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Production of Vegetable and Animal Foods from a Resource Point of View

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Production of Vegetable and Animal Foods from a Resource Point of View

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Abstract
The hominoids, living in the tropical forests millions of years ago, were mainly herbivorous, but a gradual change in food availability has resulted in the omnivorous Homo sapiens. Since the introduction of agriculture, cereal grains and tubers have become important, first for direct consumption, and later also as a basis for animal foods. An example is post-war Japan. The availability of plant foods decreases from south to north, so farm animal foods are more important energy sources in northern than in southern Europe. In the USA and NW Europe there were trends towards a saturation in demand for animal foods during the 1970s, while there were no signs of this in S Europe and the USSR. Larger areas of land are needed for mixed diets than for vegetarian diets. Climate is a natural resource which can cause considerable yearly variation in crop yields. Agricultural technology in combination with commercial energy has contributed to an increased supply of animal foods, especially through increased grain yields. The prospects for sufficient grain production are good, provided sufficient energy is available.

Key words: Agricultural land, technology, animal foods, cereals, climate, food supply, omnivorous, regions, resources, saturation.

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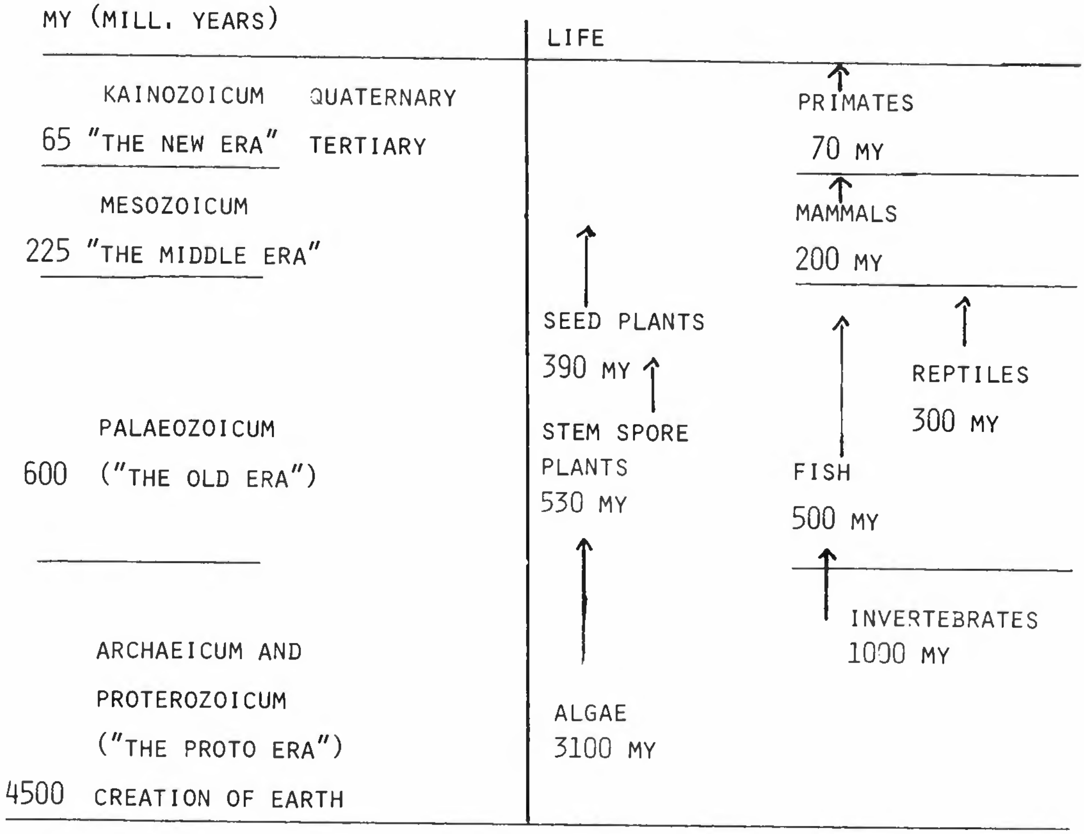

Figure 1. The eras of the earth (Strand 1969, Harrison et al. 1977).

1. THE EVOLUTION OF MAN

In order to discuss the respective roles of vegetable and animal foods in the food supply of man, it is necessary to take palaeo-anthropology as a starting point.

The creation of the earth took place 4500 My (million years) ago (Fig. 1). The geological age of the earth is divided into four eras; an early Proto era followed by the Old era, the Middle era and the New era. The New era has lasted 65 My (Strand 1969, Harrison et al. 1977). Only the New era will be mentioned here, divided into the Tertiary period (63 My) and the present Quaternary period.

Of greater interest is the occurrence of life. Algae occurred as early as about 3000 My ago, while stem spore plants and seed plants go as far back as 530 My and 390 My, respectively. As for animals, invertebrates, fish and reptiles were the first. Mammals go back 200 My, and the primates, the order to which man belongs, are 70 My old (Strand 1969).

The order of primates, called the «master animals», is divided into suborders and superfamilies. Among the latter, the hominoids or manlike apes are important in the evolution of man (Fig. 2). The superfamily Hominoidea is divided into two families: 1. The pongidae – the greater apes; and 2. The hominidae – the man's ancestors. The latter family, the hominids, has given rise to the genus Homo = Man.

Before presenting a scheme of the evolution of man it might be helpful to mention a few important terms (Fig. 3): *Homo erectus* and *Homo habilis* are both forms ancestral to *Homo sapiens*.

ORDER — PRIMATES ("MASTER ANIMALS")

SUBORDER — ANTHROPOIDEAE PLUR. ANTHROPOIDS

SUPERFAMILY — HOMINOIDEA PLUR. HOMINOIDS
= MANLIKE APES (OID MEANS SIMILAR)

FAMILY
1. PONGIDAE PLUR. PONGIDS = GREATER APES
2. HOMINIDAE PLUR. HOMINIDS = MAN'S ANCESTORS

GENUS — HOMO = MAN

Figure 2. Zoological relationship of primates (Simons 1964).

Pithecus means an ape. As an important hominid, Australopithecus, plural Australopithecenes, ancestors of man, should be mentioned, meaning «Southern apes». They have been called *near-men* and *Ape-men* suggesting their close relationship to man.

Ramapithecus, Rama's ape, which is substantially older than Australopithecus, has been suggested as being an early hominid (Simons 1977).

Considering Ramapithecus as a hominid, the division of hominoids into hominids and pongids may have taken place as early as about 15 My ago. It is as likely, however, that the division occurred between 4 and 8 My ago, a period during which there is a fossil gap (Fig. 4). The lower apes may have separated from the hominoids more than 30 My ago. True hominids, the Australo-pithecenes, are known from about 4 My ago, after the fossil gap. Homo forms, *Homo habilis* and *Homo erectus,* can be traced back to 2-2.5 My and 0.3-1.5 My, respectively. These homo forms evolved from Australopithecenes and coexisted with these hominids. The Australopithecenes, however, became extinct perhaps about 1 My ago. In this connection it should be mentioned that the brain volume of *Homo erectus* was about twice that of the Australopithecenes. Extirpation of the Australopithecenes may have been because they were not able to compete with the genus Homo in adjusting to environmental changes, for example to a colder climate (Simons 1964, Herbert 1983).

In addition to the larger brain, bipedalism, walking on the two hind limbs, is characteristic of man and the hominids near to man. The forelimbs developed into hands which could be used for making tools and for carrying tools and foods. This ability has an important bearing on the food supply of early man.

HOMO SAPIENS ("THE WISE MAN") MODERN MAN
HOMO ERECTUS ("THE UPRIGHT MAN")
HOMO HABILIS ("THE ABLE MAN")
AUSTRALOPITHECUS[1)] PLUR. AUSTRALOPITHECENES
("SOUTHERN APES") NEAR-MEN, APE-MEN
IMPORTANT HOMINIDS
RAMAPITHECUS[1)] ("RAMA'S APE") POSSIBLE HOMINID

1) PITHECUS = APE

Figure 3. Important terms concerning the evolution of man.

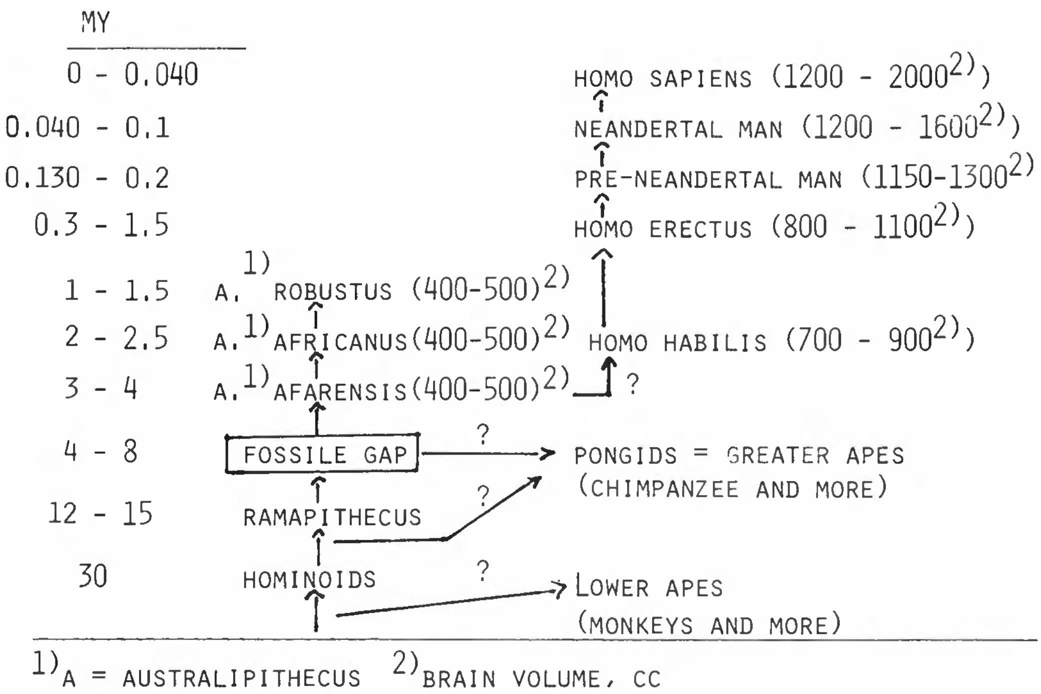

Figure 4. Evolution of man.

2. FOOD SUPPLY OF EARLY MAN

The hominoids, the manlike apes, were arboreal animals, tree dwellers, living in tropical rain forests with little seasonal variation. Accordingly, the hominoids were herbivorous, eating mainly plant foods of which fruit was important.

