FOOD SECURITY

New Solutions for the Twenty-first Century

Proceedings from the Symposium Honoring the Tenth Anniversary of the World Food Prize

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IOWA STATE UNIVERSITY PRESS / AMES

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World Food Production, Food Security, and Sustainable Land Use

Introduction

Food production and food security have been major issues for humankind throughout its existence. Food collection and production was the most time-consuming activity in all societies and only in this century has the decrease in employment in agriculture accelerated.

Currently, only 4 to 5 percent of the professional population is directly involved in agriculture in the industrialized world. In the developing world that figure still varies between 50 and 70 percent, and a decrease in that number is likely within the next decades. With only very few people involved in agriculture, the food production and food security for all may be guaranteed. Worries about that guarantee have been uttered frequently in the past.

Two centuries ago the limits to growth were proclaimed by English economist Thomas Malthus and world food security was, in his opinion, in danger. One century ago similar warnings were on the top of the policy agenda, and food production was again considered to be an important issue that would make the future very dark due to structural shortage.

Now at the turn of the century food production and food security for the next century are again on the top of the policy agenda. Worries about the future are widespread, and recently the number of conferences, symposia, workshops, and summits on food production and food security has mushroomed.

Not that food production has decreased during the last century. On the contrary, this age has seen a five-fold increase in the number of people on the globe and a six-fold increase in food production—an unprecedented achievement of humankind. In this century, land productivity in the industrialized world increased five- or six-fold; labor productivity, 200- to 300-fold; and although external inputs such as water and nutrients increased considerably, their efficiency also increased. Yields of 8 tons of wheat per hectare are no longer an exception. The amounts of water, labor, oil, nitrogen, and phosphorous per kilograms (kg) of wheat, rice, potato, or any other product that is produced have decreased. That increase in efficiency has been due to a synergistic effect among various inputs.

Productivity increase has been widespread and has shown discontinuities (Green Revolutions) during this age in the industrialized world after World War II and in many places in Asia in the late 1960s and early 1970s. Before those revolutions, productivity increase took place with 5- to 10-kg grain equivalents per hectare per year; after those revolutions, productivity changed to a rate of 80- to 150-kg grain equivalents per hectare per year. These Green Revolutions have not yet taken place in Africa, but they are urgently needed in the coming decade.

So at this moment, if you consider these developments during the last century you can, in fact, only be hopeful, because of what happened in the last age. Why should it not happen in the next few decades again? The present situation, however, is complicated, as indicated by Norman Myers in his opening discussion, because many important phenomena occur at the same time. Those phenomena include the leveling off of grain production, which we have seen during the last few decades; the decrease of grain stores, which has occurred during the last few months; the decrease in aquifers; the lowering of water tables; and the decrease in fish harvest. The leveling of grain production is, however, due to the effect of active policies in Europe and in the United States to promote set-aside. The per capita grain production is also decreasing as a result of the increasing use of the marginal areas instead of further promotion of the well-endowed lands.

We see indeed that fish harvest is decreasing and we see that fish harvests are not produced by aquaculture in fish ponds, but as much as 80 percent of the fish production is still caught in an old-fashioned way in the sea or in fresh water. If the method would change, then the productivity of fish would increase considerably. There are, of course, undeniable environmental side effects that are due to an unsustainability spiral in which much of agriculture—Africa, for example—finds itself at this moment.

One example of this unsustainability spiral is the decreasing soil fertility in Africa, which occurs as a result of poverty. If we consider the estimated shares of the various activities that cause decreased quality of land, and that may cause many difficulties for the continuity of production in agricultural land, we find the following: 35 percent of the unsustainability is due to overgrazing; 29 percent is due to deforestation; 7 percent is due to overexploitation; 28 percent is due to mismanagement on a world scale; and only 1 percent is due to overuse of inputs. In the Western world, we tend to overestimate, in fact, the consequences of the too-intensive agriculture systems. On a world scale, that is of minor importance.

Much more important, of course, is the unsustainability due to poverty. When you are not bringing enough external imports into a system, that creates a decrease in the production and results in an overuse of that land.

Two authors, Lester R. Brown of the Worldwatch Institute and Mark W. Rosegrant of the International Food Policy Research Institute, take the past and consider trends and use them to look ahead in time; they come to very different conclusions. Their conditions are being characterized as pessimistic views or optimistic views. Both authors are technically right as they look at the same statistics and the same tables, but they have different interpretations and predictions.

When you consider the productivity rise, and mention the efficiency increase, and realize what has been achieved during the last century, then you can have an optimistic view and say "Oh, that is going to repeat in the near future."

If you consider the negative side effects of many of the changes then you see the system's unsustainability spiral, which takes place at several places. If you see that there is a problem in the use of land in many places, then you can become a pessimist.

It is for this reason that predictive studies that only consider trends and extrapolate them are of limited value to investigate the long-term possibilities and future perspectives. For that reason "explorative" studies are needed.

Explorative Food Production Studies

An example of an explorative study of food production is given by the Netherlands Scientific Council for Government Policy. That study investigated the future possibilities of food production, food security, and sustainable land use.

