created considerable fluctuations and changes in local climate. Abnormal droughts have been experienced in Sahelia, North America has had unusually cold winters, whereas Eastern North America has enjoyed milder winters and Australia has been flooded by torrential rains. A U.N. task force has been established to determine the magnitude of the changes and examine the possible causes. Although the problem has not been fully investigated the results of the climate change are already apparent in, for example, the decrease in crops in Canada and the U.S. in a year in which a record harvest was confidently predicted. The serious nature of the problem has been summarized by Alexander King last year in writing that "the facts of present climate change are such that the most optimistic experts would assign near certainity to major crop failures within a decade. If national and international policies do not take these near certain failures into account, they will result in mass deaths by starvation and probably in anarchy and violence that could exact a still more terrible toll".

The impact of the shortage of energy and materials is more comprehensible. However, it is surprising to read so many articles written by confident optimists which, by the simple manipulation of data purport to prove the possibility of raising agricultural productivity in the underdeveloped countries to the North American standard. They also neglect to realize, incidentally, that the achievement of this end result could prove to be disastrous for the underdeveloped countries in causing a mass migration to the cities.

In a recent paper, Steinhart and Steinhart analyze the energy use in the U.S. food system and the serious implications for the developed and underdeveloped world, of energy shortages are emphasized. In brief, they show that in the U.S. food system the energy input has steadily increased with the result that labour requirements have been reduced to 1/5 of the level in 1920; that farm output has doubled over the same period but that increasing amounts of energy are bringing smaller returns; that worldwide adoption of this system is impossible since it would mean that almost 80% of the world's annual energy expenditure would be required just for the food system. With restricted energy supplies it is clear that the underdeveloped countries cannot look forward to establishing a North American agricultural system. The implications for the developed world are important in terms of our accustomed way of life. In the U.S., Steinhart and Steinhart estimate that 13.0% of the total energy consumed is devoted to the food system. Increased costs and decreased availability of energy will make some food production operations nonviable and substantially raise the cost of food.

World economic affairs, as the last factor, appear to be in such a period of turbulence that even professional economists are beginning to question some basic premises. The impact of increased oil prices with the consequent increase cost (coupled with shortages) of fertilizers and insecticides and the higher transportation charges has dealt a crippling blow to the underdeveloped dountries. Increased energy costs have, in many cases, negated the effect of foreign aid programs and have so reduced the purchasing power of the countries concerned that some crops are now being planted without the use of fertilizers. With the lack of purchasing power and the partial failure of the crops in North America it is obvious that 1975 could be the year of the great famine for millions.

CONCLUSIONS

In this lecture an attempt has been made to at least mention most of the many factors which determine the world's food supply. The reader is referred to the bibliography for further information with the cautionary advice that unduly pessimistic or optimistic writing be carefully checked for omissions of fact and errors of oversimplification.

At the root of the world food problem is the basic, well known fact that the world population is growing more rapidly than our ability to produce food. It is conceivable that if the immediate food gap is closed the world could support a much greater population by considering food not as one of life's pleasures, but as a fuel, which will become more basic and synthetic in nature as the population expands. This will be one of the sacrifices to be made, merely in order to satisfy our desire to procreate.

It is impossible to predict the course of future events but the material presented in this lecture leads to the following conclusions:

(1) Starvation and malnutrition are already being experienced by large sections of the world's population. Whether stimulated by fear or humanity, every effort should be made to determine the social and economic means by which these problems can be alleviated.

(2) Increasing the percentage of land now under cultivation may not, by itself, meet the food demands of the population in the year 2000.

(3) A far better approach to feeding the increasing population would be to devote more thought to raising the productivity of existing land and reducing food losses. The food demands of the year 2000 might be met in this way.

(4) Beyond the year 2000, and even before this date, we will have to change our diets considerably to provide for better land utilization and to reduce the "biomass" of cattle. Processed foods could be the standard fare.

(5) World shortages of energy and material, climatic changes and world economic troubles are new and significant factors that could create problems which lack technological solutions.

(6) There are no reasons to be optimistic. Even if ten times the current population can be supported, the future for many people hinges on the availability of food for this week.

(7) All our hopes for future food supplies, for feeding the hungry and for providing a diet which will allow individuals to achieve the most from life rest upon man's ability to change national and individual attitudes. Once again, education and communication appear to be prime factors in determining the future of mankind.

In the 1974 F.A.O. report which reviewed the state of food and agriculture, the following conclusions were made:

> "*1. Per capita food production in the developing countries as a whole in 1974 remained lower than in 1970, in Africa and the Far East very substantially so.*
>
> *2. Cereal production fell sharply in several regions in 1974. Drought was again the principal cause.*
>
> *3. The total cereal stocks in all countries (excluding China and the USSR) have dropped below the minimum levels for world food security.*
>
> *4. The world fisheries catch again failed to expand in 1973.*
>
> *5. Sharply rising food prices have been a major factor in high rates of inflation since 1973.*
>
> *6. Malnutrition affects around 460 million people, a conservative estimate. It is strongly correlated with poverty. The world food situation will remain perilous until a much higher sustained rate of increase in food production is attained in the developing countries.*
>
> *7. It is entirely within man's capacity to solve the food problem in both its short and its long term aspects; the tools for the job are available even if some of them need improving.*
>
> *8. However, a prodigious effort for the mobilization of resources - physical, financial and human is called for, based on the realization that human society is indeed contronting in food and population two of the most crucial problems that have been of fundamental importance throughout history."*

These conclusions reinforce the conclusions which can be made from this brief review of the world food situation. "The challenge to the world's governments and to the international community could not be clearer. It was acknowledged by all at the World Food Conference. The efforts to meet the challenge will be watched anxiously in the coming months. There is no time to lose if these efforts are not to be too late to save the situation." A.H. Boerma, Director General, F.A.O.

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