About 20 My ago the mountain ranges of the earth were formed (Napier 1967), and from about 16 My ago the climate gradually became drier and colder (Leakey 1981). These environmental changes led to the shrinking of the tropical rain forests and a new environment with grasslands, an open woodland savannah, developed (Napier 1967). This brought about a change in the availability of foods. Instead of fruits, plant foods such as roots, grass seeds, shoots, leaves and nuts became available. The toughness of these foods suited individuals with robust jaws and thickened tooth enamel, which were characteristic features of Ramapithecus and Australopithecenes (Simons 1977).

The early homo forms, *Homo habilis* and *Homo erectus*, consumed animal foods, mainly meat, as well as plant foods. The use of tools was more conducive to meat-eating. Stone tools are known from as far back in time as 2-2½ My. Sharp-edged stone flakes, 1½ My old, have been found to be well suited for cutting meat (Leakey 1981). It has been stated that there is a connection between tool-making and adaptation to carnivorous habits, i.e. the eating of meat (Breirem 1983). The larger brain capacity and the better developed hands of the Homo forms compared with the Australopithecenes were features more conducive to tool-making. From a dental point of view, it has been stated that man should be vegetarian or herbivorous, lacking the strongly developed canines and incisors of the carnivorous animals. The carnivores, however, use these teeth to attack and tear up their prey. In man this primitive function of the teeth is performed by our hands and tools (Washburn 1960).

It should also be mentioned that after its discovery half a million years ago, fire was used for the preparation of meat for food. This also promoted meat-eating.

According to this discussion, man's ancestors have been consuming animal foods for at least 2-3 My. Agriculture has been practised for only about 10 000 years, which is not more than a half to a third of 1 % of the time span of 2-3 My.

It was mentioned above that the consumption of animal foods by early man apparently was related to the use of tools made possible by man's enlarged brain capacity and well-developed hands. It is in accordance with this view that apes, the primates nearest to man, have been considered to be true vegetarians living solely on plant foods. Based on recent research, however, it is proposed that the apes be re-classified as *omnivores,* living on plant and animal foods similar to man (Leakey 1981, Breirem 1983).

In both man and apes, the proportion of food supplied by animal foods depends on availability.

It is important to understand that *food availability* varies greatly between regions depending on *geographic* and *climatic* conditions (Lowenberg et al. 1974). In southern regions with tropical or subtropical climates there is a great variety of food plants which, together with minimal seasonal variation, is conducive to a vegetarian type of diet. In the far north, on the other hand, there is a limited number of food plants.

Consequently in northern regions the pre-agricultural diets were of a carnivorous type, largely based on animal foods derived from ruminants, fish and other marine animals. Typical omnivorous mixed diets were most likely in the temperate zones. According to this scheme the animal foods increased in importance going *north.*

As will be mentioned later, this apparently is also the case with regard to present-day food supply.

3. PROPORTIONS OF ANIMAL FOODS IN PRE-AGRICULTURAL FOOD SUPPLY

As mentioned previously, consumption of animal foods by the pre-agricultural people has been proved by archaeological studies. However, even with the aid of archaeology, it is not possible to obtain quantitative information about the respective quantities of animal and vegetable foods consumed. Science, however, should aim at quantitative information as stated by the famous British physicist William Thomson who was raised to the peerage under the title of Lord Kelvin:

«When you can measure what you are speaking about and express it in numbers, you know something about it, but when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind».

In order to gather information about the pre-agricultural food supply of man dietary surveys have been carried out on *aborigines* living in Africa, Asia, Australia and America. Aborigines have a way of living *similar* to that of the palaeolithic people, the Old Stone Age people, as they also obtain their food by gathering, hunting and fishing. The dietary studies of these

Table 1. Diets of Kung bushmen, Kalahari Desert, Botswana 1964 (Lee 1968)

	g/cap./day	Weight %	Energy %	Protein %
Hunted: Meat	230	37	32	37
Gathered: Mongongo nuts	210	33	59	61
Other plant foods	190	30	9	2

Daily intake per capita 2.14 Mcal (9.0 MJ), 93 g protein (17 %).

people show that, like the Palaeolithic people, aborigines are *omnivores* eating a great variety of plant and animal foods (Robson 1975). No milk was consumed after weaning, however, because this was not available before the introduction of agriculture.

Valuable quantitative information about the food supply of gathering and hunting aborigines was obtained by Richard Lee in a study in 1964 of the Kung people living in the Kalahari desert in Botswana, SW Africa (Lee 1968). Meat supplied 32 % of the energy, 37 % of the protein (Table 1), and also 37 % of the weight of the foods consumed. There was a *high preference for meat* in spite of the fact that hunting took 2½ times more hours per unit of edible energy than the gathering of plant foods. Richard Lee found that the Kung people *«eat as much vegetable food as they need, and as much meat as they can»*. This is in line with the suggestion that meat was the prestige food during the Old Stone Age (Breirem 1983). The quantity of 230 g meat per person per day corresponds to 84 kg per person per year or 105 kg expressed in terms of carcass weight. This is a higher meat supply than that of any European country today, and similar to the present meat supply of North America (Breirem 1983).

Based on these and other studies Richard Lee (1968) concluded that, except for the highest latitudes, gathering and hunting people derived 20 – 40 % (35 % mean) of their diet (energy) from hunting. He considers similar proportions of animal foods as reasonable for palaeolithic man also. At latitudes higher than 40° from the equator, fish increased in importance. In North America, hunting and fishing supplied 70 – 100 % of the food at 60° or more from the equator. These findings confirm the previously mentioned view that animal foods make up an increasing part of the food the further north one is.

An interesting observation from Richard Lee's (1968) study in the Kalahari desert was that the food supply by gathering and hunting took an average of 15 hours per person per week, i.e. more than 2 hours per day. Under similar conditions Sahlins (1972) found that an average of 4 hours per person per day was used for food supply, including food preparation and repair of tools and weapons. There was no difference between males and females in this respect. Apparently the Old Stone Age people had a less strenuous life than was generally the case after the introduction of agriculture (Sahlins 1972, Mikkelsen 1979).

4. CONCLUSIONS ON THE FOOD SUPPLY OF EARLY MAN

To conclude the discussion on the food supply of early man, there appears to be firm evidence that man is *omnivorous.* Furthermore, man is able to eat from a *very wide range of foods* of plant and animal origin, depending on availability. This apparently explains why man has been able to «inhabit virtually every part of the

Table 2. Judged proportions of foods in the Tehuacan Valley, Mexico during development of agriculture (R. MacNeish, cit. by Harris, 1977).

	Animal foods % of food energy	Plant foods % of food energy	
Years BC	Max Min	Cultivated	Gathered
7000 – 5000	89 – 76	0	11 – 24
5000 – 3400	69 – 31	1	30 – 68
3400 – 2300	62 – 23	8	30 – 69
2300 – 1850	41 – 15	21	38 – 64
800	18	40	42

globe», as John Yudkin (1975) expressed it. Man shares his omnivorous food habits with the pig and the rat.

5. FOOD SUPPLY AFTER THE INTRODUCTION OF AGRICULTURE

The introduction of agriculture in the Near East about 10 000 years ago at the beginning of the Neolithic, the Young Stone Age, was likely caused by population pressure. According to FAO (Stout et al. 1979), under favourable conditions hunter-gatherers need 1.5 km^2 per person and in harsher environments as much as 60 – 80 km^2. Agriculture greatly increased the amounts of food which could be obtained from a limited area. After the introduction of agriculture, starch-rich cereal grains and tubers became the most important energy sources for man. As pointed out by Yudkin (1964), the increased consumption of starchy foods, also called *staple foods,* was followed by a decline in the consumption of animal foods compared with the pre-agricultural period. Yudkin also stated that when given the opportunity man reverts to a pre-agricultural diet with a high proportion of animal foods.

This view is supported by MacNeish's archaeological studies in the Tehuacan valley in Mexico where maize (American corn) originated (Harris 1977). The proportion of food energy supplied by animal foods decreased considerably from about 7000 to about 800 years BC, while the proportion of plant foods increased, particularly those derived from agriculture (Table 2).

Table 3. Food supply in Japan (FAO).

	1948–52	1961–63	1972–74	1983–85
kcal/cap./day	1900	2520	2830	2804
g protein/cap./day	49	72	86	85
Animal foods:				
% of diet. energy	3	11	19	19
% of diet. protein	17	33	47	51
Cereals and tubers, % of energy	87	65	49	46 (1979–81)

FAO-data from Japan illustrate that the increased use of starchy food staples was caused by population pressure and not by food preference (Table 3). In relation to the agricultural area Japan is the most densely populated country in the world having only 0.04 ha agricultural area per capita (1985). At the end of the 1940s when Japan had to rely on its own resources, starchy food staples supplied 87 % of the edible energy, the highest proportion ever recorded. Later, when rapid economic development made it possible to import foods and feeds the proportion of starchy foods decreased substantially to 49 – 46 %, with a corresponding increase in the proportion of animal foods.

The anthropologist Marvin Harris (1977) discusses how meat shortage caused by population pressure and environmental limitations influenced the form of religions. In the Near East, with poor conditions for pig husbandry, the eating of pig meat was forbidden by the Jewish as well as the Mohammedan and other religions of this area. In India, a country with strong population pressure, the eating of cattle meat was gradually forbidden by the prevailing religions, Buddhism and Hinduism, probably because it could not be afforded. As already mentioned, in Central America the extirpation of game animals was due to population pressure. Turkeys were an indigenous meat animal in this area, but they had to be fed cereal grains in order to produce meat. About AD 1500, when the Spanish arrived, the Aztecs living in Mexico were systematically practising cannibalism, mainly in the ruling class, which included warriors (Harris 1977).

As a contrast Harris (1977) mentions that the religions which stressed love, mercy and equality developed mainly in the north, where cannibalism was tabu, perhaps because of access to grass-fed ruminants as meat-producing animals.

The reduction in the supply of animal foods per person which followed the introduction of agriculture took place particularly in the southern arid regions. In the regions of the temperate zone the introduction of agriculture was followed by animal domestication, which partly compensated for the increasing shortage of game animals. In the humid areas of Europe ruminants became important for food provision, particularly the dairy cow, which supplied milk and milk products in addition to meat.

Table 4. The proportions of animal foods[1] in the food supply of different regions 1972–74 (FAO 1977).

	Animal foods in % of:		
	Energy	Protein	Fat
World	17	35	56
Africa	7	20	27
Asia	8	20	40
Latin Amerika	16	39	50
North America	42	68	72
Western Europe	32	55[2]	64
Eastern Europe and USSR	28	48	72

[1]) Fish included
[2]) N.W. Europe 64 %

6. ANIMAL FOODS IN PRESENT FOOD SUPPLY

At present the contribution of animal foods to the food supply varies greatly between regions, as can be shown by FAO-data for 1972 – 74 (FAO 1977, Breirem 1983).