For the purposes of the study a number of assumptions were made with respect to sustainability. In the first place, sustainability presupposes the aim of closing all cycles as effectively as possible. Agriculture makes use of nature's productive capacity, tapping outputs from the system in the form of products. If agriculture is to be maintained over a lengthier period, inputs need to be added to the system in order to compensate for the tapped-off outputs. By definition, inputs can never be 100 percent converted into outputs; this implies that part of the inputs will be lost to the environment as leakages. These leakages can never be sealed off completely, so that the substance cycles in agriculture can never fully be closed.

Various strategies may be pursued in order to obtain an optimal result. Efforts may be made to close cycles as far as possible at the regional level in order to bring the losses to the environment under local control. Another strategy is based on closing the cycles at the global level to maximize the efficiency of the system and thus minimize the overall losses. Within each of these two approaches the agricultural system can be organized in many different ways.

Two different systems of agriculture are considered to demonstrate the extreme estimates for the production potential without violating the principles of sustainable production. These are Globally Oriented Agriculture (GOA) and Locally Oriented Agriculture (LOA).

The first system, GOA, seeks to achieve sustainability by aiming at the maximum efficiency of agriculture at the global scale. It is based on the notion that the environment is best served by the *lowest possible loss of inputs per unit of output.* This then makes it possible for comparatively high local leakages to the environment to be accepted with a view to reducing the overall burden on the environment. By making use of efficiently produced fertilizer and transporting it to places where these nutrients can be converted as efficiently as possible into agricultural products, an attempt is made to limit the total losses as far as possible.

With a view to guaranteeing sustainability, LOA aims as far as possible at closing regional or local cycles. This is based on the underlying premise that the quality of the environment is best served by the *lowest possible loss of inputs per hectare.* This principle results in the deployment of techniques that avoid the use of external, alien substances such as fertilizers and pesticides wherever possible. Efficiency is therefore defined at a totally different level of scale.

Both globally and locally oriented agriculture aim at maximum efficiency within their own limiting conditions, with a view to the sustainable functioning of the entire system. Under the GOA system the output is ultimately limited by the available agricultural land and the local availability of water. Under the LOA system the output is limited not only by the local availability of land and water but also by the amount of nitrogen that can be fixed from the atmosphere by natural means. In addition, other physical conditions, such as the quality of the soil, play a role in determining the production potential. The computations have been made on the assumption that other aspects, such as energy, minerals, investments, and labor, do not impose constraints. Any demand for energy or investment can therefore be met in both the GOA and the LOA system. In relation to the present situation this represents a substantial expansion of production.

In many parts of the world, however, there are distinct limitations attributable to the lack of resources and manpower. The necessary quantities of fertilizer or energy are, for example, by no means procurable universally. Furthermore, the necessary infrastructure is lacking in many places. Even if money were available under development projects to buy fertilizer, it remains questionable whether the fertilizer could be applied in the right place in the right way. The assumptions on which this model study is based clearly indicate, therefore, that the calculations can provide insight into the maximum potentialities of both agricultural systems, but these potentialities tell us little if anything about probable developments in the various regions. For this, far more information is required on the range of obstacles impeding agricultural development in various places.

The availability of water does, however, constitute a possible obstruction in calculating the production potentials of both systems. The maximum possibilities have therefore been made dependent on physical factors. This has been calculated by examining how much water is available for irrigation purposes in each catchment area in the 19 regions shown in Figure 10.3.2. For each region, the demand that can be derived from possible population developments on the basis of United Nations (UN) scenarios has been combined with the production possibilities. The basic calculations of these potentials have been made on a 1°x1° grid basis. The comparison between demand and supply indicates whether the demand for food can be satisfied in each of the 19 regions, while at a world scale it is possible to establish whether agricultural production is able to feed the growing population. The differences between the regions are indicative of the need for the transport of food from surplus areas to shortage areas.

Opinions on sustainable food production differ not only in relation to the potential agricultural techniques but also as to the package of food which the average world citizen could consume in the future.

The choice between a *Western* diet or a *Moderate* diet is prompted by differing estimates of the environmental consequences. The choice in favor of a Moderate diet may be based on the view that in the long term the world population cannot be fed at the present level of Western consumption, as this would impose an undue strain on the environment. In the case of a Western diet, by contrast, the environmental risks are deemed acceptable. It may be noted that neither of these two diets is extreme; the Moderate diet is substantially higher than the present world average, whereas the Western diet is lower than the present level of consumption in, for example, the United States. The Western diet contains a comparatively high proportion of meat and is equal to the present level of average European consumption. This requires a primary production of around 4.2 kg of grain equivalents per person per day. (The use of grain equivalents enables various agricultural products, for example, wheat, rice, millet, and maize to be brought under a common denominator.) The Moderate diet requires around 2.4 kg of grain equivalents per person per day. The difference is due to the conversion of cereals into meat. In some countries, including the

Netherlands, a high degree of efficiency has been achieved in converting animal fodder into meat. This applies especially to intensive livestock farming. The global average is approximately 8 kg of grain per kilo of meat. A diet containing more meat therefore leads to a substantial increase in the necessary volume of grain equivalents.

The calculations have drawn on two estimates for the growth of the world population based on figures in the 1992 UN publication *Long-range World Population Projections (1950–2150).* The low estimate produces a figure of 7.7 billion people in 2040 and the high estimate a figure of 11.2 billion. A decision in favor of either one of these variants will obviously have a major impact on the results of the calculations.