In Africa and Asia animal foods constitute 7 – 8 % of the food energy in contrast to 30 – 40 % in North America and Europe (Table 4). Animal foods provide a greater proportion of protein and fat than of energy, in North America and Europe 50 – 70 %. Even in the developing countries in Africa and Asia, however, animal foods are important sources of protein and fat. On a world wide basis animal foods supply more fat than plant foods (Breirem 1983).

The regional differences in animal food supply depend on many factors. An important fact is that in the developed countries in the temperate zones, conditions for animal production are better than in the developing countries in the tropics and subtropics. Another important factor is that in the developed countries population pressure is less, sometimes nearly absent, compared with the developing countries. Important, too, is the fact that the developed countries, based on research, have developed agricultural technologies which have greatly increased productivity compared with the traditional pre-scientific agriculture prevailing in the developing countries (see later). Finally, it has to be mentioned that differences in food supply may depend on differences in general economic

Table 5. Proportions of food energy derived from farm animal foods 1972-74 (FAO 1977, Breirem 1983).

	% of food energy from:		
	Farm animal foods	Meat	Milk, milk products incl. butter
Iceland	45	16	28
Finland	41	14	26
Norway	31	11	19
Sweden	34	15	18
Denmark	37	19	16
Average	38	15	21

Eggs = Farm animal foods – (meat + milk).

development. It has already been mentioned that Japan's rapid economic growth since World War II led to a considerable increase in the supply of animal foods.

Using FAO-data from 1972 to 74 (FAO 1977), at the end of the period with the most rapid economic growth in world history, it is possible to illustrate the contribution of animal foods to the food supply of different European countries. For the five Nordic countries (Table 5) it is noteworthy that Iceland and Finland have the highest provision of farm animal foods, expressed in terms of proportion of food energy, of all European countries. This is due to a very high supply of milk and milk products (Breirem 1983).

When comparing different European regions with regard to supply of animal foods, there is a pronounced difference between northern and southern Europe (Table 6). The Mediterranean countries and the SE European countries derive only about *half* as much of their food energy from farm animal foods as the countries in northern Europe (Breirem 1983). Still more striking are the differences between north and south in the proportions of food energy derived

Table 6. Proportions of food energy derived from farm animal foods in different European regions 1972 – 74 (FAO 1977, Breirem 1983).

	% of food energy from:			
	Farm animal products	Meat incl. carcass fat	Milk, milk products incl. butter	
5 Nordic countries	38	15	21	3
Ireland	41	19	20	
7 other NW European countries	36	21	14	2
3 NE European countries	33	17	15	
Hungary	35	27	7	
4 Mediterranean countries	19	11	7	1
3 SE European countries	19	11	7	

from milk and milk products. The proportions of milk and milk products are on average 21 % for the Nordic countries and Ireland, 14 % for the other NW and NE European countries, to only 7 % for the countries in southern Europe. The ratios between these averages are 3:2:1, thus representing substantial differences between regions (Breirem 1983). As mentioned previously, there can be no doubt that ecological conditions in the north are more conducive to animal production, particularly for milk production in ruminants.

7. SATURATION IN DEMAND FOR ANIMAL FOODS

The present surplus of animal foods is a formidable problem in the developed Western countries. This problem correlates with biology as well as economy.

Physiologically, regulation of the food energy intake of man is largely governed by the nervous system, involving reflexes from the hypothalamus at the base of the brain where there is a *satiety centre* as well as a *feeding centre* (Balch & Campling 1969). At satiety, eating is

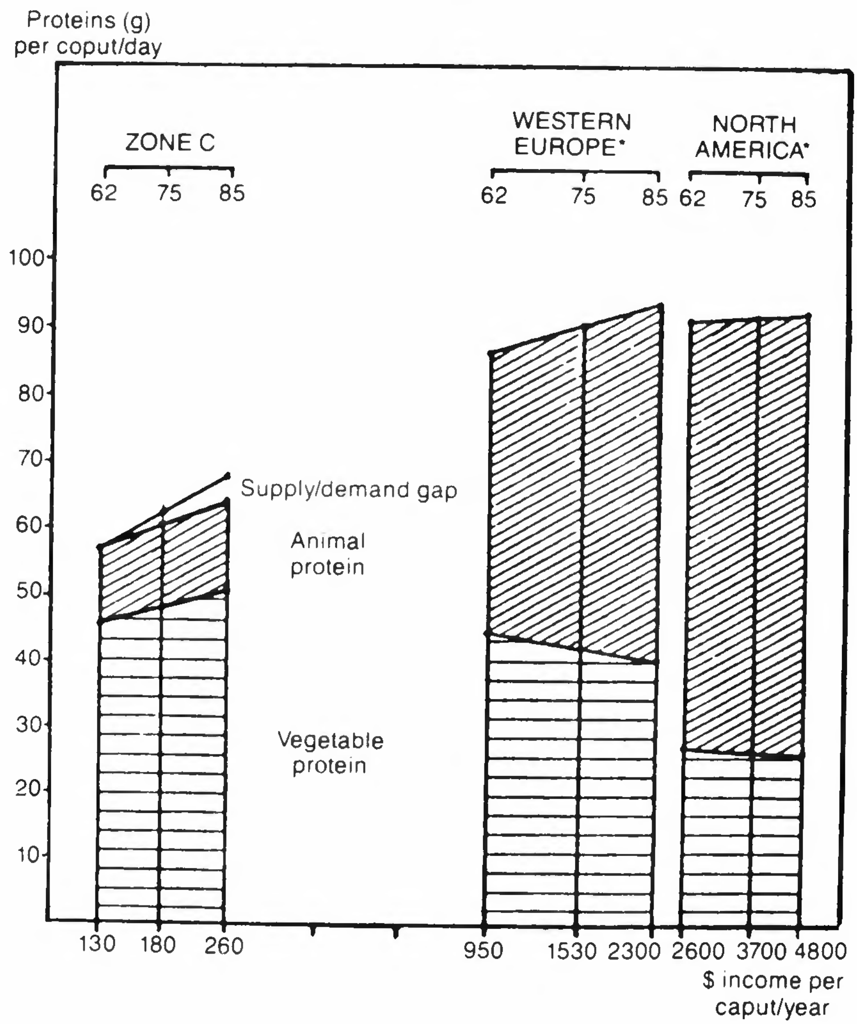

Figure 5. Projected protein supply for 1975 (75) and 1985 (85) in regions with different income levels (Autret & Perissé 1970).

stopped by signals from the satiety centre. In the hungry state signals from the feeding centre lead to eating. Normally the regulation is performed so well that the intake of food energy varies by not more than ±2 – 5 % over a few days. Within the regulated level of energy intake the energy can be supplied by different foods. This means that foods can be substituted for each other. A characteristic trend in postwar development is that sugar, fats, oils and animal foods have been substituted for the starchy food staples, cereals and tubers, as mentioned previously for Japan.

The extent to which animal foods can be substituted for other foods is partly dependent on economy in terms of income or buying power.

This is shown by a study in 1970 by Autret & Perissé at FAO Food and Nutrition Division (Fig. 5). Based on FAO-data for 1962 (1961 – 63) the demands for animal protein in 1975 and 1985 were projected for regions with different income levels in terms of dollars per capita per year. Within each region substantial increases in income were assumed (Breirem 1983).

At the highest income level, in North America, there is a clear trend toward saturation or stabilization with only a slight projected increase in the supply of animal protein from 1962 (62) to 1975 (75) and 1985 (85). In western Europe, on the other hand, a substantial increase in the supply of animal protein was projected. For the developing countries (zone C) a supply/demand gap was projected because of production constraints.

The problem of saturation in the demand for animal foods in different European regions has been studied by comparing FAO-data for food supply in 1972 – 74 with corresponding data for 1961 – 63 (Table 7). Because the period 1960 – 73 was unequalled in history with regard to rapid economic development it should be well suited for a study on the demand for animal foods in relation to economic progress. For comparison, USA, New Zealand, and Japan have been included, Japan being known for its extremely rapid economic growth during the period 1960 – 73 (Breirem 1983).

In the USA there is a saturation or reduction in the supply of animal fats, milk and eggs from 1961 – 63 to 1972 – 74, while there is an increase in the supply of meat. For New Zealand there is saturation for all groups of animal foods, considering that the increase in the supply of milk is fully compensated for by a reduction in butter supply.

In NW Europe there is a clear saturation in the supply of animal fats and milk, while there is an increase in the supply of eggs and particularly of meat. For the other European regions there is, without exception, a marked increase

Table 7. Indices of supply of animal foods, 1972 – 74 compared with 1961 – 63 (= 100) (FAO-data, Breirem 1983).

Energy basis (kcal/cap./day)	Meat	Eggs	Milk except butter	Animal fats
USA	111	92	91	101
New Zealand	97	102	112	90
13 NW European countries	121	114	100	96
4 Mediterranean countries	185	145	137	136
3 NE European countries	124	141	116	117
4 SE European countries	146	173	114	114
USSR	136	156	122	127
Japan	304	213	191	197

in the supply of all groups of animal foods. The increase in the indices for the meat supply in the Mediterranean countries and for the supply of eggs in the SE European countries is very great.

The highest increase in the supply of animal foods is found in Japan. In a mere 11 years the meat supply has tripled and the supply of the other groups of animal foods has almost doubled.

These findings greatly support the views of Autret & Perissé that at initial stages of economic development there is a strong demand for animal foods. When economic development continues and the supplies reach high levels, demand decreases and finally there will be saturation. The saturation level apparently was reached in 1972 – 74 in the USA and New Zealand and nearly so in NW Europe. In the other European regions and Japan there are great increases in demand, indicating early stages of economic development and also low supply levels.

FAO-data are available also for a comparison of 1975 – 77 with 1972 – 74 (Breirem 1983). This is of interest as 1975 – 77 was a period of economic stagnation compared with the period 1962 – 73. As can be seen in the table for the USA and New Zealand there is saturation in the supply of meat and a *reduction* in the supply of the other animal foods, particularly of animal fats (Table 8).

Table 8. Indices of supply of animal foods, 1975 – 77 compared with 1972 – 74 (= 100) (FAO-data, Breirem 1983).