Action Perspectives

Four action perspectives are described that differ in terms of food supply with respect to the combinations of production techniques and diets. Table 10.3.1 indicates how the Utilizing, Saving, Managing, and Preserving action perspectives relate to the normative differences in insight.

Table 10.3.1. Action perspectives for sustainable development of the world food supply

	Luxury package	Moderate package
Globally oriented agriculture	Utilizing	Saving
Locally oriented agriculture	Managing	Preserving

SOURCE: Netherlands Scientific Council for Government Policy. 1995. *Sustained Risks: a Lasting Phenomenon.* 44:60.

Utilizing

The Utilizing perspective aims at the provision of a Western diet on a worldwide basis as quickly as possible. It is assumed that this level of consumption is consistent with the ambitions in large parts of the world. Potential environmental problems are regarded as not insuperable. In addition, there is marked confidence in technological solutions to environmental problems. In particular, increasing agricultural output on good soils can result in the highly efficient utilization of physical inputs such as fertilizers and pesticides, to the benefit of the environment. Per unit of product, this agricultural technique requires a minimum level of physical inputs. Furthermore, comparatively little land is taken up at maximum levels of production. The social risks associated with the introduction of a production-oriented agricultural system that is required to meet a sharply increasing demand for food are regarded as acceptable under this vision. Relevant know-how also is increasingly exploited by food producers throughout the world.

Saving

The Saving perspective considers that major environmental risks are attached to feeding a rapidly rising world population. Locally oriented agriculture would, however, involve an excessive change in relation to the present forms of agriculture, for which reason it is sought to minimize the risks for the environment by limiting the demand for food. This will involve a substantial reduction in the pressure exerted by the agricultural system on the environment. The aim is for a Moderate diet—without much meat—for each world citizen now and in the future. This situation must be realized by the redistribution of the food produced. Residual environmental problems that could arise under the GOA system are regarded as soluble. The system can be finely tuned to the point that alien substances such as fertilizers and pesticides need not be released in large quantities into the environment.

Managing

The Managing perspective departs from the aim of a Moderate diet on account of the associated social risks. This must not, however, be at the expense of subsequent generations. The risks to the environment of a GOA system are therefore regarded as excessive. The environment faces threats not so much from the losses per unit product as from the local losses to the various environmental compartments. Water, soil, and air must be or remain of high quality, and energy and resources must be used sparingly. The comparatively high uptake of land that may be expected under a LOA system is regarded as less of a problem, as are the necessary adjustments in the structure of production.

Preserving

Under the Preserving perspective the risks to the environment are regarded as so grave that the demand for food needs to be limited and local substance cycles optimized by the development of modified agricultural systems. The introduction of alien substances and the long-range transportation of potentially harmful substances (e.g., fertilizers) are considered to pose an undue risk to the environment. The social risks of “adjusting” the demand to a Moderate diet are regarded as acceptable. It must be possible at the global level to hold down the trend toward rising levels of consumption of animal protein. In the rich countries, the consumption of meat will therefore need to fall sharply to around 40 grams a week. The reduction in demand combined with careful chain-management at the local level would guarantee a sustainable world food supply. Here, too, the emphasis is on an equitable distribution of the by-no-means overabundant supply of food.

Translation of the Action Perspectives into Scenarios

The potential grain yields per hectare, corrected for storage and transport losses, are between 4 tonnes (metric tons) under LOA and 10 tonnes under GOA. In the tropics, two to three crops can be cultivated per year given sufficient irrigation water. An estimate of the suitable area is required in order to determine the potential yield. The land must be capable of supporting sustained farming over a number of years, so that vulnerable lands have been left out of account. By way of illustration, 128 million hectares of land are currently used for agriculture in the European Union, whereas on the basis of the soil properties, this study reaches the conclusion that 80 million hectares may be deemed suitable for agriculture in the longer term.

The available land in each of the regions may or may not be irrigated. Clearly, this depends on the amount of water available for irrigation purposes in the region in question. It will also be clear that the various production levels of LOA and GOA result in different water requirements. Taking everything into consideration, the distribution is as shown in Figure 10.3.1. In all cases over 8 billion hectares (approximately 70 percent of the total area) is unsuitable for agriculture. In the scenarios based on LOA, approximately 20 percent of the area is irrigated. The GOA scenarios result in the irrigation of approximately 14 percent of the total area. This distribution turns out to be comparatively insensitive to the various world