Energy basis (kcal/cap./day)	Meat	Eggs	Milk except butter	Animal fats
USA	100	93	98	80
New Zealand	99	94	91	91
13 NW European countries	106	101	101	99
4 Mediterranean countries	112	111	110	109
3 NE European countries	104	107	104	106
4 SE European countries	112	116	109	111
USSR	104	110	102	99
Japan	109	98	102	89

With the exception of meat there is also a clear trend toward saturation in demand in NW Europe. In the other European regions there are some increases in the supplies of all animal foods except for animal fats in the USSR. It is noteworthy that in Japan there is saturation in demand for animal foods other than meat. This is in marked contrast to the period 1962 – 73 (shown in Table 7).

Concerning the different groups of animal foods the trends toward saturation apparently are less marked for meat than for the other groups of animal foods. The trend toward saturation is most pronounced for animal fats, mainly butter and lard (visible fats).

In this connection it is of interest to mention that during the 1970s in the USA and New Zealand the supply of animal protein is not reduced at all while there is a reduction in the supply of animal fat (Table 9). This indicates a preference for lean meat and low-fat milk (Breirem 1983).

This discussion of saturation in the demand for animal foods concerns the supply per person, per capita. For total supply, the *number* of persons who would be supplied also has to be taken into consideration. This will not be dis-

Table 9. Indices of supply of animal protein[1] and animal fat[1] USA and New Zealand 1969 – 71 (= 100) (FAO-data).

		1975 – 77	1978 – 80	1983 – 85
Animal protein	USA	100	100	99
	New Zealand	108	103	100
Animal fat	USA	93	97	94
	New Zealand	94	91	92

[1]) Fish included.

cussed here, only to say that in most European countries the rates of population growth have decreased dramatically during the last twenty odd years (since the mid sixties). There are trends toward stabilization, in some countries even to reduction of the present population. It seems likely that the best that can be hoped for is *zero-growth* in the total demand for animal foods.

8. PROGRAMMES FOR NUTRITION AND FOOD SUPPLY

Wilbur O. Atwater, a pupil of Karl Voit, Munich, and head of Connecticut Agricultural Experimental Station 1873 – 1906, has been called «the Father of Human Nutrition» in the USA. Since 1968 there has been an annual «Atwater memorial lecture» in honour of Dr. Atwater. The first lecture in this series was presented by the Nobel laureate A.I. Virtanen, Finland, certainly an honour for the Finnish science of biochemistry and nutrition.

At the tenth Atwater memorial lecture in 1978, Robert T. Olson, professor of medical biochemistry at St. Louis University, expressed the view that nutrition has *two faces.* In a sense one face is *medical,* dealing with *physiology* and *health,* while the other is *agricultural* dealing with *ecology* and *environments* including resources (Olson 1978). This view has a bearing on programmes for nutrition and food supply (Breirem 1982). In recent years several guidelines for nutrition have appeared based on medical points of view. These guidelines all aim at the avoidance of overeating, particularly of fat which may have harmful effects.

Moderation in eating is a golden rule which should be agreed upon by all. This rule is not at all new. Charles Glen King, a former president of the Nutrition Foundation in the USA, stated that even the ancient people, 2000 – 3000 years ago, knew that curbing the appetite could prolong life.

It is evident that the medical face of nutrition is valid during the present times of surplus. This means that problems of surplus cannot be resolved by recommending that people eat more. As discussed previously, in North America as well as in NW Europe, saturation trends are obvious in the supply of animal foods. In agriculture as well as in the related industries, for example the feed industry, it is apparently difficult to accept this view mainly because it means reduced possibilities for the expansion of production. It would, however, be advisable to accept the view that moderation in eating should be practised.

Ludvig Nanneson, the Swedish pioneer in Scandinavian agricultural economy, once said that «one cannot fight economical laws». Breirem has modified this sentence to: «One cannot fight biological and economical laws». The basis for this sentence has been discussed in section 7 on the saturation in demands for animal foods.

Whether or not the present abundant food supply in the developed countries should be taken for granted is questionable. Food availability is influenced by ecological constraints and resource limitations affecting agricultural production. Experience from the 1970s shows that short supplies of foods and high food prices may occur even in the developed countries. Accordingly, during times of shortage the agricultural face of nutrition moves into the foreground as regards food supply.

9. RESOURCE LIMITATIONS ON AGRICULTURAL FOOD PRODUCTION

The next part of this paper will be devoted to a summary of a few main points on how resource availability influences the production of vegetable and animal foods.

9.1. Land

Agricultural land is the most important natural resource in food production. Land has been called the*net* by which it is possible to catch energy from the sun in order to produce foods by means of the photosynthesis in plants. The size of the net, the land area, is immutable (Duckham et al. 1976, Breirem 1982).

Land availability is usually expressed per capita. FAO (1976 – 86) distinguishes between arable land, permanent food crops and permanent pasture.

With the exception of Norway, which to a great extent is a stony desert, as expressed by an American fellow traveller in 1959, the Nordic countries are well-off with regard to land compared with world and west European averages (Table 10). Taken as a region, the Nordic countries actually can be compared with France and Ireland, the land-richest countries of Western Europe.

With increasing proportions of animal foods in the food supply, more land will be needed per person. As has already been mentioned, the introduction of agriculture in many regions led to an increased supply of starchy foods, while the supply of animal foods decreased. This actually was an outcome of population pressure measured as decreasing area per capita.

Based on assumed food chains and yield levels at the Reading University farms in England, Duckham et al. (1976) estimated the arable land per man needed for four different types of diet (Table 11). The inclusion of animal foods in the last three diets greatly improves the protein quality as shown by NPU (net protein utilization). As to the need for arable land per person, 780 m^2 was estimated to be sufficient for a vegetarian diet based on cereals and pota-

Table 10. Arable and agricultural land per capita (FAO 1985).

	ha per capita 1985	
	Arable land and permanent food crops	Agric. area incl. permanent pasture
World	0.31	0.96
North America	0.90	1.93
Western Europe	0.22	0.33
Denmark	0.51	0.55
Sweden	0.36	0.43
Finland	0.49	0.52
Norway	0.19	0.23
Iceland	–	0.95
Average[1] Nordic Countries	0.39	0.43

[1]) Weighed.

Table 11. Arable land needed per capita with different types of diets (Duckham et al. 1976).

Diet	NPU[1]	ha per: Man	ha per: Capita (x 0.82)
1. Cereals, potatoes	54	0.096	0.078
2. With milk	65	0.190	0.160
3. With milk, eggs, meat	72	0.316	0.260
4. Actual British diet 1962 – 65	75	0.62	0.510

[1]) Net protein utilization.

toes. If, in addition, milk is used then the need for land would be doubled to 0.16 ha per person. By including eggs and meat, 0.26 ha would be needed per person, 3.3 times more land than for the vegetarian diet (No. 1). The first three types of diet are estimated using British standards for nutritive requirements. For the somewhat rich British diet in 1962 – 65 the need for arable land per person was estimated at 0.51 ha, 6.5 times more than for the vegetarian diet. In this case commercial production was assumed at lower yield levels than at the Reading University farms.

In relation to available agricultural land, Japan, South Korea and Egypt are the most densely populated countries in the world. These countries actually have less land than is needed for vegetarian diets according to Duckham (Table 12). Because of a large and increasing import of cereal grains these countries, as well as Israel and Norway, have a liberal food supply. In contrast, Bangladesh, a typical developing country, has a poor food supply and low grain import. In countries with high rates of popuation growth land shortage apparently will be a serious resource problem in the food production of the future.

It is noteworthy that Western Europe, with only 0.22 ha arable land per capita, is almost self-sufficient with regard to cereal grains, not counting the oil seeds.

Table 12. Available land[1], food supply and grain import in some countries (FAO 1976, 1985).

	Da (0.1 ha) per capita	Supply/capita/ day 1981 –83		Net import cereals[2] per capita	
	1985	kcal	g anim.prot.	1975, kg	1985, kg
Japan	0.39	2858	50.6	169	219
South Korea	0.52	2804	20.3	90	165
Egypt	0.53	3186	14.4	104	189
Israel	0.99	3062	54.1	467	402
Bangladesh	0.90	1878	4.9	31	21
Norway	1.9	3295	71.9	140	55
Western Europe	2.2	3385	62.7	55	-37[3]

[1]) Arable land and permanent food crops, 1985.

[2]) Oil seeds not included.

[3]) Net export.

9.2. Climate and weather

Next to land, weather is the most important but also the most unpredictable natural resource for food production.

The varying climates of the world depend on air circulation. The atmosphere is heated by the sun but at a decreasing rate passing from the equator to the poles. This is evened out by the air circulation – winds (Crichfield 1966). The basic principle is that warm moist air rises near the equator, creating the zone of tropical rain forests, and that cool, dry air sinks down at the poles (Fig. 6). In addition, there are two important zones between the equator and the poles. At 25 – 30° from the equator the air sinks, creating high pressure areas with arid zones. At 50 – 60° the air is pushed upwards, resulting in humid conditions. In Europe, mostly in the North Sea countries, mild moist westerly winds, so-called zonal circulation, create a favourable climate with regard to temperature, rainfall and variation. According to the climatologist Liljequist (1970), this may explain the role Europe has played throughout history. The zonal circulation in combination with a north-south range of mountains also explains the beneficial position of Norway with regard to water power, probably the most important source of wealth in Norway (Finn Lied), in 1977 supplying 41 % of the total energy used in Norway at the delivery level, or 57 % of utilized energy (NLVF, 1984a).

Charts showing the distribution of the arid zones of the world, reveal that such zones are absent in Europe, except for small areas in Spain, while they take up large parts of other continents, particularly in Africa, western Asia and Australia, but also some areas of the western Americas (Fig. 7). Conditions for food production are poor in the arid zones as shown by the fact that they cover 36 % of the total land area of the world, while only 13 % of the world population inhabits these zones (Verbeek 1968). Because of poor conditions for animal production the levels of animal foods in the food supply are low in the arid zones (Verbeek 1968).

Even in the temperate zones weather fluctua-

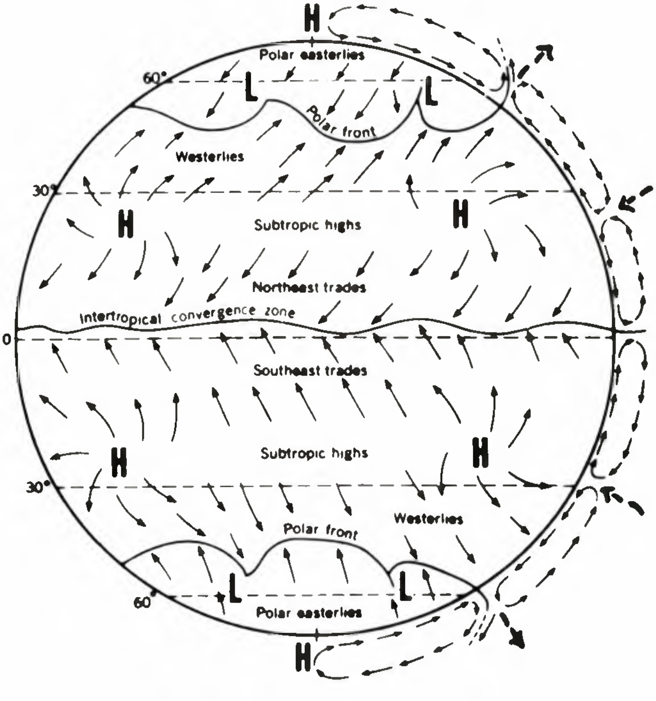

Figure 6. Schematic arrangement of winds and pressure belts (Crichfield 1966).