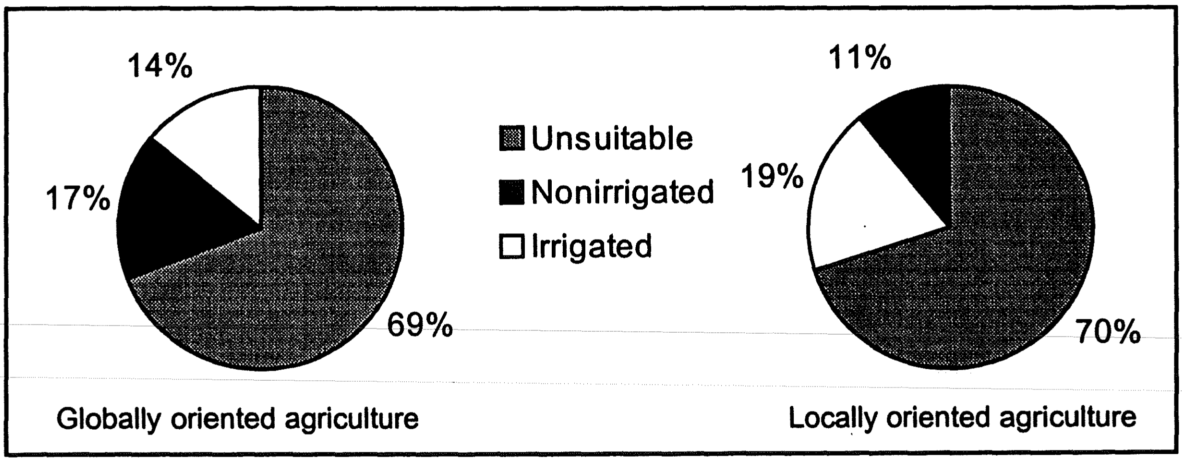

Figure 10.3.1. Breakdown into suitable and unsuitable agricultural land
SOURCE: Netherlands Scientific Council for Government Policy. 1995. *Sustained Risks: a Lasting Phenomenon.* 44:61–2.

population growth variants. Although the demand for water for household and industrial purposes rises in line with the population, this increase has little if any impact on the total amount of water available for agriculture.

The results of the calculations based on the number of people in the region, the preferred level of consumption, and the agricultural system in question are shown in Figure 10.3.2 for the high population growth variant and in Figure 10.3.3 for the low population growth variant.

From Figures 10.3.2 and 10.3.3 observe that self-sufficiency is realizable at the global level in all four scenarios. Even in the low population growth variant, however, there are shortages in a number of regions for three of the four scenarios. Only in the Saving scenario under low population growth can self-sufficiency be achieved in each region. This implies that in all other scenarios, certain regions suffer from shortages and that interregional trade is required in order to meet food needs.

A self-sufficiency index does not, of course, tell us much about the absolute quantities, for which reason the results of the scenarios are shown in somewhat different form in Tables 10.3.2 and 10.3.3. In these tables the maximum production per region is compared with the regional demand, which is equal to a self-sufficiency index of 1.1. A safety margin of 10 percent has therefore been built into all regions. Table 10.3.2 indicates the consequences of this under high population growth. In this case the Managing scenario turns out to be unattainable. The combination of LOA and the wish to provide a Western diet therefore proves out of reach given a high rate of population increase. At the world level there remains a shortfall of approximately 1.5 billion tonnes of grain equivalents.

The other scenarios show a surplus. The imposed 110 percent self-sufficiency can therefore be achieved. In all three of these scenarios, however, there remain regions with shortfalls, especially Asia (East, Southeast, South, and to a lesser extent West). These regions will need to be supplemented from other regions with a food surplus. It is not possible, however, to specify a criterion to indicate which other regions will become exporters with a view to redressing the global balance. What the scenarios can do is to indicate the total shortage in the regions with a deficit. This total shortage provides an initial indication of the trade flows that would be required in order to meet the demand in all regions.

The biggest trade flow is required under the Utilizing scenario and amounts to approximately 5.5 billion tonnes. This is followed by the Preserving scenario, with approximately 4 billion tonnes, and finally the Saving scenario with approximately 1 billion tonnes. The figures also reveal that the impact of a change in the diet is greater than that of the production technique applied. Different population growth figures also have a major