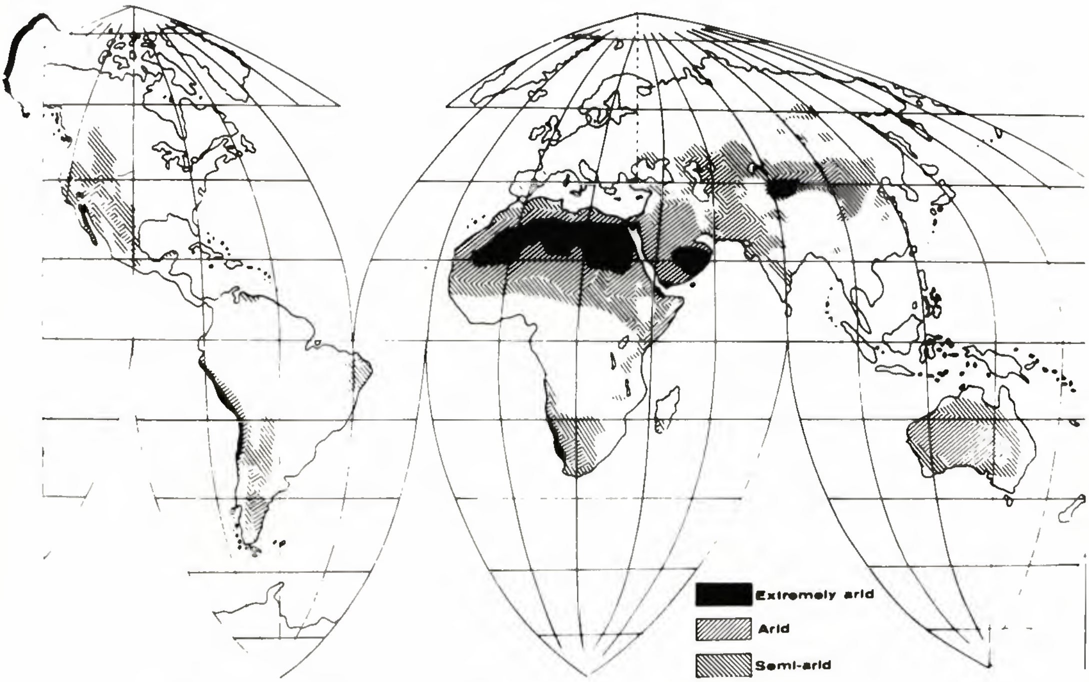

Figure 7. Distributions of the arid zones of the world (Verbeek 1968).

tions occur affecting food production. In western Europe irregular variations with long periods of warm and dry *or* cool and wet weather may be caused by a change from zonal to *meridional circulation with* stagnating high or low pressure areas. On average, for large areas the climate is more arid with this type of circulation. More rain falls near the equator and this shift to the south leads to arid conditions in the Sahel zone in Africa.

As a simple measure of how weather fluctuations affect food production, FAO has compared the grain harvest with the harvest of preceding years.

In Norway after World War II, the decline in average grain yield in eight individual years with extreme weather conditions compared with the eight respective preceding years was 12-26, an average of 19 % (Table 13). A 20 % reduction in grain harvest can seriously affect those animal productions most dependent on grain feeding.

Table 13. Average grain yields in Norway in years with extreme weather conditions, kg pr ha.

1947	Dry	1800	81 % of yield in 1946
1955	Dry	1890	81 % of yield in 1954
1959	Dry	2050	88 % of yield in 1958
1962	Cool wet	2070	74 % of yield in 1961
1966	Cool winter, late spring	2170	85 % of yield in 1965
1969	Dry	2630	75 % of yield in 1968
1975	Dry	2520	76 % of yield in 1970–74
1976	Dry	2840	86 % of yield in 1970–74

Table 14. Effects of bad years on production of grain and pig meat (FAO-data).

	Total grain, mill. tons		Pig meat, mill. tons	
USA	1973	237.4	1974	6.26
	1974	204.6	1975	5.22
		-14 %		–17 %
USSR	1974	187.0	1975	5.75
	1975	134.8	1976	4.23
		-28 %		-26 %

Two well-known bad years were 1974 in the USA and 1975 in the USSR with a 14 % and 28 % decline in grain harvest from the preceding years, respectively (Table 14). In the years following these bad years there was a similar decline in pig meat production in both countries.

With regard to the long-term prognosis for future climate, it should be mentioned that during the last million years major glacial periods have occurred at intervals of about 100 000 years (Fig. 8). Each major glacial period has been followed by a warm, interglacial period of about 10 000 – 12 000 years. We should now be nearing the end of an interglacial period. Accordingly a trend to natural cooling can be expected. However, the climatologist Murray Mitchell has suggested that carbon dioxide accumulation in the air, caused by the burning of fossil fuels, the so-called green-house effect, may result in a substantial increase in the air temperature particularly in northern regions. This may delay the expected natural cooling by a thousand years or more (Murray Mitchell 1977, Breirem 1982).

Although this may be considered beneficial for northern countries there may be some unfortunate side effects such as rising sea levels

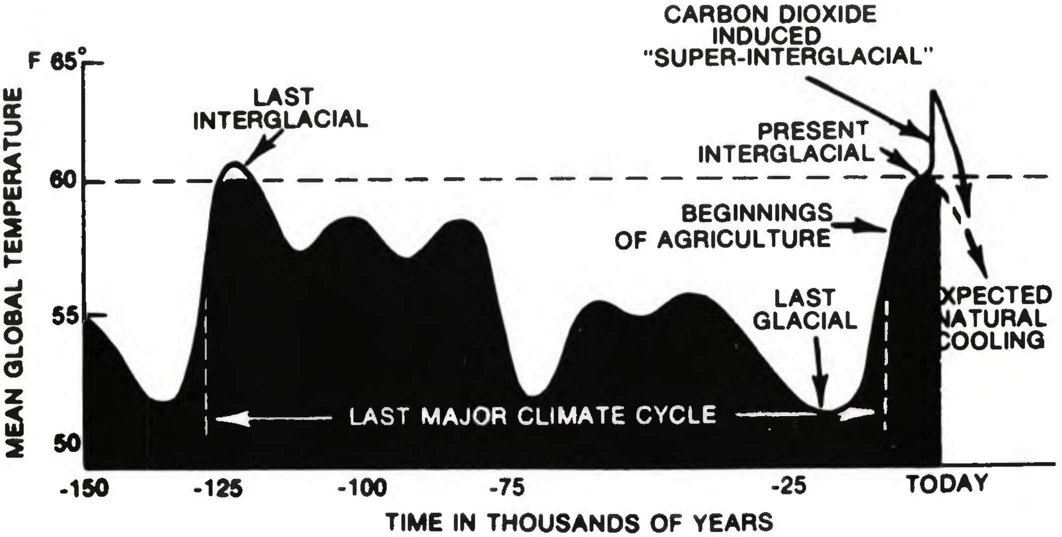

Figure 8. The last major climatic cyclus (Murray Mitchell 1977).

and shifting rainfall patterns. The latter are expected to affect some of the important wheat growing regions in North America and Russia.

During thc 1970s irregular weather had the effect of depressing food production. In fact, from 1972 to 1980 declines in world grain production occurred in six out of nine years. Murray Mitchell has expressed the view that we may be getting back to normal in the sense that the weather is becoming more variable than it was earlier in this century. It may therefore be advisable in good years to store grain for meeting the needs of bad years. The State Grain Corporation of Norway has grain for one year's use in storage.

9.3. Agricultural technology

9.3.1. Increases in grain yield as a measure of improvements in the agricultural technology.

Agricultural technology is an important resource in food production. Modern technology based on research and development can greatly increase productivity and efficiency and thereby do away with constraints related to land shortage. Also, climatic constraints can to some extent be reduced by technological means.

The nobel-laureate A.I. Virtanen (1962) and FRS Sir Kenneth Blaxter (1974) have illustrated the effects of improvements in technology by showing the progress in grain yields in the Netherlands and England (Table 15). During the long time span of about 10 000 years following the Neolithic revolution, also called the *first agricultural revolution,* progress was slow or nearly absent. In England during the 13th century wheat yields were 400 – 500 kg per ha. About the middle of the 18th century the grain yields per ha were 700 – 800 kg practising the

Table 15. Progress in productivity attributable to improved agricultural technology.

	Netherlands[1] kg grain/ha	England[2] kg wheat/ha
I. Three-field system, about 1750	700	800
II. Rotation grain, clover, roots, 1840–70	1550	2000
III. Chemical fertilizers, plant breeding etc.		
1957–60	3440	
1971–73		4250

[1]) A.I. Virtanen 1962.

[2]) Sir Kenneth Blaxter 1974.

primitive three-field system with two years of grain and one year fallow.

In England the introduction of the biologically well-founded plant rotation during the latter half of the 18th century, which may be called the *second agricultural revolution,* increased grain yields by 2-2½ times to 1500 – 2000 kg per ha. More grain was obtained on just half the area than as formerly on two-thirds. In addition, on the other half of the area, large quantities of animal feeds were produced, making it possible to expand animal production considerably, particularly cattle production.

Agricultural technology developed during the 20th century, mainly after World War II, with the use of chemical fertilizers, other agrochemicals, machinery and plant breeding, has greatly increased productivity. In the 1960 – 70s grain yields in the Netherlands and England were about 4000 kg per ha, *five times higher* than around 1750. There has been talk about a *third agricultural revolution.*

During recent years this progress in productivity has continued. Table 16 gives wheat crop data for some EC countries in 1974 – 76 and 1983 – 85. According to these data it

Table 16. Wheat crop yields in some EC countries during the 1970s and 1980s, kg/ha (FAO 1976, 1985).