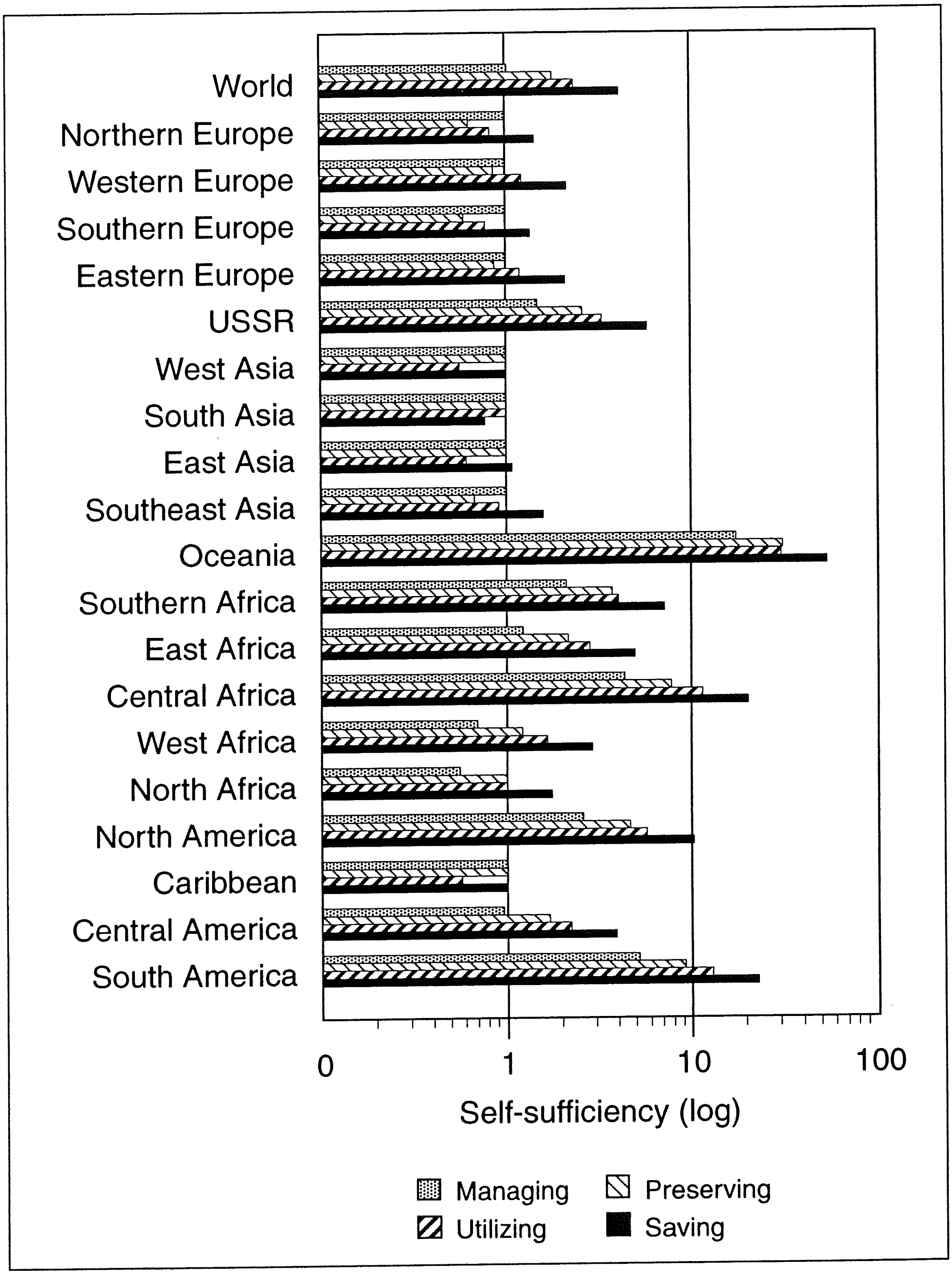

Figure 10.3.2. Self-sufficiency index in the four scenarios for the 19 world regions given high population growth, 2040

SOURCE: Netherlands Scientific Council for Government Policy. 1995. *Sustained Risks: a Lasting Phenomenon.* 44:63.

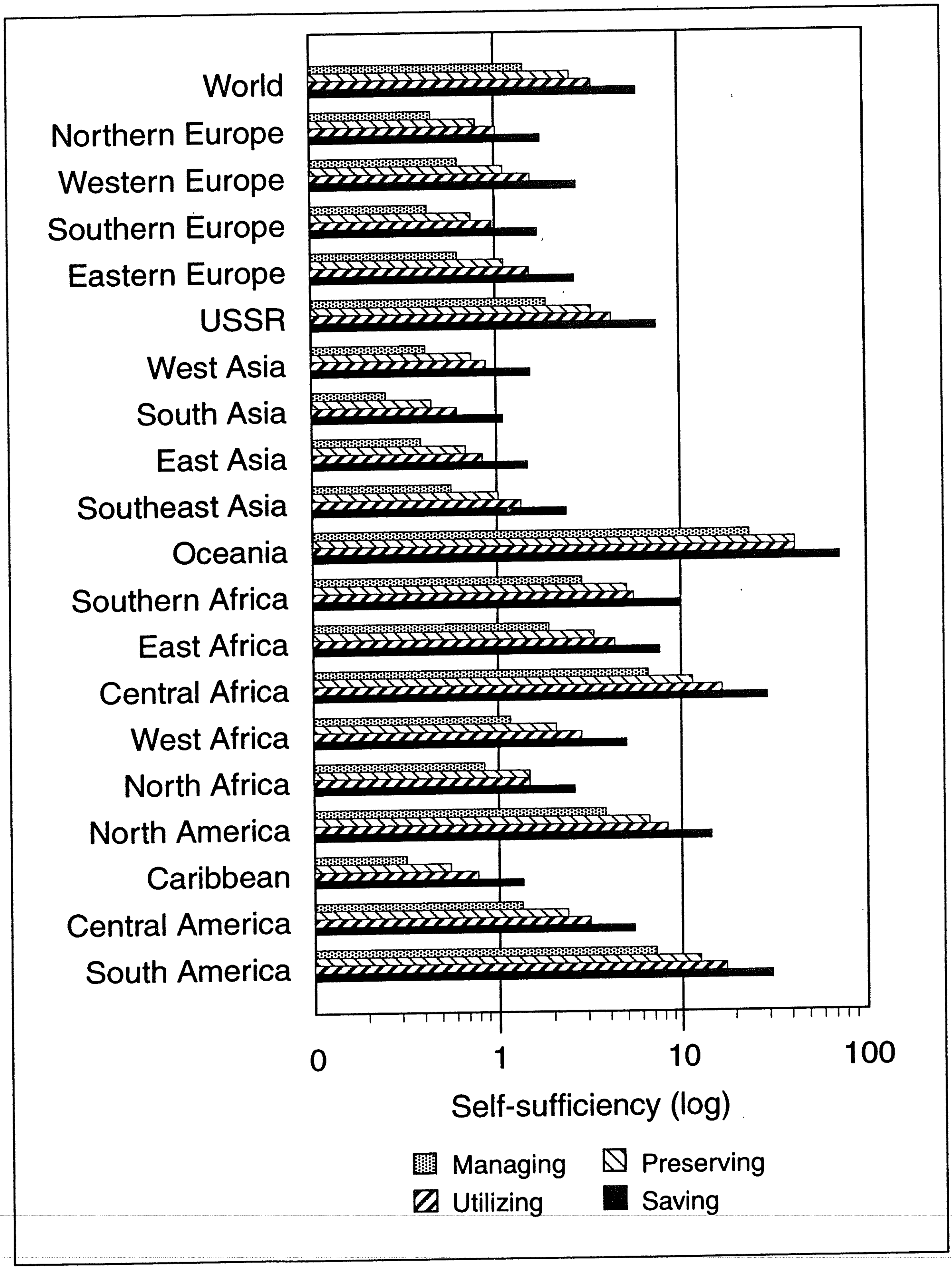

Figure 10.3.3. Self-sufficiency index in the four scenarios for the 19 world regions given low population growth, 2040

SOURCE: Netherlands Scientific Council for Government Policy. 1995. *Sustained Risks: a Lasting Phenomenon.* 44:64.

Table 10.3.2. Regional production balance in the four scenarios given a self-sufficiency index of 1.1 and high population growth (in 10^6 tonnes)

	Preserving (LOA/moderate)			Saving (GOA/moderate)		
Country	Production	Demand	Balance	Production	Demand	Balance
South America	5,353	630	4,724	13,173	630	12,543
Central America	420	268	152	976	268	709
Caribbean	23	62	-30	57	62	-5
North America	1,612	378	1,235	3,539	378	3,161
North Africa	359	398	-39	637	398	239
West Africa	847	758	90	2,049	758	1,291
Central Africa	1,944	271	1,672	4,966	271	4,695
East Africa	1,585	799	786	3,645	799	2,845
Southern Africa	399	116	282	768	116	652
Oceania	1,184	42	1,142	2,069	42	2,026
Southeast Asia	583	955	-372	1,386	955	431
East Asia	912	1,993	-1,082	1,958	1,993	-36
South Asia	775	2,744	-1,969	1,897	2,744	-847
West Asia	163	379	-216	340	379	-39
USSR	939	398	541	2,110	398	1,712
Eastern Europe	100	128	-28	245	128	117
Southern Europe	82	153	-71	188	153	36
Western Europe	128	163	-35	319	163	155
Northern Europe	52	91	-38	118	91	27
World	17,461	10,725	6,735	40,438	10,725	29,713

	Managing (LOA/Western)			Utilizing (GOA/Western)		
Country	Production	Demand	Balance	Production	Demand	Balance
South America	5,353	1,109	4,244	13,173	1,109	12,063
Central America	420	471	-52	976	471	505
Caribbean	23	109	-86	57	109	-52
North America	1,612	665	947	3,539	665	2,874
North Africa	359	700	-342	637	700	-64
West Africa	847	1,335	-487	2,049	1,335	714
Central Africa	1,944	478	1,466	4,966	478	4,488
East Africa	1,585	1,408	177	3,645	1,408	2,236
Southern Africa	399	205	194	768	205	563
Oceania	1,184	74	1,110	2,069	74	1,994
Southeast Asia	583	1,682	-1,099	1,386	1,682	-296
East Asia	912	3,511	-2,600	1,958	3,511	-1,554
South Asia	775	4,834	-4,059	1,897	4,834	-2,937
West Asia	163	667	-505	340	667	-328
USSR	939	701	238	2,110	701	1,409
Eastern Europe	100	226	-126	245	226	19
Southern Europe	82	269	-188	188	269	-81
Western Europe	128	288	-159	319	288	31
Northern Europe	52	160	-107	118	160	-42
World	17,461	18,894	-1,433	40,438	18,894	21,544

SOURCE: Netherlands Scientific Council for Government Policy. 1995. *Sustained Risks: a Lasting Phenomenon.* 44:66–67.

Table 10.3.3. Regional production balance in the four scenarios given a self-sufficiency index of 1.1 and low population growth (in 10^6 tonnes)

Country	Preserving (LOA/moderate) Production	Demand	Balance	Saving (GOA/moderate) Production	Demand	Balance
South America	5,353	457	4,896	13,173	457	12,716
Central America	420	192	228	976	192	784
Caribbean	23	45	-22	57	45	11
North America	1,612	260	1,352	3,539	260	3,279
North Africa	359	263	96	637	263	374
West Africa	847	443	404	2,049	443	1,606
Central Africa	1,944	181	1,763	4,966	181	4,785
East Africa	1,585	510	1,075	3,645	510	3,135
Southern Africa	399	84	314	768	84	684
Oceania	1,184	31	1,154	2,069	31	2,038
Southeast Asia	583	625	-42	1,386	625	761
East Asia	912	1,428	-516	1,958	1,428	530
South Asia	775	1,866	-1,091	1,897	1,866	31
West Asia	163	236	-74	340	236	103
USSR	939	307	632	2,110	307	1,803
Eastern Europe	100	99	2	245	99	146
Southern Europe	82	120	-38	188	120	68
Western Europe	128	125	4	319	125	194
Northern Europe	52	71	-19	118	71	47
World	17,461	7,343	10,118	40,438	7,343	33,095