	UK	France	Germany Fed.	Denmark
1974	4970	4610	4760	5330
1975	4330	3870	4470	5100
1976	3880	3760	4110	4740
Average 1974–76	4390	4080	4450	5060
1983	6420	5130	5440	6400
1984	7710	6460	6260	7320
1985	6150	6010	6070	5800
Average 1983–85	6760	5870	5920	6510

would not be unrealistic to expect average cereal yields of 6000 – 8000 kg per ha, 8-10 times higher than in the prescientific period before 1750.

The great variation from year to year reflects the importance of weather conditions. Yields are clearly depressed during the extreme dry years of 1975 and 1976 in contrast to very high yields in 1984, when growing conditions were ideal.

As stressed by Sir Kenneth Blaxter (1974) the third agricultural revolution relates to the use of commercial energy, mainly oil. This means that modern agricultural technology is

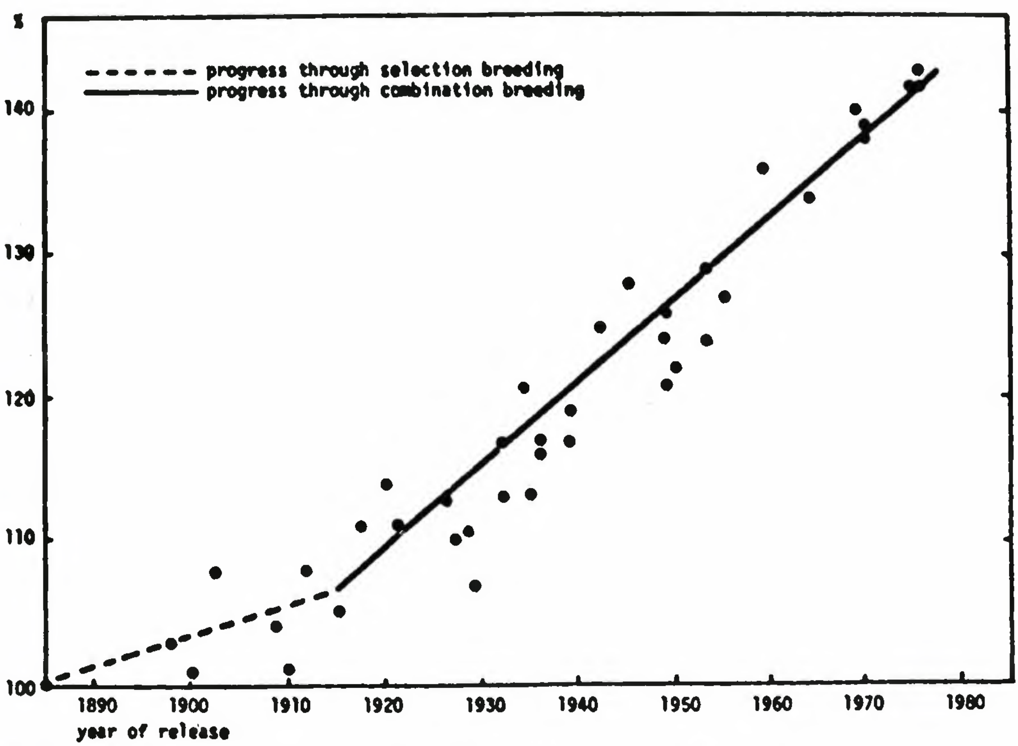

Figure 9. Progress in Swedish breeding of winter wheat (Mac Key 1978).

energy intensive. Accordingly, energy is an important resource in modern agricultural food production, as will be mentioned later.

There is still a potential for considerable increases in grain yields. Sir Kenneth Blaxter (1980, 1986) suggests a maximum theoretical production of wheat grain of 15 600 kg per ha when there are no limitations. According to the Swedish plant geneticist Mac Key (1978), field experiments seldom show more than half of the maximum growth rate.

Mac Key illustrates the progress in Swedish breeding of winter wheat by combination breeding. Throughout the long 60-year period from 1915 to 1975, the growth in yields is linear without any sign of flattening. (Fig. 9)

In Norway, cereal grain yields (all cereal grains) have increased considerably from 1931 to 1985. During the war (1941 – 45) these yields were 14 % lower than in 1935 – 40, but since the war there has been a steady increase without flattening. For the most part, the increase in yields was somewhat higher during the period 1966 – 85 than in 1946 – 65. (Fig. 10)

9.3.2. Grain per capita as a measure of the potential for food supply.

As an adviser in connection with the Norwegian food supply during World War II Breirem understood the overwhelming importance of cereal grains in the food supply. In 1960, on the basis of this experience, he proposed to use *kg grain produced per capita per year as a measure of the potential* for food supply. In his prize winning book, «Man, Land and Food» Lester Brown (1963) stressed that grain production per capita is a good measure for food supply. He

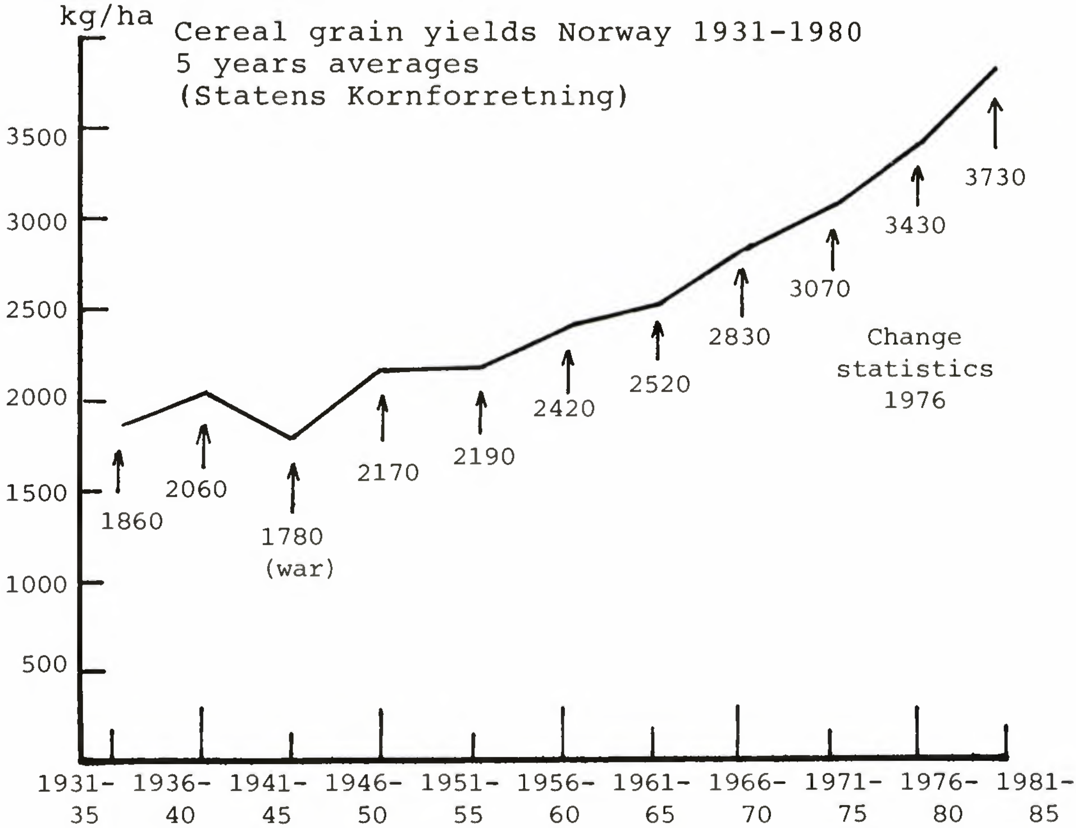

Figure 10. Cereal grain yields in Norway 1931-85 (5-year averages). (Norwegian Grain Corporation).

maintains that grain supplies the main part of the food energy, whether consumed *directly,* for example as bread, or *indirectly* after conversion to animal products.

One can use the *gross* production, meaning total production, or the *net* production, or *available* grain, i.e. gross production less seed and losses. Usually 12.5 – 15 % is deducted from the total production for estimating available grain. According to the Norwegian State Grain Corporation the deduction will be no more than 7 – 8 % with high yield levels and good drying facilities. Accordingly, gross production should be a good measure for food supply potential.

It has been mentioned earlier that because of progress in agricultural technology during the 19th and 20th centuries, the availability of grain has greatly increased in the developed countries. Existing data suggest that up to the end of the 18th century not more than 150 – 200 kg net grain was available per capita per year in countries now considered as developed. This corresponds to 170 – 230 kg produced grain assuming 12.5 % deduction for seed and losses which may be valid at low technology levels. It is worth noting that the developing countries today have similar levels for cereal grain supply.

Based on FAO-data (1976 – 86) the gross grain production per capita per year has increased since World War II in spite of the high rates of population growth (Table 17). On a world basis the grain produced is in excess of the about 200 kg per person per year needed directly for food.

Table 17. Gross grain production, kg per capita per year (FAO-data).

	1948–52	1969–71	1979–81	1984–86
World	280	333	359	380
North America	980	1080	1370	1430
Western Europe	250	387	453	613
Africa	180	172	152	185
Denmark	940	1350	1430	1648
Sweden	370	595	651	732
Finland	350	624	626	737
Norway	110	200	275	317
Average[1] Nordic countries	450	705	755	855

[1]) Weighed.

There are, however, great variations between regions. In Africa grain availability became reduced from 1950 to 1980 and is lower than is needed to give a sufficient food supply. This is due to high rates of population growth, an arid climate and poorly developed agricultural technologies. A permanent food crisis may be expected for this continent.

In the developed countries with moderate and declining population growth the availability of grain has increased considerably during the post-war period as shown for North America and Western Europe. Of the Nordic countries, Denmark is in line with North America with regard to grain produced per capita. It is apparently not an overstatement to consider Denmark as the most advanced agricultural country in the world. Norway is below the world average with regard to grain production per capita. Taken as a whole, however, the Nordic countries produce more than double the world average of grain per capita.