Country	Managing (LOA/Western) Production	Demand	Balance	Utilizing (GOA/Western) Production	Demand	Balance
South America	5,353	805	4,548	13,173	805	12,367
Central America	420	338	81	976	338	638
Caribbean	23	80	-57	57	80	-23
North America	1,612	459	1,154	3,539	459	3,080
North Africa	359	463	-104	637	463	174
West Africa	847	780	67	2,049	780	1,268
Central Africa	1,944	318	1,626	4,966	318	4,648
East Africa	1,585	899	687	3,645	899	2,746
Southern Africa	399	148	250	768	148	620
Oceania	1,184	54	1,131	2,969	54	2,015
Southeast Asia	583	1,101	-518	1,386	1,101	285
East Asia	912	2,515	-1,603	1,958	2,515	-557
South Asia	775	3,287	-2,512	1,897	3,287	-1,390
West Asia	163	417	-254	340	417	-77
USSR	939	541	398	2,110	541	1,569
Eastern Europe	100	174	-74	245	174	71
Southern Europe	82	211	-130	180	211	-23
Western Europe	128	220	-92	319	220	99
Northern Europe	52	125	-73	118	125	-7
World	17,461	12,935	4,526	40,438	12,935	27,503

SOURCE: Netherlands Scientific Council for Government Policy. 1995. *Sustained Risks: a Lasting Phenomenon*. 44:66–67.

impact on the necessary trade flows. Given low population growth (Table 10.3.3) all four scenarios prove attainable. The necessary transport flows amount in this case to 5.5 billion tonnes (Managing), 2 billion tonnes (Utilizing and Preserving), and zero (Saving).

Evaluation

Prior Conditions for Safeguarding World Food Production

Enough food can be produced to feed the entire world in almost any of the scenarios. Depending on the level of consumption selected, the agricultural system in question, and the availability of water, between 11 billion (Managing scenario) and 44 billion (Saving scenario) people can be fed worldwide. A sustainable food supply does not, therefore, run up against the limits of a physical environmental utilization space for the world as a whole. The extent to which the world population can be fed depends rather on political and socioeconomic factors.

An important demand made in many countries and regions is the ability to feed one's own population. Various economic blocs, such as the European Union (EU), the North American Free Trade Agreement (NAFTA), and the former COMECON attach major importance to food security, thereby underlining the strategic importance of food. The analysis in this report does not permit statements to be made at the individual country level, although the possibilities for self-sufficiency at the level of large regions can be established.

The results indicate that sufficient food can always be produced in South America, North America, Central Africa, and Oceania to meet the demand, irrespective of the preferred diet. In East and South Asia, however, this is only the case given a Moderate diet and a GOA system. Problems can arise in various regions. In a limited number of regions (North and South America and Europe) one can in fact afford the luxury of a Western diet combined with LOA, but this is an exception. For the rest of the world the distribution of food is a possibility. This presupposes an economic climate conducive to international trade, adequate purchasing power in the deficit regions, and a high degree of international solidarity. In terms of the present world community, these are extremely exacting conditions.

In the regions where more food is produced than is required for self-sufficiency, it is in principle possible to increase production in order to offset the shortages in other regions. The regions in which such extra production would need to take place would depend on the optimal level of production in each region. The desire to minimize the transportation of agricultural commodities throughout the world might, for example, lead to a choice to locate the additional production as close as possible to the areas of shortage. On the other hand, the optimization requirement might mean that the additional production was located in those areas where the highest yields could be obtained with the least amount of irrigation.

In all cases the scenarios outlined above will involve enormous changes in the agricultural system in comparison with the present structure. These adjustments will require across-the-board cooperation by all concerned. In both a system aimed more at self-sufficiency and one based on international trade, considerable demands will be made on international cooperation and solidarity. Just how likely this is to succeed can be assessed very differently.

Both the agricultural systems that have been elaborated are based on optimal management methods. This will require a great deal of know-how, insight, and "green" fingers—which will also need to be combined with "green" brains. The entire know-how innovation system will need to be geared to this end. In practice, this is asking a great deal. It implies, for example, that farmers will be well educated and that modern technologies will be available worldwide. This will require an enormous transfer of know-how and technology. A huge effort will be required to achieve this situation within a time frame of 50 years. As noted earlier, the results mainly indicate the potential, not the most probable development. If it proves impossible in large parts of the world to meet the prior conditions for optimal agriculture, this will create additional problems. The aim of a Western diet in a situation where regional food needs can scarcely be met will then be an illusion. There will probably be numerous physical and organizational obstacles towards bringing about the optimal developments.