Because of the progress in grain growing technology in the developed countries much more grain is produced than is needed directly for food for humans. The quantities of grain

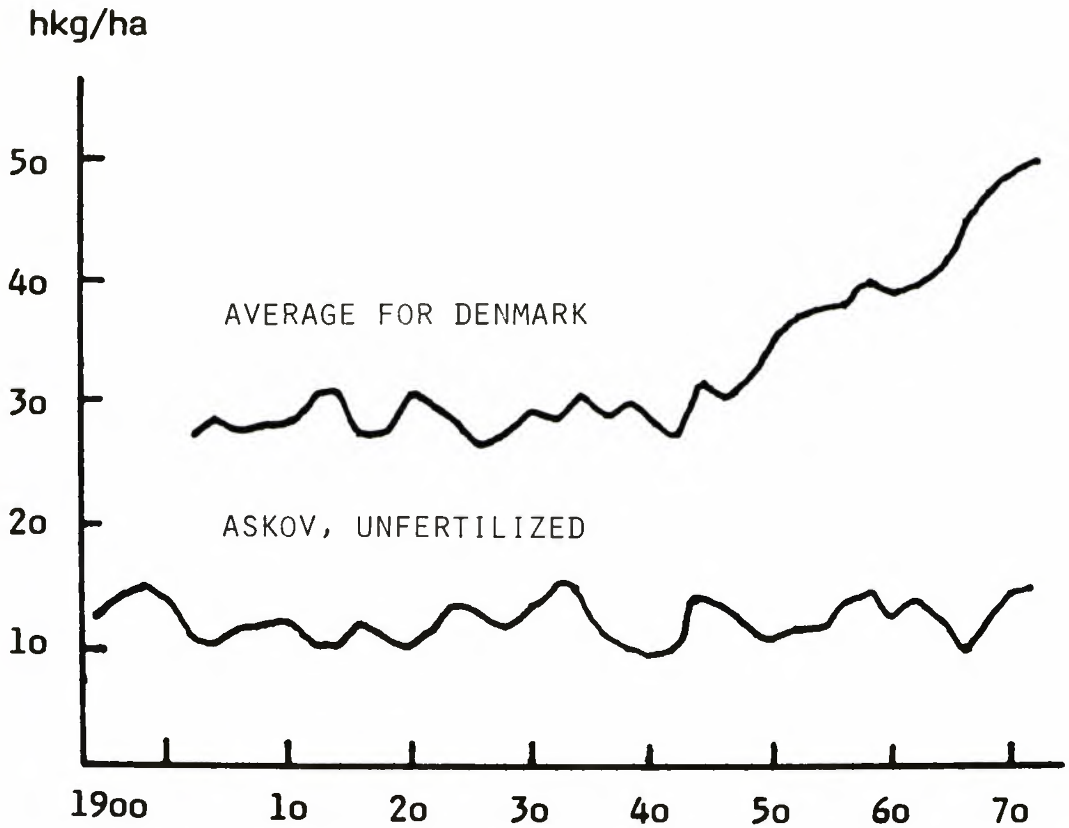

Figure 11. Wheat yields without fertilizers (Askov Experimental Station) and average for Denmark 1900-70 (Dam Kofoed 1979).

which exceed that needed for food can be fed to animals. Grain feeding has contributed greatly to the liberal supply of animal foods in the developed countries during this century, particularly since World War II. It is during this latter period that the modern feed industry has developed with grain as the most important raw product. Finally, however, the progress in animal production by means of the feed industry can be ascribed to the progress made in grain growing.

9.4. Chemical fertilizers

Water and plant nutrients are the most important growth factors for plants, strongly influencing productivity as measured by yields per ha. The importance of water has been indicated previously in the discussion on climate and weather.

In order to obtain high yields it is necessary to apply chemical fertilizers as a source of plant nutrients, particularly nitrogen. Accordingly, chemical fertilizers are an important resource in agricultural food production.

At Askov Experimental Station in Denmark wheat has been grown without fertilizers since 1893. For more than 80 years wheat yields have remained constant at about 1300 kg per ha with some fluctuations caused by weather conditions (Fig. 11). The average wheat yields in Denmark from about 1970 exceeded 5000 kg,*four times more* than those obtained on the unfertilized plots at Askov (Dam Kofoed 1979). It is important to realize that during the whole period the best suited technology was also used with regard to wheat varieties. Obviously fertilizers are needed to utilize the potential obtained by plant breeding.

According to this experiment without fertilizers the yields are in *equilibrium*, corresponding to the situation in the developing countries using prescientific technologies. Also for the average wheat yields in Denmark an equilibrium stage is apparent from 1905 to 1945, but at a higher level than at the unfertilized Askov plots. The increase in the average wheat yields after the war apparently can be ascribed to increased fertilization. It should, however, be noted that the great response to fertilization would not have been possible without the breeding of short stature wheat varieties (Mac Key 1978).

Phosphorus resources are considered by many to be marginal while potassium resources are abundant (NOU 1974). Nitrogen fertilizers are manufactured by fixation of nitrogen from the air. This was first carried out in Norway by the Birkeland-Eyde process, which required much energy. In modern processing methods hydrogen is needed, as supplied from gas or oil. From a resource point of view the supply of nitrogen fertilizers is clearly an energy problem.

In Norway over a 50 year period from 1929 to 1979, the total tonnage of plant nutrients (P, K and N) increased by 12½ times, nitrogen by 24 times (Table 18). A similar increase in nitrogen was found in the UK during the same period (Cooke 1981). The energy equivalent of the chemical fertilizers in Norway increased by only about 6 times from 1929 to 1979 because of progress in energy saving nitrogen fixation compared with the Birkeland-Eyde process.

Table 18. Plant nutrients supplied by chemical fertilizers in Norway (NLVF 1980).

	1929	1979
Tons P	3 982 (1)	26 322 (6.6)
Tons K	7 260 (1)	65 455 (9.1)
Tons N	4 094 (1)	98 809 (24.2)
Total	15 282 (1)	190 586 (12.5)
Energy equivalent of fertilizers, TJ[1]	1 577(1)	9 134 (5.8)

[1]) Included lime, packing and transport.

9.5. Commercial energy

9.5.1. Use of commercial energy in modern agriculture

It has been mentioned already that the great increase in agricultural productivity in this century, called the third agricultural revolution, is strongly related to use of commercial energy, mainly oil (Blaxter 1974).

According to FAO (Stout et al. 1979), in agricultural plant production the developed countries use 11 times more commercial energy per ha than the developing countries, but a smaller proportion of the total energy use (Table 19). The energy use in agricultural plant production in Norway is close to the FAO average for developed countries.

In order to increase the food supply in the developing countries an increase in energy supply in agriculture appears necessary. According to FAO (Stout et al. 1979) 20 GJ per ha is needed to produce 2500 kg grain per ha.

The use of commercial energy in agricultural food production in Norway during a 50 year period from 1929 to 1979 has been studied by a working group of NLVF (Norwegian Agricultural Research Council) (NLVF 1980, 1984b). The energy costs of animal production are included with cost of buildings and bought feeds, also the growing of imported feeds (NLVF

Table 19. Use of energy in agriculture (plant production).

	GJ/ha	% of total energy use
Developing countries 1972–73[1]	2.2	4.8
Developed countries 1972–73[1]	24.8	3.4
Norway 1979[2]	25.3	3.2

[1]) Stout et al. (1979).
[2]) NLVF (1980).

Table 20. Use of commercial energy in agricultural food production in Norway 1929–79 (NLVF 1980, 1984b).

	PJ (10^{15} J)	% of total energy use in Norway
1929	7.5 (100)	4.0
1949	14.0 (187)	6.7
1979	34.1 (455)	4.9

1980). The use of energy in food production has increased by 4.5 times during the 50-year period. Agriculture's share of the total energy use in Norway has decreased, however, from 1949 to 1979, and in 1979 was not much higher than in 1929. (Table 20).

Regarding energy used in Norwegian food production, excluding green-houses, *direct use of energy* such as oil or electricity increased from 6 % in 1929 to 23 % in 1979 (Table 21). The *indirect use of energy,* i.e. the energy equivalent of inputs, including packing and transport to the farms, by far comprises the largest part of the agricultural use of energy in food production (77 % in 1979). In 1979 fertilizers accounted for the highest proportion of the energy, i.e. 27 % (Table 21). Fertilizers represented 41 % of the energy used in plant production of which nitrogen fertilizers accounted for 85 %.

Considering the low proportion of direct energy in agricultural energy use, excluding greenhouses, it is not surprising that agricultural food production in 1979 took only 1.1 % of the oil and 0.9 % of the electricity used in Norway. For comparison, it can be mentioned that private cars took 15 % of the oil (Table 22).

The interactions between the fundamental re-

Table 21. Distribution of commercial energy used in agricultural food production in Norway 1929–79 (NLVF 1980, 1984b).

	% of energy use:			
	1929	1949	1979	
1. Oil and electricity	6	8	23	Direct
2. Fertilizers	21	26	27	Indirect
3. Bought feeds	38	37	21	Indirect
4. Buildings	23	17	10	Indirect
5. Machinery	8	8	13	Indirect
6. Other uses	4	4	6	Indirect

Table 22. Use of oil and electricity in agricultural food production in Norway (NLVF 1980, 1984b).

	% of total energy use:	
	Oil	Electricity
1929	1.3	0.8
1949	1.1	0.7
1979	1.1	0.9
1979 incl. greenhouses, side activities and forestry	3	
1977 private cars	15	

Table 23. Indices of use of fundamental resources per unit of metabolizable edible energy in Norwegian agricultural food production 1929–79 (NLVF 1980).

	1929	1949	1979
Commercial energy	100	153	309
Land	100	83	63
Labour	100	80	25

Table 24. Use of commercial energy in production of plant foods and animal foods in Norway 1979 (NLVF 1980).

	MJ commercial energy per:	
	MJ metabolizable edible energy	kg dig. edible protein
Cereals	0.53 (100)	70 (100)
Potatoes	0.96 (180)	308 (440)
Vegetables	3.22 (610)	719 (1030)
Milk, cow meat, newborn calves	3.80 (720)	327 (470)
Pig meat	5.08 (960)	400 (570)
Eggs and poultry meat	9.12 (1720)	458 / 650)
Sheep meat	12.06 (2280)	720 (1030)
Cattle meat, bulls, etc.	15.92 (3000)	765 (1090)

Table 25. Use of fundamental resources per TJ edible food energy in Norway 1979 (NLVF 1980).

	Vegetable foods	Animal foods	Vegetable foods = 1.0
Energy, TJ	1.27	4.99	3.9
Land, ha	30.2	129.5	4.3
Labour, man years	9.6	16.4	1.7

sources, commercial energy, land, and labour, were also studied by the NLVF working group (Table 23). Expressed per unit of metabolizable edible energy the use of commercial energy increased three-fold (3.09) from 1929 to 1979, while land decreased to three-fifths (63 %) and labour to one-quarter (25 %). Clearly the use of commercial energy has enormously increased the productivity of land and particularly of labour. On average the use of commercial energy increased by 63.4 GJ, equivalent to 1.5 tons of diesel oil per man who left agriculture during the period 1929 – 79.

The NLVF working group also studied the use of commercial energy in the production of different foods, of plant as well as animal origin, expressed per MJ of metabolizable edible energy and per kg of digestible protein (Table 24). Distinctly less commercial energy is used in the production of cereals and potatoes than in the production of other foods, particularly those of animal origin.

Among the animal productions milk production is the most favourable with pig meat production as a good second. Animal foods are more competitive compared with the plant foods, with regard to energy use in the production of food protein than in the production of food energy. This would be even more marked if the biological value of protein were taken into account.

Dividing the foods into two groups, vegetable foods and animal foods, it was found that about *four times more energy and land* was used per unit of metabolizable edible energy in the production of animal foods than in the production of vegetable foods, while the difference in use of labour was far less (Table 25).

It should be taken into account that energy use here means the energy used in agriculture. For some vegetable foods, however, much additional energy is needed before final presentation to the consumers in the shops. The agricultural production of grain and sugar beet thus takes only *one-fifth* of the total energy needed at the retailer for bread and sugar (Leach 1976, NLVF 1984a,b). According to Spedding (1984) white bread, sliced and wrapped, requires 6-7 times more support energy than wheat at the farm gate. Among the animal products milk has a low energy cost from production to consumption.

9.5.2. Outlook for energy resources

With regard to the future there is justifiably some concern about how long the fossil energy

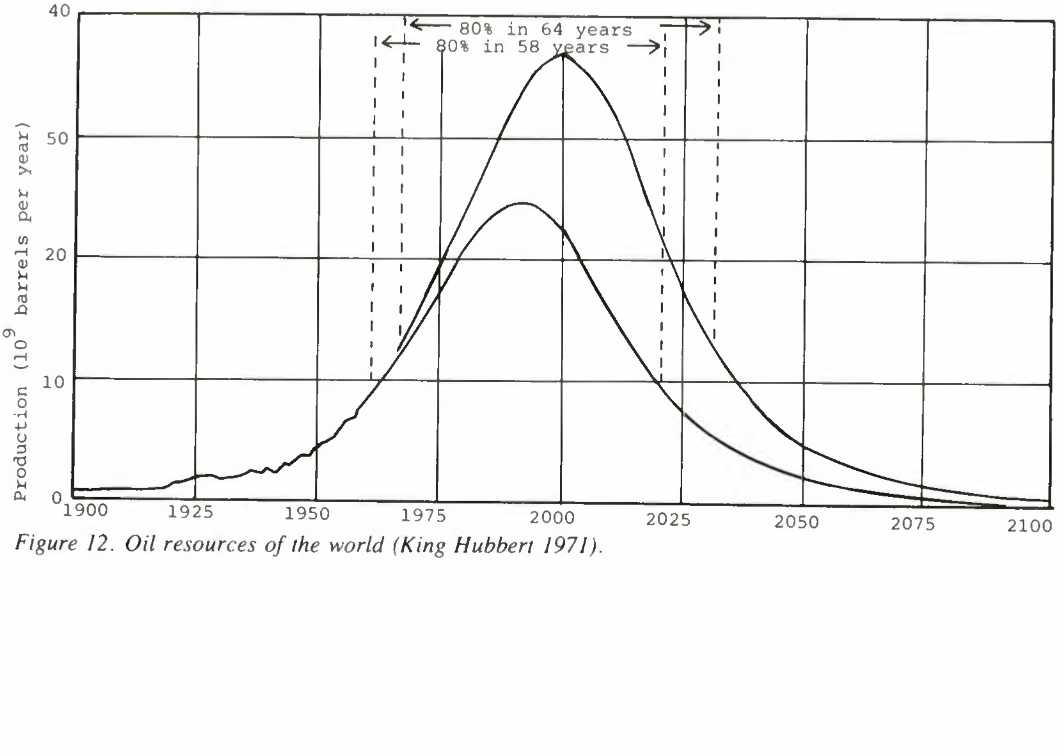

Figure 12. Oil resources of the world (King Hubbert 1971).

resources will last. Regarding world use of commercial energy in 1975, 97 – 98 % was fossil energy, 31 % coal, 19 % natural gas and the remaining 48 % oil. In 1929 the use of commercial energy was one-fifth of that in 1975 (52.0 and 248.3 EJ, respectively) and the proportion of oil in 1929 was only 16 % (NLVF 1984a).

It is particularly the outlook for oil that gives cause for concern. According to the oil geologist King Hubbert (1971) the oil resources of the world can be described by a bell-formed curve showing maximum resources in the 1990s (Figure 12). Based on two different estimates of the oil resources King Hubbert found that 80 % of the oil resources will be used in the short span of about 60 years. He expresses it in this way: In 1965 10 % percent of the oil resources were used. Sixty years later, in 2025, there will be only 10 % left (NLVF 1984a).

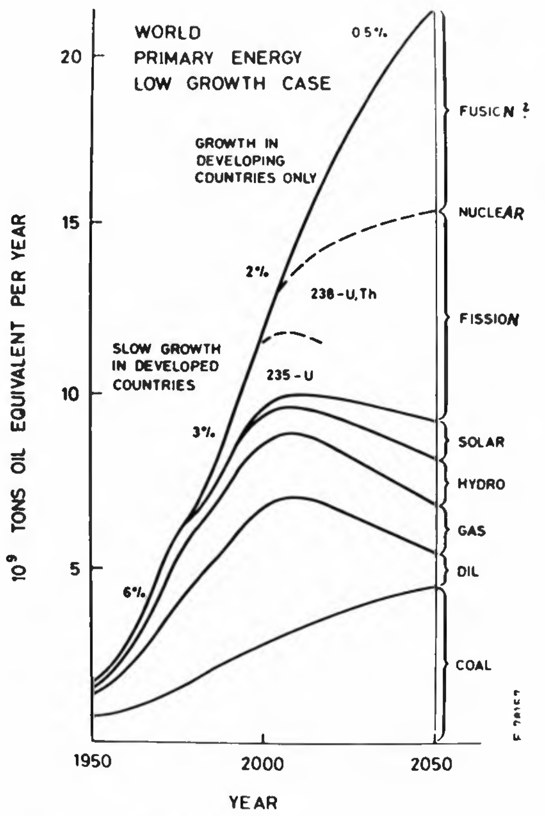

Figure 13. Prognosis for energy supply in the future (Elbek 1978).

The Danish physicist Bent Elbek (1978) gives a similar picture of the energy supply of the future, and includes energy sources other than oil, too (Figure 13). He considers it likely that in the next century an energy equilibrium will be reached with regard to demand. Up to the year 2050 the demand, however, will increase even without economic growth in the developed countries. It is assumed that by 2050 the energy demand will be four times greater than in 1977. Up to about the year 2000 there will be sufficient oil to meet the demand but in the next century there will be serious supply problems. Nuclear energy and use of breeder reactors based on U-238 apparently will be necessary. To close the supply/demand gap, however, fusion will be needed in the long run (Elbek 1978, NLVF 1984a).

It could be said that the energy demand will rise by less than estimated by Elbek provided the rate of population growth in the developing countries decreases.

Considering the importance of energy for agricultural productivity it seems reasonable that agriculture should be given top priority for allocating scarce petroleum supplies, as expressed by FAO (Stout et al. 1979). This is generally accepted. It should, however, be recognized that if economic growth is limited by shortages in energy supplies then this may reduce buying power and the demand for animal foods.

10. SUMMARY

1. The primates, the zoological order to which man belongs, go back 70 My in time. Under the primates the super-family hominoidea, the manlike apes, is divided into two families; pongidae, the greater apes, and hominidae, man's ancestors. The division of these families probably took place 4-15 My ago. Forms of the genus Homo, man, have existed for 1.5 – 2.5 My.
2. The hominoids, living in tropical rain

forests, were largely herbivores. Environmental changes took place 20-16 My ago. A colder climate led to the shrinking of the tropical rain forests and open woodland savannah developed, leading to tougher plant food. The early homo forms consumed animal foods in addition to plant foods promoted by the use of tools engineered by their enlarged brain capacity and well-developed hands. Man is clearly omnivorous, eating from a wide range of plant and animal foods. According to Richard B. Lee palaeolithic man, the Old Stone Age man, likely derived 20 – 40 % of his food energy from animal foods, in similarity with the inhabitants of developed countries today.

3. After the introduction of agriculture, starchy food staples, cereal grain and tubers, became the most important energy sources for man, while the supply of animal foods decreased. When given the opportunity, however, man reverts to a food supply with high proportions of animal food, as shown in Japan during the post-war period.
4. The availability of plant foods decreases from south to north. As a consequence the supply of animal foods increases the further north one goes. Apparently this is also the case for the present food supply. According to FAO-data for 1972 – 74 farm animal foods supply 31 – 45 % of the food energy in the countries in northern Europe, and 15 – 21 % in the countries in southern Europe.
5. In the economically developed countries, the USA and the countries in NW Europe, with high supply levels of animal foods, there were trends toward saturation in demand for animal foods during the 1970s. This was most pronounced for visible animal fats, milk and eggs, while saturation was not fully reached for meat. For countries in the initial stages of economic development, such as southern Europe, eastern Europe and the USSR, signs of saturation were absent.
6. R.E. Olson states that nutrition has two faces; one is medical and deals with physiology and health, the other is agricultural and deals with ecology and environment. The medical face is valid during times of food surplus while the agricultural face comes into the foreground during times of shortage.
7. Food production may be limited by decreased resource availability.
8. Land is the most important natural resource for food production. More land is needed for mixed diets than for vegetarian diets. Some densely populated countries have less land than is needed even for vegetarian diets and are therefore strongly dependent on the importing of cereals.
9. Climate is also an important natural resource for food production. Compared with other continents Europe has a favourable climate with regard to temperature, rainfall and variation. Weather fluctuations can decrease grain production by about 20 % compared with production for preceding years. More variable weather than that experienced earlier in this century is now expected.
10. Agricultural technology is an important resource in food production. The liberal food supply of the developed countries can be traced back to progress in agricultural technology, particularly to the introduction in this century of an energy intensive technology. Increased grain availability in the developed countries has greatly contributed to increased supply of animal foods.
11. Chemical fertilizers, particularly nitrogen, are needed in order to make use of the yield potential obtained by plant breeding. The supply of nitrogen depends on availability of fossil energy.
12. Commercial energy is an important resource when high productivity is aimed at. By using of energy the productivity of land and particularly of labour can be greatly increased. Expressed per unit of edible energy the production of animal foods needs more energy than the production of vegetable foods. It should, however, be recognized that for some vegetable foods,

such as bread and sugar, the energy needed to produce grain and sugar beet, respectively, makes up only one-fifth of the energy needed in the food chain, including agricultural production, to the shop.

13. The outlook for energy is not bright. Oil scarcity is expected early in the next century. As stated by FAO, it appears necessary «that agriculture should be given top priority» in allocating scarce petroleum supplies.

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