Environmental Consequences of the Scenarios

The GOA system assumes the availability of the necessary external inputs. The requirement of best technical means assumes that the production techniques applied will have only limited negative effects on the environment. The quality of the soil will, for example, need to be maintained. In the present situation this is not the case. It will also be difficult to limit nitrogen losses under LOA, meaning there will be an impact on the environment. Locally, the leakages per hectare will be greater under GOA than under LOA. However, because the production under LOA is lower than under GOA, the leakages per unit product will be higher. Both LOA and the desire to provide a Western diet will necessitate a higher volume of interregional food trade. In the case of LOA this will in fact be at variance with the underlying premises, such as that of closing substance cycles.

The differences between nonirrigated and irrigated production are dramatic. In river basins there will often be no lack of water to realize maximum production. In Europe, for example, a good deal of water is available in a comparatively small area. Similarly, there is sufficient water for food production in Iran even though the availability of water in the catchment area is lower, because the agricultural area is extremely limited. In South America, which has a large catchment area, water is by contrast a limiting factor for food production because the area available for agriculture is so enormous.

The application of irrigation is based on the most efficient techniques. Even more would be possible if household and industrial wastewater were to be used for irrigation. All this makes heavy demands on the available technical know-how, on the institutional and social structure, and on the political stability in the region in question. There is the potential for conflict among the various categories of water users, not only among households, industry, agriculture, fishery, and the like but also among individual countries and regions. Access to water is already giving rise to conflicts, which can only be exacerbated as population pressures mount.

Apart from increasing yields, irrigation can also have negative effects on the environment, such as a growing nutrient load, salination, diseases, drying up of soils elsewhere, and soil erosion. The quality of the water available for irrigation is also important. High salt concentrations and other forms of pollution are harmful to agricultural crops and will lower the potential yield.

Relationship with Other Goals

The availability and suitability of land constitute vital factors for food production. Together with the availability of water, these factors determine the potential yield of a region. The availability of land depends in part on the agricultural system chosen. A production-oriented agricultural system will require less land than biological agriculture.

Few standard figures are available on the suitability of land on a worldwide basis. Suitability is at present determined on the basis of relatively simple criteria. Soils that cannot be farmed with modern, mechanized agricultural techniques are designated as unsuitable. Processes such as acidification, nutrient exhaustion, deforestation, and overexploitation are left out of account in determining suitability. These processes can, however, substantially damage both the quality of the soil and its suitability for agriculture.

A large area of land is required for food production. A good deal of land remains available for agriculture, for example in South and North America and in Central and North Africa. The area considered suitable for agriculture, however, includes the present tropical rainforests, including those in Central and Southern Africa. Realization of the agricultural potential in these regions will often involve large-scale deforestation, with an increased risk of soil erosion.

Clearly, other claims on land can come into sharp conflict with the demands made by food supply. The overall picture is, however, that 70 percent or more of the total area is not deployed for agricultural purposes in all the scenarios. This area is therefore available for other claims, e.g., nature conservation. These macro figures do, however, disguise the locally strong competition between the various forms of land use. In general it is fair to say that the less land demanded for agriculture the more opportunities there are for the realization of other goals. This means that both the aim of a Moderate diet and the development of a GOA system can contribute towards the solution of land-use conflicts.

In the Saving action perspective, confidence in the resilience of the environment does not extend across-the-board. On account of the enormous growth in the scale of human activities, the continuity of those activities is even regarded as under threat in the long term. A cut in living standards is therefore required, which is where policy comes to bear. The possibilities for applying technology must not be overestimated.

Under the Managing action perspective, the risks to the ecological system are avoided as far possible. This is, however, subject to the condition that the rise in living standards is largely left undisturbed. Under this perspective, the social risks of rigorous intervention are regarded as so great as to call into question the legitimacy of such intervention. Although the Managing perspective does provide for some moderation of consumption, the solutions are primarily sought in the technological sphere.

The Preserving action perspective exhibits little confidence in the resilience of the environment, for which reason adjustments are required to economic and other social activities that impose a burden on the environment. Measures can be brought to bear both in the field of consumer behavior and with respect to the production system. Ultimately, the necessary social willingness is deemed to exist under this perspective.

Epilogue

The four options described above demonstrate the possibilities to feed the world and to maintain sustainable land use. They illustrate that there are sufficient natural resources to feed many more people than there are at this moment in the world. They require, however, in all cases a tremendous effort of humankind. That is the mission and task of agriculturists, researchers, and farmers. That task is not impossible; it is a rewarding task but it demands a combined effort of many people.

Agricultural research is urgently needed to raise productivity, improve the efficiency of water and nutrient use, and promote the wise use of control measures for pests, diseases, and weeds. This is why research in agriculture should be stimulated and the tendency on a world scale for reduced investments in agriculture should be stopped.

The so-called "double Green Revolution" is urgently needed. There are ample possibilities for a double Green Revolution—a discontinuity in productivity rise per hectare and a better use of natural resources. That Green Revolution (a discontinuity in productivity rise per hectare per year) could be followed by white, yellow, and blue revolutions. Discontinuities in water use efficiency, nitrogen use efficiency, and phosphorous use efficiency, respectively, are possible. Various production ecological studies have demonstrated the biological possibilities to increase water use efficiency with at least a factor 5, nitrogen use efficiency with a factor 3, and phosphorous efficiency with a factor 5. To achieve such discontinuities, combinations of technologies, inputs, and social infrastructural changes will be needed. The world community has the possibility to supply or support such combinations and efforts. Why not use them?